STUDIES ON THE PHYSIOLOGICAL AND BIOCHEMICAL CHANGES IN RELATION TO REPRODUCTIVE EFFICIENCY IN CHICKPEA (*Cicer arietinum* L.)

S. SESHADRINATH

DIVISION OF PLANT PHYSIOLOGY

INDIAN AGRICULTURAL RESEARCH INSTITUTE

NEW DELHI

1981

STUDIES ON THE PHYSIOLOGICAL AND BIOCHEMICAL CHANGES IN RELATION TO REPRODUCTIVE EFFICIENCY IN CHICKPEA (*Cicer arietinum* L.)

By

S. SESHADRINATH

A Thesis

Submitted to the Faculty of Post Graduate School,
Indian Agricultural Research Institute, New Delhi,
in partial fulfilment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

IN

PLANT PHYSIOLOGY

Approved by :

Chairman : ..... (Dr.(Miss) Sabra Abbas)

Members : 1. ..... (Dr.S.C. Bhargava)

2. ..... (Dr.K.N. Srivastava)

3. ..... (Dr.(Mrs.) G. Ghosh)

4. ..... (Dr. Namprakash)

Dr. (Miss) Sabra Abbas
Scientist-2

Division of Plant Physiology,
Indian Agricultural Research
Institute, New Delhi-110012.

CERTIFICATE

I certify that the thesis entitled " Studies on the physiological and biochemical changes in relation to reproductive efficiency in chickpea (*Cicer arietinum* L.)" submitted in partial fulfilment of the degree of Doctor of Philosopy of the Post-Graduate School, Indian Agricultural Research Institute, New Delhi is a *bona fide* record of the research carried out by Shri S. Seshadrinath under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma or published in any other form.

The assistance and help received during the course of this investigation have been duly acknowledged.

Sabra Abbas

(Dr. (Miss) Sabra Abbas)
Chairman,
Advisory Committee

New Delhi-110012.

December 26, 1981.

ACKNOWLEDGEMENT

I record my deep sense of gratitude and indebtedness to Dr.(Miss) Sabra Abbas, Scientist-2, Division of Plant Physiology, Indian Agricultural Research Institute, New Delhi- 110012, for suggesting the problem, her valuable guidance, encouragement during the course of the investigations and help in the preparation of this thesis.

I am extremely thankful to Dr. S.C. Bhargava, Senior Plant Physiologist, Dr. K.N. Srivastava, Biochemist, Dr. (Mrs.) G. Ghosh, Soil Scientist and Dr. Namprakash, Senior Scientist, the members of my Advisory Committee for their valuable counsel during the course of the investigations.

I am highly grateful to Dr.T.V.R. Nair, Dr. (Mrs.) Santha, Dr. S.L. Mehta, and Miss Sarla Gupta for their help during my laboratory analytical works and to Dr. Y.N. Rao for his kind suggestions.

It gives me pleasure to acknowledge the help rendered by Shri Amarjeet Singh and Miss Radhamani, Sh. G.P. Srivastava and Sh. Ram Charan.

I am thankful to Dr. S.P.Singh, Professor (Rtd.), Plant Physiology, Division for his help in various academic matters.

I express my sincere gratitude and thanks to Dr. G.S. Sirohi, Head, Division of Plant Physiology for providing necessary facilities.

My warmest thanks are due to my colleagues Mr. R.R.Nair, Mr. Vilasa-Chandaran, Mr. J. Thomas, Mr. Balachandaran, Mr. Mohan Kumar, Mr. Ramavatharam and Mr. S.B. Pande for their help in many ways.

contd.. 2/0--

Acknowledgement (contd...)

I sincerely thank the authorities of the Kerala Agricultural University for giving me deputation and necessary financial assistance to complete this programme.

Finally, I am grateful to the Director and Dean, Indian Agricultural Research Institute, New Delhi, for giving necessary facilities for my stay at I.A.R.I.

Seshadrinath

(S. SESHADRINATH)

New Delhi

December 26 , 1981.

C O N T E N T S

		Pages
1. INTRODUCTION	...	1-6
2. REVIEW OF LITERATURE	...	7-45
2.1 Floral biology	...	9
2.2 Flower and pod development	...	12
2.3 Factors affecting flower and pod development	...	
2.3.1 Relative humidity	...	15
2.3.2 Vernalisation and photoperiod	...	16
2.3.3 Light intensity	...	17
2.3.4 Temperature	...	18
2.4 Factors affecting growth and development		
2.4.1 Vernalisation and photoperiod	...	22
2.4.2 Light intensity	...	23
2.4.3 Temperature	...	24
2.4.4 Water stress	...	27
2.5 Correlation studies	...	27
2.6 Leaf and area and dry matter production	...	30
2.7 Source-sink relationship	...	31
2.8 Effect of chemicals including growth regulators	...	
2.8.1 Gibberellins	...	33
2.8.2 Cytokinins	...	35
2.8.3 Auxins	...	36
2.8.4 TIBA	...	36
2.8.5 Growth retardants	...	37
2.8.6 Miscellaneous chemicals	...	38

2.9 Biochemical studies ... 39

2.9.1 Chemical composition ... 39

2.9.2 Organic acids ... 41

2.9.3 Photosynthetic rates and chlorophyll content ... 42

2.9.4 Biochemical changes during seed development ... 43

3. MATERIALS AND METHODS ... 46-68

3.1 Expt. No.1 Evaluation of reproductive efficiency of different genotypes of chickpea ... 46

3.1.1 Observations and experimental procedure ... 47

3.1.2 Morphological observations ... 48

3.1.3 Leaf area and dry matter production ... 48

3.1.4 Yield and yield components at final harvest ... 49

3.2 Expt. No.2 Studies on the influence of temperature ... 50

3.2.1 Date of sowing ... 50

3.2.2 Time, intensity and duration of flowering ... 51

3.2.3 Morphological attributes ... 52

3.2.4 Changes in leaf area and dry matter production ... 53

3.2.5 Growth analysis ... 53

3.2.6 Yield and yield components at final harvest ... 54

3.2.7 Reproductive efficiency ... 55

3.2.8 Temperature data ... 56

3.3 Expt. No.3 Response of cv. L-550 to different concentrations of different growth regulators at different stages of growth. ... 57

3.3.1 Experimental design ... 57

3.3.2 Observations ... 58

3.4 Expt. No.4 Effect of stage vs growth regulators interaction on yield attributes in cv. L-550 ... 59

3.4.1 Experimental design ... 60

3.4.2 Observations recorded ... 61

3.5 Expt. No.5 A comparative study of biochemical changes in fresh abscised plant parts ... 62

3.5.1 Total nitrogen ... 62

3.5.2 Total proteins ... 63

3.5.3 Soluble protein ... 64

3.5.4 Soluble sugars ... 64

3.5.5 Nucleic acids ... 65

3.5.6 Pigments ... 67

3.6 Expt. No.6 Changes in organic acid contents in leaf as influenced by temperature ... 68

4. RESULTS ... 69-136

I. Evaluation of Reproductive efficiency

4.1 Experiment No.1 Evaluation of reproductive efficiency in different genotype (1979-80) ... 69

4.1.1 Time, intensity and duration of flowering ... 69

4.1.2 Days to first pod ... 70

4.1.3 Changes in morphological attributes ... 71

4.1.4 Changes in dry matter accumulation ... 73

4.1.5 Reproductive behaviour ... 75

4.1.6 Reproductive efficiency ... 76

4.2 Expt. No.2 Effect of different dates of sowing (influence of temperature) ... 78

4.2.1 Time intensity and duration of flowering ... 78

4.2.2 Morphological attributes ... 80

4.2.3 Changes in leaf area and dry matter accumulation ... 86

4.2.4 Changes in percentage dry matter distribution in plant parts ... 96

4.2.5 Changes in RGR, CGR and LAI and IAD ... 99

4.2.6 Reproductive behaviour ... 104

4.2.7 Retention and abscission of flowers and pods ... 112

4.2.8 Reproductive attributes ... 120

4.2.9 Temperature regimes ... 127

II. Improvement of reproductive efficiency

4.3 Expt. No.3 Response of cv. L-550 to different concentrations of different growth regulators at different stages of growth ...

4.4 Experiment No.4 Effect of stage vs growth regulators interaction on yield attributes in cv. L-550 ... 130

III. Biochemical studies in relation to reproductive efficiency in chickpea

4.5 Expt. No.5 A comparative study of biochemical change in fresh and abscised flower parts ... 131

4.5.1 Total nitrogen, total protein soluble proteins and soluble sugars in normal and abscised flowers and pods ... 132

4.5.2 Changes in nucleic acid content in normal and abscised flowers and floral parts ... 133

4.5.3 Pigment content in normal and abscised flowers and floral parts ... 134

4.6 Expt. No.6 Changes in organic acid contents of leaves under the influence of temperature ... 136

5. DISCUSSION ... 138-176

5.1 Evaluation of reproductive efficiency

5.1.1 Evaluation of reproductive efficiency in different genotypes ... 139

5.1.2 Effect of different dates of sowing (influence of temperature) ... 140

5.1.3 Morphological attributes ... 150

5.1.4 Reproductive attributes ... 154

5.1.5 Various parameters determining reproductive efficiency ... 159

5.2 Improvement of reproductive efficiency by chemical manipulations

5.2.1 Stage vs concentration ... 163

5.2.2 Auxin ... 164

5.2.3 Cycocel ... 165

5.2.4 Benzyl amino purine ... 165

5.2.5 Ethrel ... 165

5.2.6 Stage vs growth regulator interaction ... 166

5.3 Biochemical studies in relation to reproductive efficiency ... 167

5.3.1 Total nitrogen, total protein, soluble proteins, soluble sugars in normal and abscised flowers/pods ... 167

5.3.2 Nucleic acid contents in normal and abscised flowers and floral parts ... 169

5.3.3 Pigment content in normal and abscised flowers and floral parts ... 171

5.3.4 Changes in organic acid contents in leaves ... 173

6. SUMMARY ... 177

7. BIBLIOGRAPHY ... i-xii

8. APPENDICES ... I-XV

****

LIST OF TABLES

Table No.	Title	Between pages
1.	Time, intensity and duration of flowering in relation to crop duration in different genotypes of chickpea during 1979-80 ..	69-70
2.	Morphological attributes of different genotypes of chickpea at different stages in field during 1979-80 ..	71-72
3.	Morphological attributes of different genotypes of chickpea at different stages in pot culture during 1979-80 ..	71-72
4.	Changes in dry matter production in different plant parts at various stages in different genotypes of chickpea in field during 1979-80 ..	73-74
5.	Changes in dry matter production in different plant parts at various stages in different genotypes in chickpea in pot culture during 1979-80 ..	73-74
6.	Reproductive behaviour/plant of different genotypes in chickpea in field during 1979-80 ..	75-76
7.	Reproductive behaviour/plant of different genotypes in chickpea in pot culture during 1979-80 ..	75-76
8.	Characteristics determining reproductive efficiency in different genotypes in chickpea under field and pot culture during 1979-80 ..	76-77
9.	Effect of different dates of sowing on time, intensity and duration of floweringin JG-62, L-550 and BG-209 in field and pot culture ..	78-79
10.	Effect of different dates of sowing on the morphologi-eal attributes of cv. JG-62 in field and pot culture ..	80-81
11.	Effect of different dates of sowing on the morphological attributes of cv. L-550 in field and pot culture ...	82-83
12.	Effect of different dates of sowing on the morphological attributes of cv. BG-209 in field and pot culture ..	84-85

13.	Effect of different dates of sowing on leaf area and dry matter production in cv. JG-62 in field.	..	87-88
14.	Effect of different dates of sowing on leaf area and dry matter production in cv. JG-62 in pot culture	..	87-88
15.	Effect of different dates of sowing on leaf area and dry matter production in cv. L-550 in field	..	90-91
16.	Effect of different dates of sowing on leaf area and dry matter production in cv. L-550 in pot culture	..	90-91
17.	Effect of dates of sowing on leaf area and dry matter production in cv. BG-209 in field	..	93-94
18.	Effect of different dates of sowing on leaf area and dry matter production in Cv. BG-209 in pot culture	..	93-94
19	Effect of different dates of sowing on the percentrage dry matter distribution in cv. JG-62 in field and pot culture	..	96-97
20	Effect of different dates of sowing on the percentage dry matter distribution in cv. L-550 in field and pot culture	..	97-98
21	Effect of different dates of sowing on the percentrage dry matter distribution in cv. BG-209 in field and pot culture	..	98-99
22	Effect of different dates of sowing on RGR, CGR, LAI and LAD in cv. JG-62	..	100-101
23	Effect of different dates of sowing on RGR, CGR, LAI and LAD in cv. L-550	..	101-102
24	Effect of different dates of sowing on RGR, CGR, LAI and LAD in cv. BG-209	..	103-104
25.	Influence of different dates of sowing on percentage retention of flowers and pods during a specific period over total formed in cv.JG-62 in field and pot culture	..	112-113

26.	Influence of different dates of sowing on the percentage retention of flowers and pods during a specific period over the total formed in cv. L-550 in field and pot culture	..	115-116
27.	Influence of different dates of sowing on the percentage retention of flowers and pods during a specific period over total formed in cv. BG-209 in field and pot culture	..	117-118
28	Number of flowers retained and flower abscised over the previous specific period upto peak flowering in cv. JG-62 in different dates of sowing in field and pot culture	..	113-114
29	Number of flowers retained and flowers abscised over the previous specific period upto peak flowering in cv. L-550 in different dates of sowing in field and pot culture	..	116-117
30.	Number of flowers retained and flowers abscised over previous specific period upto peak flowering in cv. BG-209 in different dates of sowing in field and pot culture	..	119-120
31	Effect of different sowing dates on the reproductive attributes of cvs. JG-62, L-550 and BG-209 in field and pot culture	..	120-121
32	Effect of different sowing dates on the various parameters determining reproductive efficiency of cvs. JG-62, L-550 and BG 209in field and pot culture	..	123-124
33	Response of cv. L-550 to different concentrations of grwith regulators at different stages in pot culture during 1979-80	..	129-130
34.	Effect of stage vs growth regulators interaction in yield attributes of cv. L-550 in pot culture and field during 1980-81	..	130-131
35.	Relative amounts of total nitrogen, total proteins, soluble proteins and soluble sugars in normal and abscised flowers and pods in chickpea	..	132

36.	Nucleic acid contents in normal and abscised flowers and floral parts of chickpea	..	133-134
37.	Relative amount of chlorophyll and carotenoid content in normal abscised flowers and floral parts of chickpea	..	134-135
38.	Anthocyanin content in normal and abscised flowers and floral parts of chickpea	..	135
39.	Change in organic acid content in leaves of chickpea as influenced by temperature	..	136
-	Important events and stages identified during the crop duration	..	141-142
-	Temperature indices during vegetative and reproductive phase in relation to crop duration of different sowings.	..	141-142
-	The relative importance of stages in relation to proportion percentage realised for respective growth characters	..	150-151

****

LIST OF FIGURES

Fig.No.	Title		Between pages
1.	Formation of abscission layer in chickpea flower/ pod at the junction of peduncle and pedicel.	....	52-53
2.	Changes in leaf area and dry matter production in different plant parts from flowering to harvest in cv. JG-62.	....	86-87
3.	Changes in leaf area and dry matter production in different plant parts from flowering to harvest in cv.- L-550	....	90-91
4.	Changes in leaf area and dry matter production in different plant parts from flowering to harvest in cv. BG-209	....	93-94
5.	Effect of different dates of sowing on the reproductive behaviour of cv. JG-62	....	104-105
6.	Effect of different dates of sowing on the reproductive behaviour of cv. L-550	...	108-109
7.	Effect of different dates of sowing on the reproductive behaviour of cv. BG-209	....	110-111
8.	Temperature record from 4.10.1980 to 6.4.1981	....	127-128

****

LIST OF APPENDICES

No.	Title
I.	Temperature indices at different stages of crop growth at different dates of sowing .
II.	Proportion percentage of respective duration of important stages of growth.
III	Proportion percentage of leaf area at various stages of growth in different stages of growth in different dates of sowing.
IV	Proportion percentage of height at various stages of growth in different dates of sowing.
V	Proportion percentage of total number of branches at various stages of growth in different dates of sowing.
VI	Proportion percentage of leaf number at various stages of growth in different dates of sowing.
VII	Proportion percentage of total dry weight at various stages of growth in different dates of sowing.
VIII	Proportion percentage of stem weight at various stages of growth in different dates of sowing.
IX	Proportion percentage of leaf weight at various stages of growth in different dates of sowing.
X	Effect of different dates of sowing on the flowers retained, flowers abscised, total flowers and pods formed per plant in cv. JG-62 in field and pot culture.
XI	Effect of different dates of sowing on the flowers retained, flowers abscised, total flowers and pods formed per plant in cv. L-550 in field and pot culture.
XII	Effect of different dates of sowing on the flowers retained, flowers abscised and total flowers and pods formed per plant in cv. BG-209 in field and pot culture.
XIII	Percentage distribution of RNA and DNA in floral parts in chickpea.
XIV	Nucleic acid content in normal and abscised flowers, pod, pod wall and seed in chickpea L-550.
XV	Dry weight of floral parts of chickpea.

****

1. INTRODUCTION

Chickpea (Cicer arientimum L.) is the leading pulse crop of India. It contributes 51 % of the total pulse production and occupies 41 % of the cropped area of the country. India is the premier chickpea growing country and the bulk of the world's chickpea production is derived from this sub-continent, which occupies 80 % of the world's area under chickpea cultivation. Out of the world's total production of 7.4 million metric tonnes, obtained from an area of 10.36 million hectares, India contributes 5.83 million metric tonnes of grain from 7.87 million hectares (F.A.O. 1979).

There is a need to increase the pulse production in India every year progressively by an average of 2.2 % in order to maintain the minimum requirement of 50 gram protein intake of daily diet against the WHO/FAO nutritional standards of 104 gram per capita per day.

The lack of basic information of improved production practices and availability of high yielding varieties with resistance to adverse conditions, together with poor transfer of existing improved technologies are recognised as some of the major constraints to increased pulse production. Smartt (1976) pointed out " it is important to know the extent to which the physiology of a crop can be modulated to fit a particular set of environmental condition or production practices and conversely to the extent to which techniques need to be modified or accommodate unalterable physiological processes".

The average yield of chickpea is only 700 kg/ha and varied greatly with both sites and seasons from about 190-1600 kg/ha. One of the major causes for low yield in chickpea, among others, can be attributed to low reproductive efficiency which can be as low as 5 %. The seed yield is basically determined by the number of flowers that a plant can produce and the percentage of those which could develop into mature seeds of proper size.

Flower and fruit drop of chickpea is a common feature resulting in excessive losses of seed yield to the extent of 50-95 %. No systematic study has been so far undertaken to understand the physiological basis of flower and fruit drop in chickpea, which occupies the most significant position in pulse cultivation in India.

The cause of low reproductive efficiency is mainly due to heavy shedding of reproductive structures. This problem is further aggrevated by the fact that chickpea is an indeterminate type, where vegetative growth continues for a long period and overlaps with the reproductive growth. It appears that there is a lag phase and only when sufficient photosynthates are available can these young fruits begin to develop. Besides the deficiency of assimilates for the developing fruits, other causes have been suggested which include nitrogen supply, hormonal factors, gaseous exchange, mineral nutrient supply, soil moisture, humidity and temperature. One or more of these prime causes permit eventual regulation of fruit set and yield. Factors affecting abscission of flowers and fruit influence the yield and therefore warrant further study. Hence pod and seed setting

becomes the critical stages requiring improvement for increasing the yield. An understanding of physiological and biochemical aspects of flower and fruit development and their shedding is essential and the knowledge thus acquired can be gainfully applied for attaining higher seed yield.

Nevertheless, attempts have been made using growth regulators to reduce flower and fruit drop in order to increase pod set. Different growth regulators have been used by various workers : IAA (Srivastava and Tomer, 1973), TIBA (Sinha and Ghildiyal, 1973), Cycocel (Alhawat et al., 1974; Saraf et al., 1974; and Sekhon and Kaul, 1974), Alar and GA (Khan et al., 1976) are the growth regulators which have been tried on chickpea. Despite these efforts no recommendation could be made to the farmers for want of consistant results. One of the possible reasons could be that the concentration and stage of application had been arbitrarily chosen. Hence the need for determining the appropriate stage of application and concentration of respective growth regulators and for this an interaction of stage vs concentration study is desirable.

Although information is available on the extent of pod set (Kadam et al., 1938; Pal and Rao, 1940 and Agrikar, 1957), yet, very little is known of either how or at what stage during development variation in yield components arises under varied environmental condition. Literature is lacking with respect to an integrated approach regarding time, intensity and duration of flowering and the sequential determination of

the reproductive efficiency of chickpea. Obviously detailed studies on the effect of climate on flower and pod setting in chickpea and the mechanism involved are required, before the major limitations to reproductive efficacy, and their major effects on yield can be alleviated.

The seed yield in chickpea, like other grain legumes, depends upon the vegetative and reproductive components, which are markedly affected by environmental factors (Summerfield and Minchin, 1976). Summerfield et al. (1980) considered the growth and development of an annual legume plant resulting in a number of consecutive phases; vegetative(including Juvenility), mature (ripeness of flowers), reproductive (flowering and setting of fruits) and senescent (which includes maturation of fruits). This quantitative performance of plants throughout each stage of development is often determined or limited by those environmental factors which also initiates phase changes. According to them the traditional components of yield analysis equates legume seed yields to the product of three components only i.e. the number of pods that reach maturity, the average number of seeds in them and the mean weight of individual seeds. They argued that these aggregated data alone are of limited values in furthering over comprehensions of the physiological limitations to legume seed production. We cannot use them to identify with confidence, the main effect and interaction of climatic factors on the more responsive components that contribute significantly to variations in yield until these relations have been studied more carefully.

As it is true of other species, the number of pods that reach maturity

have a major effect on the seed yield in chickpea (Sandhu and Singh, 1972). Little is known also for chickpea of the effects of environmental factors on the rate or duration of seed fill; at which loci within fruits and at what age abortion is more prevalent or the consequences of maturation environment on the biochemical composition of seeds.

Various causes have been assigned to low pod and seed setting in chickpea. Earlier workers emphasised the importance of relative humidity (Sen and Mukherjee, 1961) for higher pod set, which was later ruled out by van der Maesen (1972). Several workers have stressed the importance of photo periods (van der Maesen, 1972; Smartt, 1976; and Summerfield et al. 1981), light intensity (Sandhu and Hodges, 1971; van der Maesen, 1972 and Summerfield et al., 1979). Among these factors temperature has received the highest attention and many attempts have been made to evaluate the performance of chickpea as affected by different dates of sowing (Sur et al. 1966; Eshel, 1967; Sharma et al., 1967; Kaul et al., 1976 and Ageeb, 1977). Temperature has also been emphasised as a factor affecting shedding in chickpea (Saxena and Sheldrake, 1980 and Summerfield et al., 1981).

Summerfield et al. (1980) rightly questioned how environmental variations in time, affect physiological and morphological processes i.e. growth, development and yield.

Keeping the above considerations in view an attempt has been made to study the reproductive efficiency in chickpea. The major objectives

of the present investigations are :

1. To study the genetic variability and diversity with respect to the flowering behaviour and shedding of flowers during the reproductive stage in order to evaluate the peak periods of flowering, shedding percentage and reproductive efficiency.

2. To study the influence of temperature (based on different dates of sowing), on time, intensity and duration of flowering and reproductive efficiency in relation to growth and development of chickpea.

3. To study the possibility of improving reproductive efficiency by chemical manipulations using growth regulators.

4. To investigate the biochemical changes associated with abscission of flowers and fruits.

2. REVIEW OF LITERATURE

Although wealth of literature is available on different aspects of chickpea physiology, biochemistry and agronomy, yet literature pertaining to the reproductive efficiency is restricted to pod set only and in specific terms of the sequence of its components is completely lacking.

Reproductive efficiency is the capacity of the plant to produce reproductive structures and its conversion to economic products. The seed yield per plant is determined in a component series by the number of flowers formed per plant to percentage fruit set and number of seeds per plant and seed size (van Schaik and Probst, 1958). The importance of shedding of reproductive part is evident since the seed yield is determined basically by the number of flowers a plant can produce and the percentage of those that can develop into mature seeds and seed size (Thomas and Rafer, 1976). Summerfield et al. (1980) emphasised that the quantitative performance of plant throughout each stage of development is often determined or limited by those environmental factors which also initiate phase changes and suggested the following sequence of components of seed yield in determinate legumes.

1. Number of nodes/plant (N_o) — Vegetative growth rate x Duration of preflowering period.

2. % of N_o that becomes reproductive
   (1 x 2) = Phenological potential

3. Number of flowers per reproductive node (F)) Number of pods per reproductive node (P)

4. % of F that set pods)

5. % of P that are retained

6. Number of seeds per pod (S)
   (3 x 4 x 5 x 6) = Reproductive efficacy } Carbon supply, Nitrogen supply

7. % of S that attain maturity

8. Mean seed weight = Mean seed growth rate x duration of pod-fill
   (7 x 8) = Yield culmination

$$\text{Yield / Plant} = (1 \times 2) \times (3 \times 4 \times 5 \times 6) \times (7 \times 8)$$

Considerable work has been done on the reproductive efficiency of cotton, where bud and ball shedding is of great economic importance (Balls, 1912; Harland, 1917; Ewing, 1918; and Llyoid, 1920). Reproductive efficiency has been estimated in Arachis hypogea (Smith Ben, 1954), white pea bean (Davis, 1945), Lima bean (Cordnex, 1933; Lambeth, 1950) and soybean (Swen, 1933; van Schaik and Probst, 1958; Hardman, 1970; Thomas and Rafer, 1976 and Mc Blain and Hume, 1981).

Indirectly reproductive efficiency can be evaluated for the pulse crop from the reported percentage of pod set in literature. However, these estimates are approximate, because they do not take into account of the number of immature pods fallen or the undeveloped pods, which do not express the full seed size. Moreover information regarding the flowering behaviour is also not complete.

Shedding has been reported to be 40-97 % in soybean (Swen, 1933) for Kharif pulses Kaul et al., (1976) reported 40-50 %, 32-46 % and 47-61 % for urd, mung bean and cowpea respectively. In case of chickpea earlier reports pertain only to percentage of pod set. However, recently

Varma and Promila Kumari (1980) reported for G-130 and Kabuli cultivar L-144 that the flower shedding ranges between 18.5 and 19 % and pod shedding between 26 and 43.1 %. Abbas (1979) (Personal communication) found that flower shedding occurs to the extent of 41-88 % and pod shedding 2-14 % in the study of 12 cultivars of chickpea.

Percent fruit set has been reported for soybean as 13 % to 22 % (van Schaik and Probst, 1958), mung bean and cowpea as 11-31 % and 17-21 % respectively (Singh, 1977). For chickpea pod set has been reported to vary between 22.2 and 36.8 % (Pal and Rao, 1940), and 14-44 % in 4 cultivars Chaffa, Gigus, N. 30 and Harachana by Agrikaraz (1957). Abbas (1979) in 12 chickpea cultivars observed that pod set varied between 11-65 % and fruit set 10-55 %.

From the above it is clear that information on reproductive efficiency of chickpea is almost lacking and there is not a single reference in literature where the different components of reproductive efficiency have been studied in a sequence. Floral biology on the other hand has been studied in detail and flower formation has been received considerable attention. In view of the above this review will be confined to the floral biology, factors affecting flower and fruit formation and physiology of growth and yield of chickpea.

2.1 Floral Biology :

Floral biology in chickpea has been extensively studied. The time of active blooming has been reported to vary between 9 A.M. and 10 A.M.

(Ayyar and Balasubramanian, 1935), 9 - 10.30 A.M. (Agrikar, 1957) and between 6.15 A.M. and 4.50 P.M. (Oreon et al., 1977). Average time taken for complete blooming of corolla varies from 1.30 to 4.45 hours. Flower started to close after 2 P.M. and by 10.25 P.M. they completely closed.

Average number of flowers opening was 5 per plant and the maximum being 12 per plant (Kadam et al., 1938). The duration of opening varies between 7 to 15 hours and 1 to 17 hours depending upon the variety and on an average it usually varied from 2.6 to 5.23 hours (Agrikar, 1957). The process of closing was found to be more gradual from that of opening and the total period in which a flower remained open was less in the second day of opening (Ayyar and Balasubramanian, 1935). The interval between the first closing and the start of the second opening of flower varied from 11-13 hours and from the start of the second opening to the full opening was 1.46 hours. The period between the second full opening and second closing was found to be of similar order, however, periodicity of these phases varied with different cultivars (Agrikar, 1957). Further, the buds open when they attain a size of 9 mm x 5 mm. Moreover, 4 to 29 % of the buds do not open at all.

Agrikar in his above study also noted that the mode of flowering of the 4 cultivars viz., Chaffa, Gigus, N. 30 and Harachana was distinctly different although there was a general ascending or descending order of number of flowers that opened progressively. The duration of flowering was also found to differ which was found to be 18 days for cv. Chaffa

against 14 days in case of N. 30 and Harachana, while this was narrowed to 11 days in case of Gigus. Ayyar and Balasubramanian (1935) found that the anther dehiscence and pollination occured one day before the opening of flower and there was hardly any cross pollination, although all the pollen grains present at the time of flower opening were viable. Agrikar (1957) found that on the whole 69 % of the total buds had the anther dehiscence between 7 A.M. and 8 A.M. The optimum time for anthesis or pollination was found by Eshel (1968), between 12-29 hours before the flower was fully opened and the observed that at this stage the pollen germinated in vitro at a higher degree and the pollen tubes grew faster than in a fully opened flower. Sinha and Coworkers (1980) studied the germination of pollen and pollen tube length in cv. JG-62 and M-450 under varying temperature and they observed that both germination and growth of pollen tube is marked by low temperature. Oreon et al., (1977) from their observation on 12 cultivars reported that the dehiscence of anther took place between 9 A.M. and 2.50 P.M., one day prior to opening of flowers. Pollen grains were oblong when ripe and became spherical under wet condition. Pollens were viable for eight and a half hours at 27°C and 95 % relative humidity and for 9 days at low temperature of 7.2°C and zero relative humidity. Stigma became receptive 24 hours before flower opening and it remained so until 12 hours after the opening of flowers. Thus the total period of receptivity was 36 hours. In general there is full agreement that there is no cross pollination in chickpea. It is self pollinated.

2.2 Flower and Pod Development :

In chickpea flower is typical of leguminasceae family consisting of a five leaf calyx and a corolla which includes a standard, wings and a keel, 10 stamens and one carpel gynoecium. Nine of the 10 filaments are fused and the ovary is superior with placenta at vental suture. Eshel (1968) studied the stage of flower development in chickpea from bud. In early stages the style elongates simultaneously with the petal. The stigma is at the edge of the keel, while the stamens remain at the base of the bud with the anthers arranged alternatively in 2 levels when the petals protrude from the calyx, the filaments start to elongate one gradually reach the pistil height and the anthers surrounding the stigma. Dehiscence takes place at this stage.

Saxena and Sheldrake (1976) studied the patterns of reproductive growth and found that flowering, as measured by the weight of flowers per plant, increased and then declined as seed development took place most rapidly. They compared the ovule number in early and late formed flowers in Kabuli and desi cultivars and observed no variation in ovules in early or late formed flowers. Summerfield et al. (1980) summerised the major events during embryogenesis in various legumes and generalised that final cell number in the embryo is attained early in its ontogeny, the subsequent increase in embryo weight being the result of cell expansion and the concomitant synthesis and deposition of starch and thereafter storage proteins. The seeds derive a large proportion in their carbon from photosynthesis of

foliar organs at the parent node (Dure, 1975).

In chickpea the fruit wall grows to a large extent before seed development proceeds. A lag period that lasts about 15 days after anthesis is followed by a linear period of growth of about 20 days duration, during which the individual seed accumulate the vast proportion of their dry matter (Saxena and Sheldrake (1980). Saxena (1979) had earlier noted that pod filling was limited by the supply of assimilate or nutrients in case of late formed pods. Singh et al. (1981) also observed the same trend. There was a rapid addition of dry matter in the seeds starting about the time the growth of pod wall had ceased. In the early cultivars which studied at the peninsular India the addition of dry matter in the seed continued upto 35-40 days, whereas cultivars of longer duration which were subjected to forced maturity dry matter addition ceased after 25-30 days. This period may be considered as the time to reach physiological maturity of individual pods. They reported that cultivars differed in rate of pod development at the time of maximum dry matter accumulation. Pods of smaller seeded cultivars tended to reach physiological maturity earlier. Sinha (1977) reported that grain growth in legume is more fast as compared to cereals. Indeed the maximum seed growth rates for chickpea are among the fastest recorded for grain legumes (Summerfield and Wein, 1979).

Chickpea plant have some ability to compensate for the loss of potential sinks. Saxena and Sheldrake (1980) from their studies on the

effect of flower removal found that the compensation took place in 3 ways i.e. I) by the extension of the growing period in response to flower removal. Continued growth reproductive period caused addition of flowering nodes, hence more pods II) by way of increase in seeds per pod which was in the range of 24-26 % of plants in which flowers were removed. III) increase of seed weight and this compensation usually occurred in small seeded cultivars and was relatively small, ranging from 8-20 %. In bold seeded cultivars the seed weight declined in response to flower removal.

Sinha and coworkers (1980) found that the rate of photosynthesis declines after the commencement of pod setting. Therefore, it was suggested that the photosynthetic ability could be limiting grain yields in gram. They tested the above two suggestions in two different ways by shading to different degrees after flowering and by culturing a shoot bearing flower and young fruits in a medium of glucose or glutamine. They observed that shading clearly resulted in decreased fruit setting and yield. In culture medium they could culture the fruits upto six days and they found that the rate of development of fruit was more than those of comparable fruits in the field. However, they observed this only in young fruits as the older fruits did not show any significant difference in culture medium and in the field and thus they concluded that the photosynthetic availability could be a limiting factor to grain yield in chickpea by its influence on pod formation and its growth. And in chickpea he found the average gain of 3.28 mg of dry weight per day per pod.

Saxena and Sheldrake (1976) and Sinha and Coworkers (1980) observed a fall in RGR at the time of pod development. Kumari and Sinha (1972) found that in 22 chickpea cultivars showed that almost in all of them the rates of photosynthesis dropped sharply after flowering. They observed a variation in fruitwall photosynthesis in chickpea, however, they made no assessment of its contribution to seed yield, but observed that it was more than the contribution of leaf near the pod.

2.3 Factors affecting flower and pod development :

2.3.1 Relative humidity :

Sen et al. (1964) observed that high relative humidity affects the pod set, even though it does not affect the flower formation. Earlier Sen and Mukherjee (1961) had observed defective pod formation and seed setting in plants flowered by the end of December. They saw that the percentage of pod formation increased in all gram cultivars from the end of February. They attributed this phenomenon to atmospheric humidity, which was high in December/January. This interfered with the pollination by preventing the anther sac to burst. They observed that pollination occurs best at minimum atmospheric humidity, which were high in December/January. They observed that the pollination occurred best at a minimum atmospheric humidity, the suggested optimum being from 20-40 %, which increased pod set. Sen et al. (1964) found that pod set goes as high as 60 % when the crop is sown in 2nd week of January. Sahai (1955) also had observed the same earlier. However, van der Maesen (1972) ruled

out the possibility of atmospheric humidity having a controlling effect on pod set.

2.3.2 Vernalisation and photo period :

It has been reported by Pal and Murthy (1941), Singh (1958) and Moursi et al. (1963) that chickpea is a quantitative long day plant, hence day length had an important role in its early flowering. Nanda and Chinoy (1960 a) studied the effect of photoperiod in vernalised and unvernalised plants. They transplanted unvernalised and vernalised seedlings to earthen pots to day length of 6, 11, 18 and 24 hours. The effect of the treatments on 2 vegetative periods i.e. number of days from transplanting to bud initiation and flower opening were studied. The vegetative period was reduced by vernalisation and photoperiod treatment. The difference between vernalised and unvernalised plants became more pronounced as day length decreased. Bud initiation and flowering were markedly hastened with long day conditions in unvernalised plants and earliness increased with length of daily photoperiod. The effects of photoperiodic treatments were less pronounced in case of vernalised plants. The flower bud initiation is controlled by a thermophase and different photoperiod to which the plants were exposed subsequently did not affect the period of bud initiation. They found that the period between the bud initiation and flower opening was mainly determined by the photoperiod and was reduced by long days. There was an inverse correlation between the photoquantum and thermoquantum upto the stage of bud initiation in unvernalised plants. They suggested

the concept of photophasic development of a plant in spite of the fact that the energy required for the completion of a given phase may be supplied in the form of heat or light.

Sandhu and Hodges (1971) in their growth chamber experiment with 8 cultivars of chickpea with various combinations of 8-12 h. or 16 h. photoperiod observed that flowering was earliest and seed yield highest with 16 hour photoperiod. van der Maesen (1972) observed that chickpea was a quantitative long day plant, flowering was advanced 20-35 days by 16 hour photoperiod in comparison to 9 hour photoperiod.

Pandey et al. (1977) in other study at Pantnagar with 15 gram genotypes of different origin, grown under natural day, long day of 24-h and short day of 8-h period found that all genotypes were photosensitive. Short day conditions delayed flowering, produced less assimilation products which reduced the number of pods per plant, however, Summerfield (1981) observed that shorter days delayed flowering only by 3 days, in 10 of the 15 cultivars examined. Recent studies under controlled environments by Roberts et al. (C.f. Summerfield et al., 1981) suggest flowering in chickpea is mediate by mean diurnal temperature rather than night temperature per se although the latter might be important in determining critical photoperiod.

2.3.3 Light intensity :

Flowering is also influenced by light intensity level (Salisburry, 1963). It has been also reported that fruit setting is indirectly affected by low light intensity. Sandhu and Hodges (1971) observed that high light

intensity of 28063 lux favoured flowering and fruit setting, which was later confirmed by van der Maesen (1972).

2.3.4 Temperature :

Variation of atmospheric temperature had been reported to have profound effect in flowering in gram. Nanda and Chinoy (1960 b) noted that the process leading to bud initiation was mainly governed by temperature as there was a specific thermophase for bud initiation.

Sen et al. (1964) by sowing gram at 15 days interval from the end of October to middle of January, observed a reduction in flower number when sowing was delayed beyond mid-November. They observed that the gradual rise in atmospheric temperature from the beginning of February was not conducive for formation of flowers and therefore the number of flowers decreased gradually from 496 in October sown crop to 103 in January sown crop. Eshel (1967) from his experiments with 2 gram cultivars viz., Califorma and Bulgaria sown in field at 3 weeks interval from 3rd October to 2nd week of May observed a reduction in growing period, flower production and reproductive ability by delayed sowings. He observed that the length of the flowering period was positively correlated with the number of growing days prior to flowering and negatively correlated with the temperature during the flowering period. An increase in the average daily temperature during flowering from 14-26°C was associated with the restriction in flowering period and consequently with restricted flower production. A growth stimulation due to temperature increase did not compensate for the

reduction in the number of flowers which resulted from a shorter flowering period. Similar relationship between temperature and flowering were reported by Bosewel (1962) and van Dobben (1963) in pea and by Kovac (1963) in soybean.

van der Maesen (1972) reported in chickpea, optimum temperature for better flower formation was between 21 - 29°C for cv. Vilrimorin and for C-237, equally favoured between 15 - 23°C, 18 - 26°C and 21 - 29°C. Recently, Summerfield et al.(1981) in their studies with 15 cultivars of gram under controlled conditions found that appearance of first flower was hastened by warm nights and longer days. They observed that all the cultivars showed some response to a reduction in mean diurnal temperature consequent upon a 8°C decrease in night temperature. They found that a double podded character was more expressed in environments where cool (10°C) nights were in association with warm hot days. They observed that plants which produced fewer pods and smaller yields matured sooner and had slightly shorter reproductive periods than which produced much larger yields in cooler environments. Longer days, warmer nights and hot days all contributed to rapid maturity.

Gram when sown in October gives maximum grain yield through maximum pod formation. Sen et al. (1964) observed that pods number decreased from 213 to 62 when sowing was delayed, as in case of flower. They observed pod setting percentage steadily increased in late sown plants. The setting percentage increased from 34, in October sown to 60 in January sown crop and this confirmed the results of Sahai (1955) who had earlier observed

that sunshine and atmospheric temperature played an important part in pod setting, as high percentage of pod set was seen in late part of growing season.

Eshel (1967) showed that reproduction ability of plants decreased with the reduction of growing period. The number of pods decreased much more steadily than the number of flowers in plants of delayed sowing. He further observed that longer pre-flowering periods resulted in more number of flowers and pods. Kaul and Sekhon (1976) from the data of their two year experiment with four dates of sowing at two weeks interval from first October to 15th November, with cultivars G-130, L-550 and L-345 noted that podding potential showed decline as sowing is delayed. They attributed this to temperature. The results were in confirmity with the findings of Mathur and Tomer (1966). Sinha and Coworkers (1980) pointed out that Ist formed flowers of December/January did not set fruit in Delhi, however, flowers opening in early February did set fruits. From experiments conducted at Delhi, Indore and Hyderabad with cultivars JG-62, L-550 and C-304, they observed that except at Delhi the first formed flowers set fruits ranging from 83 % at Indore to 62 % at Hyderabad. At Indore the maximum and minimum temperatures were 25°C and 15°C during the period of opening of flowers. They opinioned that low temperature was the cause of failure of fruit set in Delhi. Again Sinha and Coworkers (1980), observed a genetic variably in sensitivity to low temperature, as some mutants set fruits in low temperature, while the parents did not set fruit. By subjecting the shoots of parents JG-62 and mutant M-450 to temperatures 15°C, 20°C and 25°C before

opening of flowers, they studied the germination of pollen grains and pollen tube growth. They found that the parent had 24 and 32 percent germination where as the mutant had 42 and 46 per cent germination at 15°C and 20°C respectively and at 25°C there was no significant difference in germination between the two. At 15°C and 20°C prebloom temperature the pollen tube growth was also found to be more in mutant than the parents.

Saxena and Sheldrake (1980) at Hyderabad observed that pod set commenced with the onset of flowering, but at Hissar, the flowers of early cultivars and late sown cultivars did not bear fruits while temperature was low. They found that the pod set commenced in all cultivars at the same time when the temperature were high enough, irrespective of time of flower initiation. Earlier, Sheldrake and Saxena (1979) observed that as compared to plants grown in optimum soil moisture, the moisture stressed plants showed an earliness in flowering, podding and maturity and they attributed this to high evaporative demands in relation to air temperature.

Murfet (1977), concluded that in general, early maturing genotypes are least susceptible to environmental influence. Summerfield et al. (1980), also arrived at a similar conclusion with their studies on the long duration cultivars and short duration cultivars. They found that the long duration G-130 yields best when day temperature is maintained at 30°C throughout the growth, but it is poorly adapted to hot days during the reproductive period. The short duration cultivar Annagiri has a similar response, but by maturing most of its pods before the days became really hot, it produced larger than average yields by escaping the potentially adverse conditions.

Cultivars L-550, Rabat and RS-11 showed very similar responses to G-130, whereas, cvs. 850-3/27 and P-222-1 were very similar to Annigiri.

2.4 Factors affecting growth and development of chickpea

2.4.1 Vernalisation and photoperiod :

Day length has an important role in the growth and development of chickpea. Nanda and Chinoy (1960 b) studied the effect of vernalisation and photoperiod on the growth, number of branches and leaves per plant. The effect of photoperiod on the stem growth was more marked in unvernalised than in vernalised plants. The initial rate of stem elongation was greater under long day condition treatments than with normal and short days, but maximum plant height was reached under 18 hour day treatment. Vernalisation hastened stem elongation, so that stem length was reached sooner in vernalised than in unvernalised plant under the same photoperiod treatment. The effect of vernalisation was marked in plants exposed to shorter day length than those under longer day length. There was highly significant positive correlation between the vegetative phase and the period of attainment of maximum height, indicating that the effect of vernalisation and photoperiodsm on stem growth is probably due to their effects on flowering. Branch production under short day was found to be less than under normal day and they suggested that possibly this is because of reduced carbon assimilation. Vernalisation also reduced branching irrespective of photoperiodic treatments. Similar trends were observed by them in the number of leaves per plant under different treatments.

Sandhu and Hodges (1971) in their growth chamber experiment with eight chickpea cultivars with various combinations of 8 to 12 h. or 16 h photoperiod light intensity of 136 or 28063 lux observed growth and yield highest with 16 hour photoperiod. van der Maesen (1972) reported yield of dry matter was higher in long days and increasing photoperiod was more favourable for this than decreasing photoperiods. Pandey et al. (1977) on the other hand in their studies with 15 chickpea cultivars observed that long day conditions decreased the number of primary branches and total dry matter, while the natural day condition produced more branches and dry matter.

2.4.2 Light intensity :

It was reported by Sandhu and Hodges (1971) that low light intensity favour vegetative growth and it influences fruit set indirectly. They further observed that growth and yield was greatest in higher light intensities, which was confirmed by van der Maesen (1972), who found that all the parameters of growth and yield was enhanced significantly. Light intensity has been indirectly studied by investigating the effect of shading on growth and yield. When horizontal shade was given to a canopy during reproductive period of growth at Hyderabad to reduce the photosynthetically active radiation (PAR) to 50 %, senescence was delayed and yield significantly increased upto 15 % and this was ascribed to the fact that shading reduced to stress which was accelerating senescence process. Moreover, it was thought that light intensity would be near saturation even by reducing the

PAR to 50 %. Further reduction in light intensity delayed senescence, even further, but reduced the yield. The same trend was seen by Sinha and Coworkers (1980).

Saxena and Sheldrake (1980) in the shading experiment with different light transmission percent at Hissar with four chickpea cultivars from pod stage observed that yield was progressively reduced in all cultivars with the increase in thickness of shade or with decrease in light transmission percentage. There was significant reduction in yield in all the cultivars even with the shade intercepting only 25 % of the sun light. Drastic reduction in total dry matter, harvest index and pods/m^2 and seeds/pod occurred at 84 % light interception i.e. 16 % transmission. They concluded that at Hissar light became the limiting factor to dry matter production and yield, even at levels only 15 % below full sun light. Due to high leaf area value (5.0) at Hissar with mutual shading, light penetration with the canopy is hindered, causing light a limiting factor. At Hyderabad L.A.I is low (2) and light transmission ratio was about 50 %.

2.4.3 Temperature

The effect of temperature on growth, development and yield of chickpea has been studied by way of staggered sowings and the optimum time of sowing for gram has been found to be from mid-October to end of October. Earlier or later sowings other than that period resulted in poor growth and low yield in most of the cultivars (Saxena and Yadav, 1975).

Sen and Mukherjee (1961) from their fortnightly sowing studies from October to mid-June observed that the yield of gram was eleven mounds when sown in October end and it reduced to four mounds when sown in January. This was due to poor growth and resulted in poor pod formation when sown late. Again Sen et al. (1964) from a detailed six fortnightly sowing trial commencing on 28th October through 1957-60 observed plant height, number of branches and pods per plant progressively decreased with delay in sowing dates. Sharma et al. (1967) in a two year trial in Ferozpur with twelve desi and eight Kabuli types of chickpea sown at three fortnightly intervals from 21st October observed that mid early sowing (21st October) resulted in higher growth, thereby leading to higher yields. Later sowings resulted in lower yield in all the cultivars. These findings were confirmed by Sur et al. (1966) from their six fortnightly sowing studies commencing from 13th October and by Mathur and Tomer (1966) from their results of three year trial sown on three dates from Ist week of October. Luthra and Gill (1974) in Punjab under irrigated trials with cv. Pb-7 with periodical sowings from 10th October found that yields declined by delayed sowings.

Eshel (1967) in Israel in field trials with two cultivars of chickpea California and Bulgaria sown at 3 weeks interval from 28th October to 16th May observed that delayed sowings shortened the growing period and caused a great reduction in plant size, number of main and sub-branches and plant total dry weight . The reproduction ability was also greatly reduced with delayed sowing resulted in poor yield. van der Maesen (1972) found that

plants produced more dry matter and grain when sown early. Kaul and Sekhon (1976) in their fortnightly sowing trials from Ist October to 15th November with three varieties i.e. G-130, L-335 and L-550 during 1973-74 observed a significant reduction in plant height, number of branches, pods/plant and yield with delayed sowings and they attributed this to the fall in air temperature when sowing was delayed. The podding potential also showed a sharp reduction due to delayed sowing.

A detailed study by Ageeb and Ayoub (1976) in Sudan in different types of soils with fortnightly sowings from Ist October to 21st January revealed that plant survival, number of pods and seeds per plant, total dry weight/plant at vegetative reproductive and at harvest decline progressively from sowings of 2nd week of November. This was true for the crop growth rate for all the sowings from one month before flowering.

Summerfield et al. (1979) reported promoting effects of warmer nights and longer days on vegetative growth, early flowering, rapid leaf senescence and pod maturation. Recent studies of Summerfield et al. (1981) on 15 chickpea genotypes of various maturity period revealed that the appearance of perfect flowers was hastened by longer days and warmer nights, reduced the vegetative period and reduced seed yield from 4 to 16 per cent. They found that hot day not only had a great effect on pod and seed numbers per plant, but they also decreased the mean seed dry weight slightly (4 %). On the other hand warm nights had the opposite effect which tended to effect the detrimental effect of hot days. They further observed that in cooler

environments plants which had slightly shorter reproductive periods and which produced fewer pods and smaller seeds matured sooner than those which had longer reproductive periods and larger yields. Longer hot days and warmer nights, also contributed to rapid maturity. Variation in vegetative growth contributed more to changes in crop duration in comparison to reproductive growth.

2.4.4 Water stress :

Even though chickpea is grown as an unirrigated crop in many parts of India, it has been seen, irrigation of chickpeas during reproductive phase generally leads to increased growth and yields. Sheldrake and Saxena (1979) observed a ten fold increase in yield and dry matter production with irrigation, while they saw that a moisture stress results in earlier senescence and maturation in plants, resulting in low dry matter production and yield.

2.5 Correlation studies in chickpea

Literature pertaining to correlation studies in chickpea are summerised below.

Correlation studies between Character vs character(s)		No. of cultivars	Correlation +/-	Workers
1	2	3	4	5
Seed yield	Plant height	9	+	Baluch and Soomro (1968)
"	"	45	-	Katiyar et al. (1977)
"	Leaf area	10	-	Singh (1968)

1	2	3	4	5
Seed yield	No. of branches	9	+	Baluch and Soomro (1968)
"	"	10	+	Singh (1968)
"	"	15	+	Sharma et al. (1969)
"	"	60	+	Bhardwaj and Singh (1972)
"	"	20	±	Joshi (1972)
"	"	20	+	Choudhry and Khan (1974)
"	"	81	+	Patel and Pokle (1974)
"	"	21	+	Bahl et al. (1976)
"	"	10	+	Oraon et al. (1977)
"	"	75	+	Singh et al. (1977)
"	"	45	+	Katiyar et al. (1977)
"	"	50	+	Gupta and Sohanlal (1981)
"	Days to maturity	45	-	Katiyar (1979)
"	Pods/plant & Seeds/plant	45	+	Katiyar (1979)
"	100 seed wt.	15	+	Sharma et al. (1969)
"	"	45	+	Phadnis et al. (1969)
"	"	60	+	Bhardwaj and Singh (1972)
"	"	81	+	Patel and Pokle (1974)
"	"	21		Bahl et al. (1976)
"	Biological yield	14	+	Lal (1976)
	and harvest index	16	+	Bahl and Jain (1977)
"	"	50	+	Gupta and Sohanlal (1981)

contd...

1	2	3	4	5
Seed yield	No. of flowers	15	+	Sharma et al. (1969)
Effective pod number	Total plant weight	30	-	Dahya et al. (1976)
100 seed wt.	Seed No./pod	20	+	Choudhry and Khan (1974)
"	"	21	+	Bahl et al. (1976)
"	Seeds/plant	20	+	Choudhry and Khan (1974)
"	Pod number	10	+	Oraon et al. (1977)
"	Days to maturity	10	+	Oraon et al. (1977)
Days to flowering	Flowering period	10	+	"
"	Seed number/ plant	10	-	"
"	Days to maturity	10	-	"
"	Plant height	10	-	"
"	No. of leaf	10	-	"
"	Total No. of pods	10	-	"
"	100-seed wt.	10	-	"

From the above table it is clear that among the vegetative attributes the number of branches per plant was the most important component which always had positive correlation with yield. However, the plant height also showed positive correlation with yield. The reproductive attributes which showed positive correlation with yield were number of pods per plant, seeds per plant and 100 seed weight . Although days to flower were positively

related with flowering period it was found that both these characters had negative correlation with days to maturity, plant height, number of leaf per plant, total number of pods per plant and 100 seed weight.

2.6 Leaf Area and Dry matter production

The pattern of dry matter accumulation in short and long duration chickpea cultivars cv. JG-62 and T-3 respectively grown at Hyderabad (Peninsular India) and at Hissar (North India) was studied by Saxena and Krishnamurthy (1979). They observed that at Hyderabad leaf area continued to increase along with stem weight half way through reproductive phase. However, in cv. T-3 there was better net gain in weight in vegetative structure after flowering. The leaf area began to decline only during the late reproductive phase. In both cultivars there was no net gain in pod number per plant after LA1 started to decline rapidly due to senescence and abscission of leaves. This decline in leaf area began earlier in late cultivars than in early cultivars, though in both cases LA1 fall at the start of reproductive phase. Saxena and Sheldrake (1980) described the pattern of accumulation of dry matters in cultivar grown at Hissar. Increase in leaf area and addition of dry matter continued even before flowering in both the cultivars. Since chickpea is indeterminate addition of dry matter in vegetative structure, continues even after the on set of reproductive growth, which is more vigorous in early cultivars like JG-62.

Pod number increased hand in hand with the increase in dry matter and leaf area, but once the leaf area started declining there was no

increase in pod number. The accumulation of dry matter continued for a protracted period owing to longer growth duration. Saxena and Sheldrake (1980) concluded that source is not a serious constraint to total dry matter production, but yield was relatively more sensitive than total dry matter production. Since the capacity of flowering and fruiting potential of this crop is not limiting, the achievement of greater dry matter production based on improved photosynthetic rates per se or some related attribute such as RuDP carboxylase activity or chlorophyll content could be positive on approach to get higher yields (Kumari and Sinha, 1972; Sinha, 1977). However, Summerfield et al. (1980) did not agree with the above suggestion because in their opinion selection for photosynthetic rate presents very great problem with very little surety of return.

2.7 Source sink relationship in chickpea

The two important factors that determine the yield are photoassimilate supply (source activity and the storage capacity e.g. number and size of pods and seeds (sink size). Saxena and Sheldrake (1980) tried to evaluate whether source or sink is limiting the yield of chickpea.

Saxena and Sheldrake (1980) studied the effect of defoliation at different stages of growth and the effect of different degrees of defoliation throughout the reproductive phase. Different degrees of defoliation carried out at the time of flowering and continued throughout the reproductive phase showed that the removal of 25 %, 33 % or 50 % of the leaves had little or no effect on yield. They found that removal of half of the

leaves at the time of flowering resulted only slight reduction in yield and complete defoliation at the time of flowering lead to yield reduction of 30-40 %. Yield was reduced with higher degrees of defoliation largely a consequence of reduction in pod numbers per plant.

Evaluation of the source was also done by observing the effects of shading on yield and yield component by placing cloth shade over plant throughout the reproductive period. Shading involved 75 and 80 % reduction of light intensity had not significant effect on yield; Under thinner shades (50 % light reduction) the yield was significantly increased over controls.

Further evaluation of source effect was done by flower removal and its effects were observed on yield and yield components. Flower removal lead to the reduction in yield as a result of reduction in pod numbers. The total dry matter production of deflowered plants was also reduced.

It was concluded from the above studies that the size of the photosynthetic source did not seem to be the main factor limiting yield. They suggested that leaf area is not a primary factor in limiting yield. However, the remaining leaves might be able to compensate for the removal of leaves by an increased photosynthetic rate. They ruled out the possibilities of such treatments modifying the water balance, since the water potential of defoliated and non-defoliated plants did not differ. Comparison of results at Hyderabad and Hissar suggested that leaf area is not a serious constraint for total dry matter production, but yield was relatively more sensitive

than was total dry matter production, but yield was relatively more sensitive than was total dry matter production to defoliation.

The effect of altered sink size was evident on partitioning of dry matter. The prevention of pod set by different flower removal resulted in both roots and nodules and delayed senescence in plants. Removal of the flowers on some branches and not on others of the same plant resulted in delayed senescence on which pod set was prevented. They suggested that the stimulus of signal that initiate senescence was related to pod set and was localised within the plant, as observed and reported for soybean by Lindoo and Nooden (1977). They finally concluded that chickpea plants have some ability to compensate for the loss of potential sink.

2.8 Effect of chemicals including growth regulators on chickpea

Most of the investigations on the effect of growth regulators in chickpea has been of a pure physiological nature in which the chickpea happen to be chosen as a test plant, however, there are numerous reports where the response of chickpea to these have been studied in order to improve yields.

2.8.1 Gibberellins

Studies pertaining to Gibberellins have been exclusively done with Gibberellic acid. (GA_3). The earlier researches by Hugon (1960, 1961, 1962) and Mange (1962, 1969) showed that GA at 50 ppm caused the release of apical dominance and thus influenced branching and stem growth.

Six weekly foliar sprays in the early stage of seedling growth were investigated in pot by Uprety (1968), who found that GA_3 (100 ppm) increased plant height and leaf numbers both in the dwarf NP 58 and tall NP 28. However, in comparison to tall it had greater effect on dwarf variety. Further, it reduced flowering, nitrogen percentage and both and total yield in both cultivars. On the contrary Khan and Chaudhry (1976), in trials at Llyalpur found that GA at concentrations of 50, 100 and 150 ppm when applied as foliar spray in seedling stage, They observed a significantly increased flower number, pod setting, seed yield at all combinations and 50 ppm being the best. Mange (1968) showed that application of 100 ppm GA to young seedlings resulted in an increase in total sugar content and amino acid content in the stem and had an opposite effect on the total nitrogen content. He reported an increase in organic acid content in the leaf and a decrease in the stem. Mange (1969) studied the effect of GA in light and dark on chickpea seedlings and he found that GA accelerated the increase in internode length with increase in sugar content, while in light GA increased the total dry matter, total N-content, respiration of the above ground parts and decreased considerably the carbohydrates, nucleic and citric acids in roots. In seedlings of gram Mange (1972) found that GA at 100 ppm increased synthesis of soluble sugar from aspartic acid and $U^{14}C$ glutamic acid. In darkness decarbocylation was increased and opposite effect was seen in light. Swaraj and Garg (1969) showed under pot culture conditions that gram inoculated with rhizobium strain 110 and treated with 20 and 100 mg of GA or ascorbic acid alone or in combination to the apices

of plants 60 days after sowing accelerated nodulation, stimulated N-fixation, increased number and weight of nodules and N-content in these plants. Swaraj and Garg (1970) observed that GA did not increase pod weight and seed weight, moreover, it delayed pod formation. Mehta et al. (1974) found that GA reversed the inhibition of seedling growth and activities of lipase and catalase in embryo axis of gram, caused by morphectin. Mehta et al. (1975) found that GA increased the activity of amylases in chickpea.

2.8.2 Cytokinins

As early as 1960-61 Hugon showed the importance of cytokinin in release of apical dominance with 5-10 ppm of kinetin. Hugon (1969) found that the treatment with 5 fluorodeoxy uridine eleminated branching induced by cytokinin application. Further Hugon (1970) reported that the application of cytokinins promoted the migration of P^{32} along the main axis to the terminal buds and its incorporation into amino acids and the effect of cytokinin could be nullified by cooling the stem or nodes of the seedling. Uscilati et al. (1974 a) observed the inhibition of the axillary buds of eight day old chickpea seedlings was overcome by the application of benzyl adinine (BA). Treatment of decapitated axillary buds by BA showed that the elongations was independent of the presence of the bud. The result showed that the process of elemination of initiation of axillary bud development began at the base of the buds. Uscilati et al. (1974 b) observed that the application of BA to bud caused stimulation of lipogenisis by six hours after treatment and tally acid contents of the activated buds was three times that of control.

2.8.3 Auxins

Fewer reports are available on the effect of auxins on chickpea, however, in literature both synthetic and natural auxins had been used. Rodriguz Lopez (1953) reported that 2, 4-D depressed seed germination when the seeds were soaked for 4 hours in a 2-20 ppm aqueous solution. Similar treatments with 2-5 ppm α-napthyl acetic acid and β-napthyl acetamide stimulated shoot growth. Only the cultivar 'Auguloso blanco' grown for 30 days in the field after germination for 11 days showed increased weight especially after treatment with β-indole acetic acid.

Srivastava and Tomer (1973) in trial with chickpea mutant, very susceptible to bud drop, observed that by spraying Indole-3-acetic acid (IAA) 10 ppm or 50 ppm fifteen days after germination reduced bud shedding. Treatment of chickpea seedlings in vitro with IAA stimulated tryptophan activity by 300 % (Srivastava et al., 1973). Mukherjee et al. (1969) used foliar sprays of 10 ppm IAA on 18 day old gram seedlings and observed an increase in shoot growth and it also induced adventitious root formation. Khan and Choudhry (1976) observed that spraying with Alar (diaminozide) at 500 or 1500 ppm or with Plano-fix whose active ingredient is napthyl acetic acid (NAA), at 10 or 30 ppm significantly increased flower number per plant, improved seed setting and gave higher yield over untreated plants.

2.8.4 TIBA (2,4,5-triiodobenzoic acid)

Sinha and Ghildyal (1973) reported that treating gram plants with

500 ppm TIBA at the start of flowering increased grain yield and 100 seed weight. Tikoo et al. (1974) found that foliar application of 75 ppm TIBA at seedling stage increased plant dry matter by 5 %, reduced height by 29 %, increased branch height by 57 %, pod number and seed yield by 78 % in cv. BG-7. Response of different chickpea varieties to foliar spray of TIBA (Saxena and Yadav, 1975) was studied at different agroclimatic centers with and without spray of 2 % urea solution at pod filling stage. Both TIBA and urea spray increased yield. At Pantnagar, even lowest concentration of TIBA (5 ppm) showed regulatory reffects on temporary spreading of the crop canopy. Studies at Ludhiana revealed that the response to TIBA was dependent on the status of soil moisture supply in relation to crop growth.

2.8.5 Growth retardants

Cycocel (2, chloromethyl trimethyl ammonium chloride or CCC).

Response to chickpea to foliar spray of cycocel at flower initiation was studied at New Delhi (Ahlawat et al., 1973 and Saraf et al., 1974) and at Ludhiana (Kaul and Sekhon 1974) using H-355 and G-130 varieties. Though the results at both the centres were inconsistent, 0.2 % cycocel increased effective pod number.

B.995 (N-dimethyl amino succinic acid)

Uprety (1968) applied 500 ppm of B 995 as foliar spray for 6 weeks at weekly intervals to 7 days old seedlings of tall NP 28 and dwarf NP 58

gram cultivars grown under pot culture conditions. He observed that B 995 significantly increased the number of flowers, fruits and seeds and yield per plant. A marked reduction was seen in plant height in both cultivars, which was more marked especially in tall NP 28.

2.8.6 Miscellaneous chemicals

Ascorbic Acid :

Swaraj and Garg (1969) observed that chickpea seeds grown in sand culture supplied with solutions containing 20 or 100 mg ascorbic acid/litre increased nodule formation, nodule number and its fresh and dry weights. The nitrogen content of ascorbic acid treated plants was 2.5 times more. The pod formation started earlier and the pod number and seed yield was more than control plants. Similar effects were also observed by Kaul and Sekhon (1974) and Gurbaksh Singh (1975).

Succinic Acid :

Ahlawat et al. (1973) reported that H-55 cultivars of chickpea showed 20 % increase in yield when seeds were treated with 0.2 % succinic acid solution, however, in subsequent studies no such response could be observed with same cultivar by Saraf et al.(1974). On the other hand Kaul and Sekhon (1974) reported that soaking gram seeds for 5-6 hours in 0.2 % aqueous solution of succinic acid enhanced the growth and yield by 20 %.

Other chemicals :

Kaul and Sekhon (1974) soaked gram seeds in other chemicals like KH_2PO_4, $CuSo_4$, KCl, $ZnSo_4$, $MnSo_4$, boric acid and molybdic acid. They found that soaking seeds in 0.5 % solution of Potassium hydrogen phosphate and 0.05 % copper sulphate solution increased yield by 41 %. Rest of the chemicals did not show any positive result.

2.9 Biochemical studies on chickpea

Different biochemical aspects have been studied extensively on chickpea, however, they are mostly confined to whole seed, germination and seedling stages and very little information is available with respect to biochemical changes during reproductive phase. No attempt has been made in the literature to compare the biochemical changes in fresh and abscised plant parts, however, sporadic information exist with respect to certain biochemical aspect which have an indirect bearing to shedding. This review is limited only to those biochemical changes which are associated either with the components of reproductive efficiency or which have a relevance in the realisation of the same. Moreover, it is confined only to those parameters which have been used in the present study namely proteins, sugars, organic acids, nucleic acids and pigments.

2.9.1 Chemical composition

Very recently Jambunathan and Singh (1980) compared the chemical constitution of a number of desi and Kabuli chickpea cultivars and reported

that the mean percentage values for protein, starch, sugar, fibre, fat and ash were 22.4, 49.2, 6.1, 2.7, 5.4 and 3.1 for the Kabuli cultivars and 22.0, 45.6, 5.3, 8.4, 4.6 and 3.4 for the desi cultivars respectively and concluded that the quantitative difference in seed coat of Kabuli cultivars appeared to be consistant and real and can be used to distinguish the two. However, first report was given by Lal et al. (1963)

Seed protein content has been estimated by different workers. Esh and De (1960), Chandra and Arora (1968) and Kadwe et al. (1974). The seed protein content has been estimated by other workers also. The changes in protein and amino acid content during seed germination and seedling growth had been described by Damodaran et al. (1946), Jadhav and Airam (1961) and Abu Sakhara et al. (1970).

Hadi (1966) reported that the quantity of RNA present was 13 g/100 g and that of DNA was 0.88 g/100 g of seed. They observed that the nucleic acid declined. In the first days of germination by 23 %. However, this decrease was not accompanied with an increase in specific activities of the respective nucleases.

Saxena and Krishnamurthy (1979) analysed the pods and seeds in chickpea for their Nitrogen (N), Phosphorus (P) and Potash (K) contents and they reported that the seeds contain 4.15 %, 0.31 % and 1.37 % of N, P and K respectively, While the pod wall contains 0.73 %, 0.06 % and 2.34 % of N, P and K respectively.

Saxena and Krishnamurthy (1979) studied the changes during growth

and development in chickpea plants. They found that nitrogen content in general commenced to decline progressively from 20 days after sowing both in stem and leaf with time till flowering and this decline was more steep in the leaf than in the stem. They further observed a sharp fall in the leaf nitrogen with pod set. Similar pattern of changes was observed for P and K.

Pokhriyal and Abrol (1980) studied the extent of nitrate assimilation via the enzyme nitrate reductase (NR) in relation to total and reduced nitrogen in chickpea (cv. BG-209) plants at different stages of growth. They found that soil derived N accounted for 15.1, 8.3 and 7.2 % of the total reduced nitrogen at preflowering (I), profuse flowering (II) and seed filling (III) stages respectively. Out of the total soil derived nitrogen, 10.1, 59.3 and 30.6 % was reduced during stages I, II and III respectively. They observed that before profuse flowering phase (II) there was an accumulation of reduced N in the stem and a significant rise in NR activity paralleled by an increase in NO_3 content. They suggested that this was associated with the heavy demand of N during this period. They observed that maximum accumulation of reduced nitrogen and dry weight took place during this period. They concluded that a high incidence of flower and pod shedding may be related to the fact that supply may not be able to cope with the demand.

2.9.2 Organic acids :

Studies on the organic acid in chickpea have been made by Mange

(1965) who observed an increase in organic acid content in stem when treated with GA. Ramdas et al. (1979, personal communication) reported for the first time that chickpea is probably the first field crop with crassulacean type of behaviour since maleic acid increased during the night and decreased during the day. However, Sinha and coworkers (1980), from their study of diurnal changes of maleic acid for three hours found that the accumulation was maximum at 18.00 hours and it stayed as such throughout the night and next morning until it was washed away by dew. They observed that organic acid is exudated by all parts of the plant, maleic acid being the main one. They estimated the maleic acid content on the surface of leaves and fruit wall of chickpea at different stages of growth and found that it progressively increased in the order of vegetative, preflowering, flowering, pod setting and seed development stages at 5, 9, 12, 19 and 15 m.eq. per g respectively. In young pod walls it went as high as 48 m.eq./g. They observed that the maleic acid content increased 2.5 folds with the increase of temperature from 5 to 30°C. They also noted that the amount of maleic acid exudated was much reduced when the glands on the surface of leaves were brushed away.

2.9.3 Photosynthetic rates and Chlorophyll content

Kumari and Sinha (1972) studied the variation in chlorophyll contents in leaves during flowering and pod development in 21 chickpea cultivars. They observed a variation in chlorophyll a (1.720 - 2.720), chl b (0.075 - 1.845) and total chlorophyll 2.395 - 4.565 mg per gm of dry weight, during

flowering and the ratio between chl a and b varied from 1.46 and 2.59. During pod development they observed a fall in chlorophyll contents. Thus the chl. a content varied from 1.615 to 2.170, chl. b from 0.720 to 1.300 and total chlorophyll from 2.335-4.155 and the ratio narrowed from 1.65 to 2.46. They suggested that this reduction in pigments might be related to low the photosynthetic rates.

Sinha and Coworkers (1980) studied the type of Co_2 fixation in chickpea and estimated the RuBP carboxylase and PEP carboxylase activity in normal and brushed leaves (to remove glands) at different stages of growth. They observed no significant reduction in the activity of RuBP carboxylase. On the other hand about 80 % of the activity of PEP carboxylase was removed by brushing the glands and hence they suggested that the plant has normal C_3 type of Co_2 fixation.

2.9.4 Biochemical changes during seed development :

Verma et al. (1964) observed that the total N-content went down as seed matured. However, Abu Shakara et al. (1970) observed that during seed development there was no change in total nitrogen content. A detailed study of changes in carbohydrates, amino acids and proteins in developing seeds of chickpea was carried out by Singh et al. (1981). Developing seed of chickpea cultivar viz., G-130, L-550 and 850-3/27, grown under field conditions, were sampled at different stages of maturity and analysed for soluble sugars, starch, soluble nitrogen, protein-nitrogen and amino acids. They observed that the fresh weight of seeds of all the three cultivars

decreased upto 28 days of flowering, while dry matter continued to increase thereafter till seed maturity. Rapid starch accumulation was observed between 14-18 days after flowering. The amount of starch in L-550 and G-130 decreased between 21-35 days after flowering but it remained constant in 850-3/27. Most of the starch accumulated from 14-28 days after flowering and this was more pronounced in 850-3/27. Changes in the amounts of the soluble sugars accompanied during the same period, therefore, the period between 14-28 days after flowering was found to be the period of intense bio-chemical acitivity. Starch as percentage of seed dry weight started to decrease after 28 days, while starch per seed increased till maturity.

Soluble nitrogen also decreased upto 28 days after flowering and then remained constant till maturity. They suggested that during early stages of development, soluble N was rapidly utilised for synthesis of proteins, which consequently increased. The soluble nitrogen when expressed as mg/seed increased upto 21 days after flowering. Percentage of protein nitrogen increased slowly throughout the development stages in G-130 and L-550. Their results suggested that rapid protein deposition occurred during the period between 14 and 28 days. However, protein nitrogen per seed to increased upto 30 days after flowering in all the cultivars. The electrophoretic pattern revealed that deposition of seed storage proteins or cotyledons occurred 14 days after flowering and according to them most of the biochemical activities apparently occurred within 14 and 28 days after flowering. Most of the amino acid increased

during seed development, however, they observed that sulphur containing amino acids (methionine and cystine) decreased along with valine. Verma and Lal (1966) reported that total soluble and inorganic phosphorus fractions increased with development of seeds and its maturity and the longer decrease in P-compound was seen in seed coat (Lal and Verma, 1968).

3. MATERIALS AND METHODS

Investigations were carried out with Chickpea (Cicer arietinum L.) during rabi season of 1979-80 and 1980-81 at Indian Agricultural Research Institute, New Delhi (28°.35'N. and 70°.12'E). To meet the major objectives of the present investigation experiments were categorised into following groups :

I Evaluation of reproductive efficiency of the various genotypes.

II Improvement of reproductive efficiency by chemical manipulations.

III Biochemical studies on the fresh and abscised plant parts.

I. EVALUATION OF THE REPRODUCTIVE EFFICIENCY

3.1 Experiment No.1. Evaluation of the reproductive efficiency of different genotypes of chickpea

The experiment was conducted both under field and pot culture under natural day light conditions. The genotypes under study were the types, JG-62, C-235 and nine BG lines viz., BG-203, BG-209, BG-212, BG-215, BG-216, BG-217, BG-220, BG-226 and BG-227 along with the Kabuli type L-550. The seeds were treated with a single strain of Rhizobium culture (B-75) before sowing.

A. Field trial :

The field trial consisted of raising of the above genotypes in a simple randomised block design with three replications. A presowing irrigation was given in order to maintain optimum moisture level for germination

of seeds and normal agronomic practices were followed from sowing onwards. A basal dose of 15 kg nitrogen as urea and 25 kg of P_2O_5 as super phosphate per hectare were applied. A supplementary irrigation was given just before flowering. Plot size was 10 x 1.5 meters for each cultivar with spacing of 30 cms between row and 10 cms between plant. As the normal date for sowing of chickpea is around the middle of October, the sowing was done on 19.10.1979. The respective cultivars were harvested as and when they ripened.

B. Pot culture experiment :

Earthen pots of 30 cms diameter were filled with a mixture of 10 kg of well sieved farm soil and well decomposed farm yard manure in the ratio of 3 : 1. A basal dose of fertilizers as described earlier was given. Initially eight seeds (2 seeds/hill) were sown and after 10 days the seedlings were thinned and finally four plants per pot were retained. All the pots were regularly watered to maintain adequate soil moisture.

The sowing date was the same as the field viz., 19.10.1979.

Sampling :

In field and pot culture the first sample for each cultivar was taken 30 days after sowing (DAS), thereafter subsequent samples were taken at 30 days interval until the time of final harvest.

3.1.1 Observations and experimental procedure :

For all the replicates of each cultivar the following data were

recorded :

1. Days to first flower
2. Total number of flowers
3. Days to first pod
4. Peak flowering
5. Flower duration
6. Crop duration

3.1.2 Morphological observations :

At the time of each sampling the following morphological observations were recorded from three plants per replication and results were expressed on per plant basis.

1. Plant height
2. Number of branches of primary order
3. Number of branches of secondary and tertiary order
4. Total number of branches
5. Total number of leaves

3.1.3 Leaf area and dry matter production :

Samples were taken at 30 days interval from time of sowing to final harvest. Three plants were harvested from field from each replicate at random. These plant parts were dried at 80°C in an oven and weighed subsequently.

Leaves from representative plants were taken and their area was recorded on Hitachi automatic leaf area recorder and then these were finally weighed after drying. The area of the rest of the plants were computed on the basis of area to weight ratio of the sampled leaves at each harvest per replicate for each genotype. The results were expressed on per plant basis.

3.1.4 Yield and yield components at final harvest :

The crop at maturity was harvested from half square meter area from two places and pooled for final yield data.

The following data were recorded :

1. Total number of pods.
2. Number of normal or filled pods.
3. Number of abnormal or unfilled pods.
4. Total number of seeds.
5. Pod weight.
6. Seed weight.
7. 100 seed weight.

The results were expressed on per plant basis.

3.1.5 Evaluation of reproductive efficiency :

Parameters determining reproductive efficiency were calculated from the various components (derived from reproductive attributes) and expressed as percentage. The parameters used for evolution of reproduction efficiency

were as follows :

1. Loss due to shedding
2. Pod set
3. Filled pod
4. Unfilled pod
5. Effective pod set

The details regarding the basis of calculations of above parameters will be described later.

B. Pot culture :

In pot culture at each harvest five plants were sampled for each cultivar and the procedure used and data recorded were identical to field which has already been described above.

3.2 Experiment No.2 Studies on the influence of temperature (based on different dates of sowing), on time, intensity and duration of flowering and reproductive efficiency in relation to growth and development in selected genotypes (1980-81).

Based on the performance of different genotypes during the year 1979-80, three cultivars were finally selected for detailed studies : These were JG-62, L-550 and BG-209.

BG-209 and L-550 were selected because reproductive efficiency was

found to be highest in BG-209 and lowest in L-550 amongst the genotypes examined and also because they represented the desi and Kabuli types. JG-62 was selected since the reproductive efficiency was found to be intermediate and also because it had a double podded character.

The experiment was designed to reflect the influence of temperature and hence this factor was studied by varying the dates of sowing.

Field trial :

The experimental lay out was a randomised block design with five replications and four dates of sowing for each of the three cultivars. Individual plot size was 8 x 3 meters, with row to row spacing of 30 cms and plant to plant distance of 10 cms with a population of 33,000 plants/ha. All agronomic procedures were same as described earlier.

3.2.1 Dates of sowing :

Four sowings were done at 15 days interval commencing from 4th October, 1980. The dates of sowing were as follows :

First sowing	S_1	4.10.1980
Second sowing	S_2	19.10.1980
Third sowing	S_3	3.11.1980
Fourth sowing	S_4	18.11.1980

3.2.2 Time, intensity and duration of flowering :

Representative plants from each replication were earmarked with the

help of an iron peg, labelled at appropriate stages. Non destructive observations pertaining to detailed flowering behaviour were recorded at 5 day interval subsequent to the appearance of first flower for each cultivar and for each date of sowing.

It was impossible to distinguish fresh flowers from one or two day old retained flowers unless the flower was very fresh. Therefore, the counts included both the retained flowers as well as the fresh flowers formed as on that day for convenience. They will be referred as flowers retained on that specific day. When flowers drop, peduncle ("Scar") is retained and therefore the number of abscised flowers have been recorded on the basis of 'scars' as shown in the Fig. 1.

The following observations were recorded :

1. Days to first flower
2. Number of retained flowers
3. Number of abscised flower
4. Total number of flowers
5. Days to peak flowering
6. Days to first pod
7. Number of pods formed
8. Flower duration
9. Days to maturity

3.2.3 Morphological attributes :

Identical observations were recorded with respect to morphological

FIG. 1

FORMATION OF ABSCISSION LAYER IN CHICKPEA FLOWER/ POD AT THE JUNCTION OF PEDUNCLE AND PEDICEL.

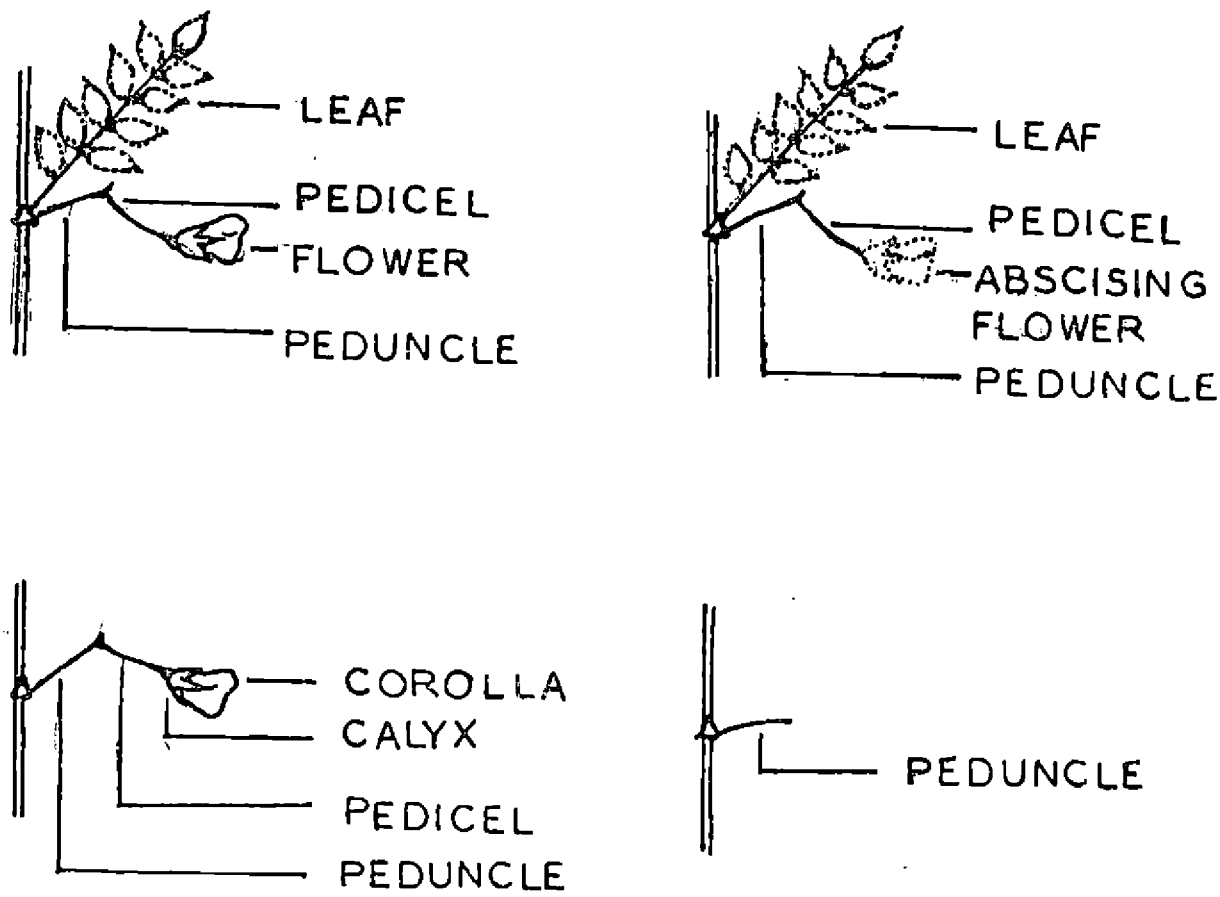
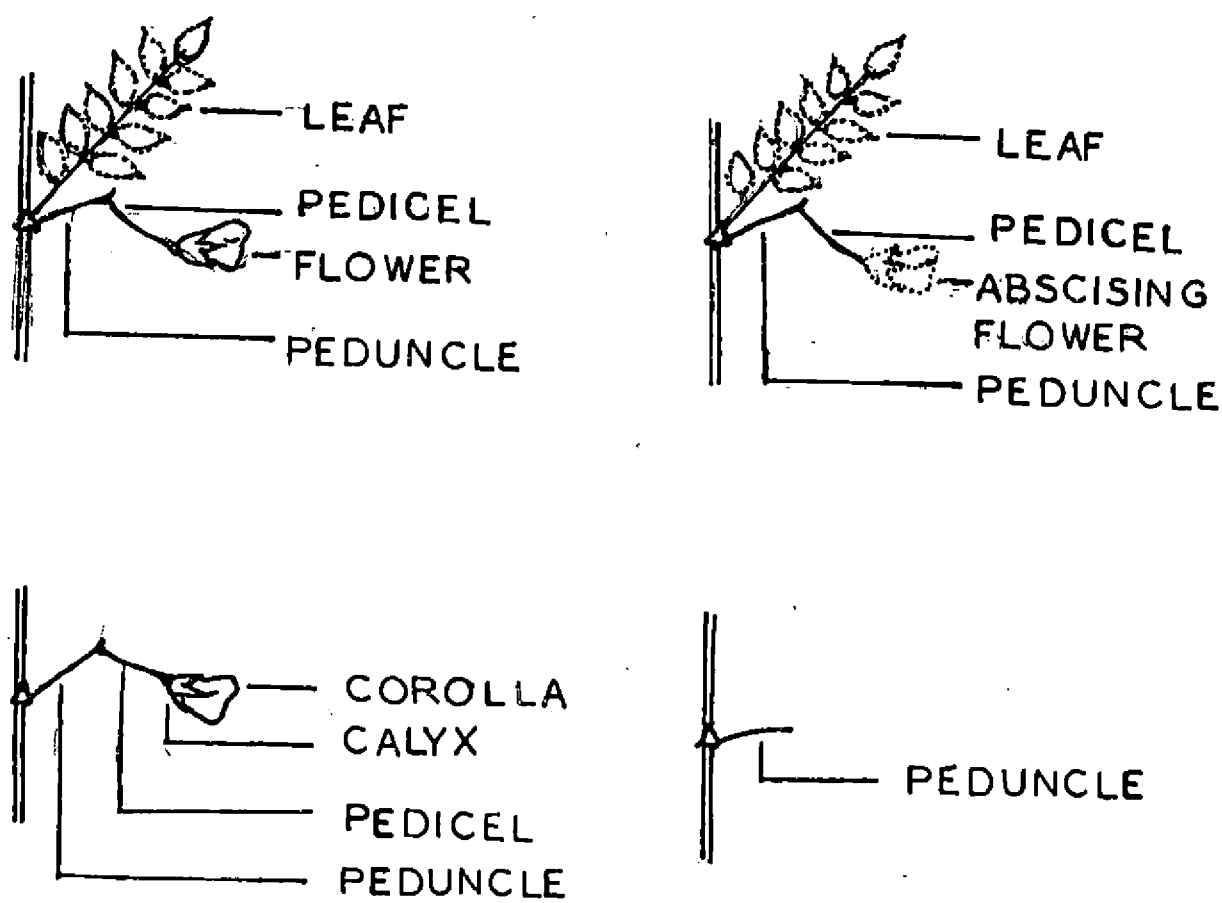


FIG. 1

FORMATION OF ABSCISSION LAYER IN CHICKPEA FLOWER/ POD AT THE JUNCTION OF PEDUNCLE AND PEDICEL.



attributes as given in section 3.1.2

The results were also expressed on per plant basis.

3.2.4 Changes in leaf area and dry matter production :

The leaf area was measured at 10 days interval in the same manner as explained in section 3.1.3

Three plants of each replicate from each cultivar were harvested at 10 day interval from 30 DAS to final harvest. The procedure adopted and the observations recorded were same as described earlier in section 3.1.3. In addition to above, rate on dry matter production in reproductive organs was also recorded.

3.2.5 Growth analysis :

The various parameters of growth analysis were calculated from the above data only from the field trial. The following equations were used to calculate the different growth parameters (c.f. Watson, 1952; Friend et al., 1962; Redford, 1967).

1. Crop growth rate (CGR)

CGR represents dry weight gained by unit area of crop in unit time.

$$\text{i.e.} \quad \frac{W_2 - W_1}{t_2 - t_1}$$

2. Relative growth rate (RGR)

RGR represents increase in dry weight in time t_1 and t_2 over the

dry weight at time t_1 :

$$\text{i.e.} \quad \frac{\text{Log } W_2 - \text{Log } W_1}{t_2 - t_1}$$

Where W_2 and W_1 represents the dry weight at time t_2 and t_2 respectively in the above parameters.

3. Leaf area index (LAI)

Leaf area index was measured in terms of total leaf area (cm^2) per square meter of land surface.

4. Leaf area duration (LAD)

Leaf area duration was calculated by integrating the leaf area index from 30 DAS to final harvest.

3.2.6 Yield and yield components at final harvest :

The crop in field at maturity was harvested for each date of sowing in similar manner as described earlier. The results were expressed per plant basis.

The following observations were recorded :

1. Total number of pods
2. Number of developed pods
3. Number of underdeveloped pods
4. total number of seeds
5. Seed number/pod
6. Pod weight

7. Seed weight

8. 100 seed weight

B. Pot culture

At each harvest 5 plants from each cultivar were taken. The procedure followed and observation taken were identical as described for field.

3.2.7 Reproductive efficiency :

From the data on various components of reproductive efficiency obtained from different reproductive attributes various parameters determining reproductive efficiency were calculated for both field and pot culture and the same were expressed as percentage.

The seed efficiency was derived by calculating the total number of ovules from the number of ovules from carpel reported from the work of ICRISAT (Annual progress report of chickpea physiology 1976-77). It has been reported from ICRISAT that the ovule number per carpel for JG-62 was 2.14. In L-550 it was 2.01 and 2.04 for early and late formed pods respectively. Therefore, an average value of 2.02 was taken for L-550. Since the value for most of the cultivars examined at ICRISAT varied only between 2.0 and 2.5 an average value of 2.2 was taken for BG-209. Calculations were made according to the following :-

1. Loss due to shedding :

$$\frac{\text{Total number of flowers and pods shed}}{\text{Total number of flowers}} \times 100$$

2. Pod set :

$$\frac{\text{Total number of pods}}{\text{Total number of flowers}} \times 100$$

3. Effective pod set :

$$\frac{\text{Total number of developed pods}}{\text{Total number of flowers}} \times 100$$

4. Effective fruiting efficiency :

$$\frac{\text{Number of developed pods}}{\text{Total number of pods}} \times 100$$

5. Ratio of under-developed pods to total pods

$$\frac{\text{Number of under-developed pods}}{\text{Total number of pods}} \times 100$$

6. Seed efficiency :

$$\frac{\text{Number of ovules released as seed}}{\text{Total number of pods}} \times 100$$

7. Effective seed efficiency :

$$\frac{\text{Number of ovules developed into seed}}{\text{Total number of ovules found per carpel per pod set}} \times 100$$

3.2.8 Temperature data

Daily minimum, maximum and mean temperatures were recorded from the Meteorological Station attached to Water Technology Centre, IARI.

Heat Units and growing degree days were calculated as follows :

Heat Unit (HU)

Heat units were calculated by the method of direct summation index

of daily maximum temperature. The basal temperature of 10°C was subtracted from individual day maximum temperature and heat unit thus obtained only represented a specific period (5 day interval).

Growing degree days (GDD)

Growing degree days have been calculated by the method of direct summation of mean temperature. Cumulative values of 5 day interval are given.

II. IMPROVEMENT OF REPRODUCTIVE EFFICIENCY BY CHEMICAL MANIPULATIONS :

3.3 Experiment 3 : Response of chickpea cv. L-550 to different concentrations of growth regulators at pre-flowering, mid-flowering and post flowering stages in pot culture during 1979-80.

Cultivar L-550 was chosen for this experiment, since it represented the Kabuli type, which has better commercial value over desi types.

The experiment was carried out under pot culture conditions in duplicate with 120 pots with uniform plants. The crop was sown on 19.10.1979.

3.3.1 Experimental design :

Treatments - 5 (including untreated control)

Concentrations - 4

Stage of application - 3

The growth regulators and concentrations used are detailed below :

Growth regulator		Concentration (ppm)			
1. Indole -3-acetic Acid	(IAA)	1	2	5	10
2. Kinetin	(BA)	1	2	5	10
3. Cycocel	(CCC)	2000	3000	4000	5000
4. Ethrel	-	500	750	1000	1250

The respective concentration of each growth regulator was applied exogenously in the form of fine foliar spray at pre-flowering, mid-flowering and post flowering stages. The first spray was given when the plants were 38 days old. Thereafter, weekly sprays were continued until the plants crossed over to the next stage. The number of sprays did not exceed more than four at any stage.

3.3.2 Observations

1. Total flowers
2. Total number of pods
3. Total number of effective pods (filled pods)
4. Total seed yield (g/plant)

The results were expressed on per plant basis.

3.4 Experiment No. 4 : Effect of stage vs growth regulators interaction on yield attributes of chickpea cv. L-550 in pot culture and field during 1980-81.

The results of the investigations (Expt. 3) carried out during the year 1979-80 formed the basis of the experimental design for the above experiment, during 1980-81. The conclusion from investigations of the previous year's were as follows :

Stage of application :

1. IAA was found beneficial at all stages viz., pre-flowering, mid-flowering and post-flowering stages.
2. Cycocel was more effective at mid-flowering stage.
3. BA was found to be more effective at post-flowering stage.
4. Ethrel gave negative results at all stages.

Concentration effects :

Results pertaining to the effect of different concentrations of growth regulators used showed :

1. IAA gave best results at lower concentrations. Since the results with 2 ppm were consistant, hence this concentration was used for further studies.
2. Cycocel was also found to be more effective at lower concentration, and therefore, lower concentration of 2000 ppm was selected for the present investigation.

3. BA was found to be equally beneficial at 5 and 10 ppm, however, lower concentration of 5 ppm was prefered for economical reasons.

The stages were as in earlier experiment, viz., pre-flowering, mid-flowering and post-flowering, however, concentrations were as described above. Ethrel was deleted from the present study, since negative results were obtained in earlier study.

3.4.1 Experimental design :

Requirement for IAA could be inferred for all the stages and that for cycocel and BA at mid and post-flowering stages respectively. Therefore, following combinations formed the various treatments. Untreated plants served as control.

Treatment	Pre-flowering	Mid-flowering	Post-flowering
1	Control	(untreated)	
2	IAA	Cycocel	IAA
3	IAA	Cycocel	IAA + BA
4	IAA	Cycocel	BA
5	IAA	-	BA
6	IAA	-	IAA + BA
7	IAA	IAA	IAA + BA
8	IAA	IAA	IAA
9	IAA	IAA	-
10	IAA	IAA	BA

The experiment was conducted both under field and pot culture conditions. Ten pots per treatment were maintained under pot culture. Field trial was conducted in randomised block design with ten treatments and four replications. The sub plot size was 3 x 2 meters, with interspace of 1 meter between them. Other conditions were same as described in section 3.1.

3.4.2 Growth regulators were applied as foliar sprays at the respective stages. At final harvest in pot culture experiment, data were recorded with respect to following characters :

1. Number of total pods
2. Number of developed pods
3. Number of under-developed pods
4. 100 grain weight
5. Seed yield
6. Stem weight
7. Total dry weight

In field, data were recorded only for seed yield and total plant weight. From the above data harvest index (HI) was calculated as follows :

$$HI = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

III. BIOCHEMICAL STUDIES IN RELATION TO REPRODUCTIVE EFFICIENCY OF CHICKPEA :

3.5 Experiment No.5 : A comparative study of the biochemical changes in fresh and abscised plant parts :

Studies pertaining to biochemical changes in fresh and abscised plant parts were carried out with the plant material collected from respective cultivars, in field. Fresh weights of the materials were recorded and then they were dried in oven for 80°C and subsequently made into powder. Proteins and sugars were estimated from the oven dried material. Pigments and nucleic acid analysis was carried out on fresh weight basis, however, for nucleic acid the material was kept in deep freeze at -10°C.

3.5.1 Total Nitrogen :

The total nitrogen was determined by Kjeldahl method (Jackson, 1967)

Reagents :-

1. Catalyst mixture : Anhydrous Na_2So_4 and pure $CuSo_4$ were mixed in 10 : 1 ratio.
2. Bromocresol green mixture indicator (0.5 g of bromocresol + 0.1 g of methyl red in 100 ml of 95 % alcohol).
3. Boric acid solution : 40 g of H_3BO_3 was dissolved in 1 L. of distilled water. 5 ml of indicator solution was added to each like of boric acid solution.
4. Sodium hydroxyde solution : 40 % NaoH prepared by using N-free NaoH flakes. This solution was allowed to stand for 24-48 hours so as to pricipate out Na_2Co_3 and other impurities.

The plant material was ground to fine powder and 250 mg of the sample was transferred to a 300 ml Kjeldahl flask. 25 ml of Con. H_2So_4 was added to it and kept overnight. 10 g of catalyst mixture was added and heated gently till no frothing was there. Then the flask was heated briskly. Digestion was continued until the solution was clear. The contents were cooled to room temperature.

The digested material was transferred to a 1 L distillation flask by carefully washing 5-6 times with distilled water. 125 ml of 40 % NaoH solution was carefully added. The flask was connected to a distillation set. The ammonia evolved was collected in 25 ml boric acid solution to which mixed indicator solution had already been added.

The ammonia collected was titrated with standard sulphuric acid till it reached faint pink end point.

Calculation was done on the basis that 1 ml of IN $H_2So_4 \equiv$ 0.014 g of nitrogen.

The results were expressed as percentage dry weight.

3.5.2 Total proteins :

First the protein nitrogen was determined by Kjeldhel's method, as described earlier and then the value was multiplied only the factor 6.25 to obtain the values for total proteins. Results were expressed as percentage dry weight.

3.5.3 Soluble proteins :

Soluble protein content were estimated by the method described by Lowry et al. (1951).

Preparation of reagents :

(A) 2 % Na_2Co_3 in 0. 1 N NaOH

(B) 5 % $CuSo_4$ in 1 % sodium potassium tartarate.

(C) 50 ml of reagent A and 1 ml of reagent B were mixed just before use.

(D) Folin's phenol reagent

20 mg of dried powdered sample was taken in 5 ml of buffer in a mortar and pestel. The homogenate was centrifuged at 10,000 rpm for 20 minutes. 0.5 ml of protein sample was then taken in a test tube and 1 ml of reagent C was added. The solution was mixed well and allowed to stand for 10 minutes at room temperature. 0.1 ml of reagent D was added very rapidly with vigorous shaking. After 30 minutes the colour was read at 610 nm using a Hitachi spectrophotometer.

The standard curve was prepared using Bovine Serum Albumin and the amount of soluble protein was calibrated from the same.

The results were expressed as percentage dry weight.

3.5.4 Soluble sugars :

Soluble sugars were estimated by the method described by Morris (1948).

Preparation of anthrone reagent :

200 mg of anthrone was dissolved in 100 ml of con. H_2SO_4 to get 0.2 % anthrone reagent. Fresh reagent was prepared each time for estimation.

20 mg of powered material was taken in a test tube. To it 10 ml of 80 % ethanol was added and extracted in hot water bath at 80°C for 30 minutes. This was then centrifuged at 6000 x g for 10 minutes. The extract was collected into a 50 ml volumetric flask. The extraction of residue was repeated thrice. Supernatent extract was pooled and the final volume was made to 50 ml. The extract was then evaporated in water both at 80°C and residue was taken up in distilled water and the final volume was made to 25 ml. 0.2 ml of the extract was taken in a test tube and to it 4 ml of anthrone reagent was added slowly. The solution was then heated in a boiling water both for six minutes. The test tubes were cooled in running water and to each tube 0.8 ml of distilled water was added. The colour developed was measured at 620 nm with Bauch and Lomb spectronic-20 colorimeter.

Results were calculated from the standard curve for sugars prepared with analar glucose. The results were expressed as percentage.

3.5.5 Nucleic acids :

Nucleic acids were estimated by the method described by Ogur and Rosen (1950) with slight modifications.

Plant material was extracted with 80 % boiling ethanol for 2 minutes to prevent enzyme action and also to remove absorbing materials other than

nucleic acids. It was then ground in mortar and the material was transferred to centrifuge tubes. The soluble nitrogen fraction was removed by centrifugation and then to defatting of the tissue was carried out by boiling the residues for 3 minutes in ethanol containing ether in proportion of 3 : 1 (v/v). The residue was further given 2 successive washings with acetone, which removed the pigments completely. Finally the nucleic acids were extracted from the remaining residues by the method of Ogur and Rosen (1950).

The residue was washed with 0.2 N cold perchloric acid to remove the soluble nucleotides. This was done very rapidly, the supernatent was rejected. The RNA was then extracted from the residue by extracting with cold 1 N perchloric acid for 3-4 hours at 4°C. The remaining residue was treated with 0.5 N perchloric acid for 20 minutes at 70°C and centrifuged. Most of the DNA comes into the solution which is decanted after centrifugation and the residue extracted by 2 N HCl. The two fractions were combined and used for estimation of DNA.

The RNA and DNA were then estimated spectrophotometrically at 260 nm using a Hitachi spectrophotometer.

Absorpition spectrum obtained for RNA from the tissue was compared with the pure synthetic RNA. The quantitative values were calibrated from standard curve prepared from pure synthetic RNA and DNA (Sigma).

3.5.6 Pigments :

(a) Chlorophyll

The amount of chlorophyll present was estimated by the method described by Arnon (1949). The optical density was recorded at 663 nm and 645 nm.

Chlorophyll a and chlorophyll b were estimated using the following formula :

Chlorophyll a = 0.0127 x D.663 - 0.00269 x D 645

Chlorophyll b = 0.0229 x D 645 - 0.00468 x D 663

Where D represents the optical desnity at respective wave length. The results were expressed as μg chlorophyll/g fresh weight.

(b) Carotenoids

Carotenoids were estimated from the same 80 % acetone extract obtained for chlorophyll and the optical density was noted at 452.5 nm. The amount was calculated using Robbler's formula (Mahlburg et al., 1966).

Carotenoids = 4.75 x D.452.5 - Chl(a + b) x 0.226

Where D represents the optical density.

(c) Anthocyanins :

The plant material was taken up in acidic methanol (1 ml of con. Hcl added to 100 ml methanol) and the extract was filtered through Whatman No. 1 filter paper. The final volume was made to 10 ml and the optical density was read at 535 nm in a Bouch and Lomb spectronic-20 colorimeter. The results were compared on the basis of the differences in

optical density.

3.6 Experiment No.6 : Changes in organic acids content in leaves of chickpea as influenced by temperature (different dates of sowing) :

Leaves were collected from nodes at specified positions (16-18) on the main axis and then pooled and estimated for organic acid content in terms of total titrable acid content as per the procedure of Ting and Duggar (1968). Leaf material was homogenized with 20 ml of distilled water and 2 ml of Con. HCl. was added to the extract. The organic acids were extracted in petroleum ether with the help of separating funnel. Petroleum ether fraction was evaporated on a water-bath and the residue was dissolved in 10 ml of distilled water and titrated against 0.01 N sodium hydroxyde. Calculation was based on :

1 ml of 0.1 N NaOH $\equiv$ 0.0067 g meleic acid

The content of organic acids were expressed as mg equivalent to maleic acid/g. dry weight.

3.7 Statistical analysis :

Requisite statistical analysis has been carried out by the technique of analysis of variance as described by Panse and Sukhatme (1978) and the values of critical differences and standard error of mean at 5 % level have been given.

4. RESULTS

The results of different experiments are presented below under respective groups. Since the same experiment was conducted simultaneously in field and pot culture, therefore the results will be presented collectively for convenience of comparison.

I. EVALUATION OF REPRODUCTIVE EFFICIENCY :

4.1 Evaluation of reproductive efficiency in different genotypes of chickpea (1979-80) (Experiment No. 1) :

Evaluations of reproductive efficiency in different genotype of chickpea was based on a number of observations ranging from flowering behaviour, morphological and reproductive attributes etc. The results pertaining to above are described in this chapter.

4.1.1 Time, intensity and duration of flowering in relation to crop duration in different genotypes of chickpea :

The days to first flower, days to first pod, peak flowering and flower duration and days to maturity of 12 chickpea cultivars viz., JG-62, L-550, C-235, BG-203, BG-209, BG-212, BG-215, BG-216, BG-217, BG-220, BG-226 and BG-227 grown both under field and pot culture conditions are presented in table 1.

JG-62 was the earliest to flower followed by L-550 and C-235 both in field and pot culture. However, the appearance of first flower was earlier in pot culture conditions. BG lines took longer time for days to first flower. It ranged between 76 and 85 days.

Table 1. Time, intensity and duration of flowering in relation to crop duration in different genotypes of chickpea during 1979-80.

Genotype	Field					Pot culture				
	Days to first flower	Days to first pod	Peak flowering	Flower duration	Crop duration	Days to first flower	Days to first pod	Peak flowering	Flower duration	Crop duration
JG-62	60	90	120	90	163	57	85	115	80	155
L-550	65	120	125	90	176	60	113	121	82	162
C-235	70	115	120	85	170	66	110	115	83	160
BG-203	80	120	125	80	175	75	115	122	74	165
BG-209	85	125	130	75	178	81	110	118	76	169
BG-212	78	120	120	76	172	75	115	118	75	168
BG-215	76	118	123	77	173	75	115	120	75	168
BG-216	76	120	125	80	175	72	110	120	74	165
BG-217	80	120	120	82	177	77	115	122	80	170
BG-220	77	120	125	80	176	74	110	118	75	166
BG-226	80	120	125	80	176	75	110	120	77	167
BG-227	80	120	122	78	175	75	112	119	76	167

4.1.2 Days to first pod :

Days to first pod was also least for JG-62 (90 days and 85 days in field and pot culture respectively). Amongst the rest of the genotypes C-235 was earliest to pod, next only to JG-62 both in field and pot culture. However, the days to first pod did not differ much between the rest of the genotypes in the field with the exception of BG-209 which took 125 days for the appearance of first pod as compared to rest between 118-120 days. Under pot culture condition, as compared to field, there was no consistency, however, it ranged between 110 and 115 days between genotypes. In field, the peak flowering in most of the genotypes was noted between 120 and 125 days after sowing (DAS), however, for BG-209 it was noticed at 130 DAS. Under pot culture condition, the peak flowering ranged between 118 and 120 days amongst majority of cultivars.

In field, the flower duration was found to be longest for JG-62 and L-550 (90 days) followed by C-235 (85 days). For BG lines it varied between 76 and 82 days. In pot culture the longest duration was found in case of C-235 (83 days) followed by L-550 (82 days) and within the BG lines it varied between 74 and 80 days.

The crop duration was shortest for JG-62 both in field and pot culture followed by C-235, however, it varied considerably in majority of genotypes under pot and field conditions.

4.1.3 Change in the morphological attributes of 12 genotypes of chickpea at different stages of growth and development during 1979-80 :

Table 2 and 3 depicts the changes in the morphological attributes of 12 cultivars of chickpea at different stages of growth and development in field and pot culture conditions respectively.

Plant height, number of primary, secondary and tertiary branches, leaves and leaf area increased with time both under field and pot culture conditions, however, higher values were obtained from field experiment in comparison to pot culture experiment. The plant height ranged from 45 to 59 cms. and 39 to 46 cms. under field and pot culture conditions respectively. The lowest plant height was recorded in C-235 and the highest in BG-227. The number of primary branches increased with time upto 120 days in most of the cultivars, however, appreciable increase was observed till 150 days in case of JG-62, BG-209 and BG-212. Although the number of primary branches did not vary much amongst the different varieties both under field and pot culture conditions, yet the number of secondary branches showed considerable difference amongst the different cultivars. Profuse branching was observed in case of JG-62 in comparison to L-550 or the BG-lines. C-235 also had higher number of secondary and tertiary branches next only to JG-62. The leaves per plant was considerably high under field condition than under pot culture condition which is evident from the fact that leaf number varied between 260 and 490 in field, whereas under pot culture condition the value was between 195 and 240. JG-62 recorded the highest number of leaves (490 and 240 leaves under field and pot culture respectively). It is interesting

Table 2. Morphological attributes of different genotypes of chickpea at different stages of growth and development under field condition during 1979-80.

Genotype	JG-62	L-550	C-235	BG-203	BG-209	BG-212	BG-215	BG-216	BG-217	BG-220	BG-226	BG-227	SEm ±	CD(0.05)
Days after sowing														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
						Plant Height (cm)								
30	17	18	17	18	18	17	18	18	18	17	19	18	2.5	5.18
60	26	29	27	31	25	31	33	23	24	23	23	24	4.7	9.75
90	37	37	35	36	38	37	39	38	41	36	39	41	4.1	8.50
120	42	52	42	40	46	49	49	48	49	47	49	48	4.3	8.92
150	49	58	45	50	53	54	54	55	57	56	58	59	5.1	10.58
						Number of primary branches/plant								
30	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	1.04
60	2.6	3.2	3.0	2.9	2.5	2.7	2.7	3.0	3.6	3.3	4.0	3.0	1.9	3.90
90	2.9	3.7	3.5	3.7	2.8	2.9	2.9	4.0	4.2	4.0	4.4	3.7	1.7	3.53
120	3.5	4.0	3.8	4.0	3.2	3.5	3.5	4.2	4.5	4.2	4.5	4.2	2.1	4.35
150	3.8	4.0	3.8	4.0	4.0	4.0	4.0	4.2	4.5	4.2	4.5	4.2	1.6	3.32
						Number of secondary and tertiary branches/plant								
30	3.8	4.0	4.0	3.4	3.8	3.6	3.6	3.6	3.2	3.8	4.2	3.2	2.3	4.77
60	16.0	12.0	13.0	6.3	3.6	6.6	6.6	7.0	8.0	9.2	9.7	9.0	3.1	6.43
90	24.0	16.0	18.0	13.0	12.0	11.9	11.9	13.6	15.0	13.9	15.8	14.9	3.4	7.05
120	40.0	20.0	37.0	21.0	19.0	20.1	20.1	20.8	23.0	24.7	24.5	24.0	3.7	9.75
150	45.0	22.0	38.0	23.0	26.6	22.7	22.7	23.0	25.0	24.7	26.0	25.3	3.9	8.09

contd...

Table 2 contd...

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
						Total number of branches/plant								
30	4.8	5.0	5.0	4.4	4.8	4.6	4.6	4.6	4.2	4.8	5.2	4.2	2.1	4.35
60	18.6	15.2	16.0	10.2	8.5	9.3	9.3	10.0	11.6	12.5	13.7	12.0	3.4	7.05
90	26.9	19.7	21.5	16.7	14.8	14.8	14.8	17.6	19.2	17.9	20.2	18.6	3.7	7.67
120	43.5	24.0	40.8	25.0	22.2	23.6	23.6	25.0	27.4	28.9	29.0	28.0	4.1	8.50
150	48.8	26.0	41.8	27.0	30.6	26.7	26.7	27.2	29.5	28.9	30.5	29.5	4.2	8.71
						Total number of leaves/plant								
30	24	36	33	27	27	33	27	29	29	50	50	24	4.2	8.71
60	170	130	120	130	135	115	125	130	130	142	134	125	10.5	21.78
90	297	197	160	190	175	180	197	190	195	200	190	175	11.3	23.44
120	490	275	260	260	280	260	268	275	280	270	250	260	16.6	34.43
150	90	310	108	300	310	320	380	340	350	350	295	290	20.4	42.31
						Leaf Area / plant (Cm^2)								
30	49	40	59	27	34	37	34	33	34	36	34	26	3.9	8.09
60	290	360	320	155	140	130	140	135	140	135	130	145	11.7	24.27
90	600	540	470	210	200	190	210	225	230	242	250	260	12.8	26.55
120	1260	770	630	390	360	330	360	370	400	395	410	436	21.7	45.00
150	200	940	260	495	480	470	510	500	530	640	589	610	19.8	41.07

to note that BG-209 under field condition did not record a higher leaf number as compared to other BG cultivars. The leaf number among the BG cultivars varied between 310 and 380 per plant under field condition and same under pot culture condition showed a variation from 195 to 240 per plant. C-235 always recorded the least number both under field and pot culture conditions. L-550 had 310 and 240 leaves under field and pot culture conditions respectively.

The leaf area in JG-62 and C-235 increased only upto 120 days in contrast to other cultivars, where the area increased upto 150 days. There was a sharp decline in JG-62 and C-235 after 120 days. The lowest area was also recorded by JG-62 at 150 DAS. The area between BG lines did not vary significantly under field and pot culture conditions. Another observation is that cv. L-550, the Kabuli variety had approximately same number of leaves as BG lines, yet the increase in area is about two fold due to larger leaf size.

Both under field and pot culture conditions the rapid period of growth and development was found to be between 30 and 60 DAS as the increase was many folds during the period with reference to most of the morphological characters. The period between 60 and 90 days was also comparatively an active phase of growth, but in magnitude it was of lower order than that observed between 30 and 60 days. Same could be said for the period between 90 and 120 days. By 120 days, most of the characters attained the maximum or showed a decline thereafter.

4.1.4 Changes in dry matter accumulation in 12 chickpea cultivars during 1979-80.

Changes in dry weight of plant parts and total dry matter at various growth and development stages of 12 chickpea cultivars during 1979-80 under field and pot culture conditions are given in table 4 and 5 respectively.

Stem weight :

Stem weight increased with time and highest weight was recorded by BG-226 under field condition (12.370 gm/plant) and by JG-62 under pot culture condition (9.0 gm/plant). Almost identical changes were observed under pot and field conditions in case of JG-62 and C-235, but C-235 showed a greater increase at 150 days. The rate of growth of JG-62 and C-235 was identical under field and pot culture conditions. The increase was often greater between 30-60, 60-90, 90-120 and 120-150 days and it was 761 %, 313 %, 200 % and 145 % for JG-62 and 258 %, 583 %, 219 % and 177 % for C-235 respectively. The increase in stem weight was of more or less similar order in other cultivars, but the rapid phase of dry matter production in stem was found between 30 and 60 days in field, whereas between 60 and 90 days in case of pot culture. The BG-203 and BG-209 showed lesser variation in the rates of dry matter production under field and pot conditions.

Leaf weight :

Leaf weight increased with time both under field and pot culture conditions, except in case of JG-62, where a sharp decline was observed at 150 days. The values obtained for field were always of higher order as compared

Table 4. Changes in dry matter production in different plant parts at various stages of growth and development in different genotypes of chickpea under field condition during 1979-80.

Genotype	JG-62	L-550	C-235	BG-203	BG-209	BG-212	BG-215	BG-216	BG-217	BG-220	BG-226	BG-227	SEm ±	CD(0.05)
Days after sowing														
						Stem weight (g)/plant)								
30	0.130	0.146	0.139	0.117	0.121	0.141	0.105	0.118	0.101	0.107	0.118	0.099	0.01	1.02
60	0.990	0.780	0.360	0.530	0.540	0.500	0.590	0.570	0.580	0.580	0.475	0.430	0.09	0.19
90	3.100	2.800	2.100	1.650	1.300	1.760	1.390	1.410	1.510	1.700	1.970	1.890	0.31	0.64
120	6.200	5.100	4.600	5.100	4.600	4.800	4.860	4.570	4.980	5.300	6.240	6.000	1.02	2.12
150	9.000	11.700	8.150	9.00	8.890	11.500	9.800	8.600	12.000	10.700	12.370	11.600	1.15	2.38
						Leaf weight (g/plant)								
30	0.254	0.185	0.200	0.137	0.167	0.185	0.169	0.167	0.168	0.180	0.167	0.126	0.03	0.63
60	1.050	1.300	0.700	0.810	0.715	0.880	0.690	0.670	0.715	0.630	0.800	0.810	0.07	0.15
90	1.940	1.900	0.900	1.000	1.050	0.980	1.000	0.980	0.995	0.980	1.060	1.000	0.25	0.52
120	6.260	3.500	2.600	1.988	2.000	1.950	2.100	2.070	2.100	2.000	2.100	2.130	0.57	1.18
150	0.900	4.960	5.960	2.050	2.100	2.000	2.130	2.090	2.135	2.100	2.160	2.200	0.91	1.89
						Total dry weight (g/plant)								
30	0.384	0.331	0.339	0.254	0.288	0.336	0.274	0.280	0.269	0.287	0.285	0.225	0.04	0.17
60	2.040	2.080	1.060	1.340	1.255	1.380	1.280	1.240	1.295	1.210	1.275	1.240	1.10	0.21
90	5.040	4.700	2.990	2.650	2.350	4.046	2.390	2.390	2.505	2.680	2.030	2.890	0.75	1.56
120	15.230	9.650	7.560	8.280	9.020	7.810	8.260	7.470	11.440	8.440	10.240	9.300	1.31	2.72
150	14.812	19.000	15.585	16.550	17.620	14.830	16.010	14.260	23.035	18.700	21.180	20.100	2.41	4.99

Table 5. Changes in dry matter production in different plant parts at various stages of growth and development in different genotypes of chickpea under pot culture condition during 1979-80.

Genotype	JG-62	L-550	C-235	BG-203	BG-209	BG-212	BG-215	BG-216	BG-217	BG-220	BG-226	BG-227	SEm ±	CD(0.05)
Days after sowing														
							Stem weight (g / plant)							
30	0.123	0.147	0.141	0.111	0.111	0.122	0.100	0.112	0.099	0.108	0.118	0.085	0.02	0.04
60	0.966	0.280	0.360	0.383	0.425	0.191	0.306	0.297	0.263	0.247	0.245	0.192	0.03	0.63
90	3.100	1.400	2.100	1.100	1.170	0.900	1.600	1.090	1.210	1.160	1.170	1.250	0.21	0.44
120	6.200	3.210	4.600	3.400	3.270	2.700	3.000	2.970	3.410	3.480	3.475	3.540	0.52	1.10
150	9.000	6.660	6.400	6.270	6.660	7.100	6.870	6.120	7.600	7.000	6.910	7.800	1.31	2.72
							Leaf weight (g / plant)							
30	0.209	0.136	0.160	0.100	0.159	0.130	0.149	0.150	0.146	0.120	0.147	0.130	0.03	0.13
60	0.899	1.055	0.582	0.654	0.560	0.305	0.461	0.422	0.427	0.404	0.328	0.241	0.03	0.13
90	1.400	1.300	1.050	0.680	0.675	0.600	0.580	0.630	0.640	0.660	0.640	0.690	0.07	0.15
120	3.400	1.900	3.600	0.975	0.980	0.800	0.970	0.980	0.970	0.980	1.000	1.100	0.04	0.08
150	0.600	3.000	5.400	1.110	1.050	1.000	1.200	1.000	1.100	1.040	1.060	1.130	0.03	0.13
							Total dry weight (g / plant)							
30	0.322	0.283	0.301	0.211	0.270	0.252	0.249	0.262	0.245	0.228	0.265	0.215	0.02	0.04
60	1.865	1.335	0.942	1.037	0.987	0.496	0.767	0.719	0.730	0.651	0.573	0.433	0.04	0.08
90	4.700	2.700	3.640	1.780	3.185	1.500	2.180	1.720	1.850	1.840	1.810	1.940	0.06	1.32
120	15.000	5.710	14.890	4.975	4.960	4.040	4.580	4.250	5.100	4.970	5.175	5.530	0.58	1.20
150	14740	13.960	14.900	11.850	12.400	12.360	12.615	10.120	12.350	13.370	11.920	16.410	3.12	6.47

to pot culture. Among the varieties highest leaf weight was observed in case of JG-62(6.260 g/plant) and C-235 (5.400 g/plant) under field and pot culture respectively. BG lines showed lower leaf weights as compared to other cultivars. C-235 and L-550 were the two cultivars which showed appreciable increase in leaf weight between 120-150 days, while the BG lines showed very little increase during the same period. The rate of dry matter accummulation in leaf is highest between 30 and 60 days and was of more or less same order both under field and pot culture conditions. The reproductive phase started between 60 and 90 days and during this period it was observed that there was a decrease in the dry matter in leaves. Further, it was noted that between 90 and 120 days, the period corresponding to peak flowering of most of the cultivars, there was a slight increase in the rate of dry matter in leaves. Moreover, at 150 days, when the peak flowering was over, no appreciable increase in leaf weight in most of the cultivars was found except in the case of L-550 and C-235.

Total dry weight :

The total dry weight increased with age of the plant and rate of increase was highest between 30 and 60 days in all the cultivars under field conditions. However, under pot culture conditions the total dry matter also increased appreciably between 60 and 90 days in case of C-235 and more or less in equal rates in many of the BG lines. The highest dry weight was recorded under field conditions in case of BG-217 (23.035 g/plant) and the lowest in case of BG-216 (14.260 g/plant). In pot culture, the highest weight was attained by BG-227 (16.460 g/plant) and lowest by BG-216 (10.120 g/plant). JG-62 is the only variety, which showed reduction in dry matter

at 150 days and that is found to be due to reduction in leaf weight which declines rapidly at 150 days after sowing.

4.1.5 Reproductive behaviour of 12 chickpea cultivars during 1979-80 :

Table 6 and 7 summerise the reproduction behaviour on per plant basis of 12 cultivars of chickpea grown in field and pot during 1979-80. From the same it may be observed that in field the highest flower number (285) was obtained from the BG lines and the lowest (121) was obtained in C-235. JG and L-550 formed 212 and 200 flowers respectively. Among the BG lines the variation was 212 to 303 flowers per plant. The highest was in BG-227 (303) and lowest was in BG-203 (212).

Under pot culture conditions the picture was different. C-235, which recorded lowest under field condition, gave appreciably high number of flowers (162) under pot culture conditions. JG-62 also recorded a very high flower number (170) as compared to the BG lines, which flowered better under field conditions. In general, the BG lines had low flower numbers as compared to JG-62 and C-235.

The shedding of flowers/pods were very high in L-550 in comparison to the number of flowers produced by it. However, the total number of flowers/pods shed were more in BG lines which had more number of flowers in field. Pod number was high among the BG lines and ranged between 50 and 75 per plant. L-550 had the least number of pods. The number of filled pods also were more among the BG lines, followed by JG-62, C-235 and L-550.

Table 6. Reproductive behaviour per plant of different chickpea genotypes in field during 1979-80.

Character / Genotype	Number							Weight (g)		
	Flowers	Flowers + Pods shed	Total pods	Normal filled pods	Abnormal unfilled pods	Total seed	Seed/ pod	Pod weight	Seed yield	100-seed weight
JG-62	212	168	44	38	6	46	1.04	6.822	5.724	8.384
L-550	200	180	20	17	3	25	1.25	3.948	3.295	17.140
C-235	121	91	30	26	4	36	1.20	2.775	1.495	10.137
BG-203	212	151	61	51	10	79	1.29	3.086	3.060	11.500
BG-209	231	156	75	63	12	90	1.20	9.570	8.240	10.504
BG-212	285	235	50	39	11	62	1.24	6.117	4.508	10.147
BG-215	288	225	63	50	13	78	1.23	6.908	5.808	9.082
BG-216	221	171	50	38	12	64	1.28	4.520	3.783	7.687
BG-217	256	184	72	57	15	85	1.18	8.103	7.192	8.595
BG-220	261	203	58	45	13	72	1.24	6.989	5.814	10.156
BG-226	272	199	73	63	10	87	1.19	9.473	7.837	10.821
BG-227	303	228	75	60	15	89	1.18	9.728	7.941	10.828
SEm ±			6.51			7.41		1.132	1.081	1.951
CD (0.05)			13.50			1587		4.420	2.180	4.046

Table 7. Reproductive behaviour per plant of different chickpea genotypes in pot culture during 1979-80.

Character / Genotype	Number							Weight (g)		
	Flowers	Flowers + Pods shed	Total pods	Normal filled pods	Abnormal unfilled pods	Total seeds	Seed/ pod	Pod weight	Seed yield	100-seed weight
JG-62	170	140	30	20	10	35	1.16	5.658	4.704	9.112
L-550	146	133	13	10	3	16	1.23	2.693	2.246	17.145
C-235	162	135	27	21	6	30	1.11	4.179	3.477	10.210
BG-203	167	145	22	16	6	27	1.22	2.671	2.297	10.504
BG-209	120	85	35	23	12	43	1.22	6.176	5.479	11.589
BG-212	141	120	21	18	3	23	1.09	4.486	3.948	10.573
BG-215	105	93	19	12	7	21	1.10	2.332	1.916	11.750
BG-216	149	120	29	13	16	34	1.17	3.165	2.686	9.095
BG-217	143	112	31	19	12	37	1.19	3.480	2.963	8.253
BG-220	108	81	27	18	9	31	1.14	3.124	2.718	9.337
BG-226	126	96	30	21	9	35	1.16	4.765	3.981	10.951
BG-227	174	136	38	23	15	44	1.15	5.316	4.260	10.969
SEm ±			3.71			3.58		1.051	0.832	1.030
CD (0.05)			7.69			7.42		2.180	1.724	2.136

The number of unfilled pods were highest among the BG lines and least in case of L-550.

Under pot culture conditions, the BG lines recorded about 50 % less pod number in most of the cases. However, the reduction in JG-62 was comparatively less and there was no variation in case of C-235 and the number of filled and unfilled pods also showed a similar trend.

The highest seed number under field condition was recorded in general by BG lines, followed by JG-62, C-235 and L-550. The seed number per pod seems to be most plastic character as it showed no variation among the cultivars and ranged between 1.04 and 1.29. Under pot culture conditions the trend was more or less similar.

A similar pattern was observed with respect to pod and seed yield in field. BG lines gave comparatively higher yields. C-235 had the least seed yield (1.495 g) among all the cultivars. As regarding 100 seed weight, the highest was observed in case of L-550 (17.140 g). The variation in BG lines in this character was 7.687 g to 11.500 g. C-235 had a higher 100 seed weight (10.137 g) as compared to JG-62 (8.384 g). Under pot culture conditions more or less same trend was observed.

4.1.6 Reproductive efficiency :

Table 8 presents the calculated reproductive efficiency in field and pot culture conditions. It will be noted from above that a very huge loss was incurred in reproductive efficiency due to shedding of flowers/pods.

Table 8. Characteristics determining reproductive efficiency in different genotypes of chickpea under field and pot culture conditions during 1979-80.

Characteristic	Field					Pot culture				
Genotype	Shedding (%)	Pod set (%)	Filled pods (%)	Unfilled pods (%)	Effective pods set (%)	Shedding (%)	Pod set (%)	Filled pods (%)	Unfilled pods (%)	Effective Pod set (%)
JG-62	79.2	20.8	86.3	13.7	17.9	82.3	17.6	66.7	33.3	11.8
L-550	90.0	10.0	85.0	15.0	8.5	91.1	8.9	76.9	23.1	6.8
C-235	75.2	24.8	86.6	13.4	21.5	83.3	16.6	77.8	22.2	12.9
BG-203	71.2	28.8	83.6	16.4	24.0	86.8	13.2	72.8	27.3	9.6
BG-209	67.5	32.5	84.0	16.0	27.2	70.8	29.1	65.7	34.3	19.1
BG-212	85.2	17.5	78.0	12.0	13.4	85.1	14.9	85.7	14.3	12.8
BG-215	78.2	21.8	79.3	20.7	17.3	88.6	18.1	63.1	36.8	11.4
BG-216	77.4	22.6	76.0	24.0	17.2	80.5	19.5	44.8	55.2	8.7
BG-217	71.8	28.2	79.1	18.9	22.2	78.3	21.7	61.3	36.7	13.3
BG-220	77.8	22.2	77.5	22.5	17.2	75.0	25.0	66.7	33.3	16.6
BG-226	73.1	26.9	86.3	13.7	23.1	76.2	23.8	70.0	30.0	16.7
BG-227	75.3	24.2	80.0	20.0	18.8	79.5	21.8	60.5	39.5	13.2

The loss by shedding ranges from 67 to 90 % among the various cultivars. The highest loss was incurred by L-550 (90 %) and lowest by BG-209 (67.5 %). The reproductive efficiency, in terms of pod set from the number of flowers produced, was highest in case of BG-209, closely followed by BG-203, BG-217 and BG-226, where the pod set was 32.5 %, 28.8 %, 28.2 % and 26.2 % respectively. L-550 showed the least pod set and it was of the order of 10 %. The ratio of filled pods to the number of flowers formed when expressed as percentage, showed that the variation was not much amongst the various cultivars. Similar results were found with unfilled pods. However, BG lines showed a higher percentage of unfilled pods. The reproductive efficiency in terms of effective pod set (completely filled pods over the total number of flowers produced) was higher for most of the BG lines, while cv. L-550 recorded the lowest effective pod set (8.5 %). C-235 also had a comparatively higher effective pod set (21.5 %) over JG-62 (17.9 %).

Under pot culture conditions the magnitude of shedding was greater in most of the cultivars and the percentage of pod set was also lower, however, the broad pattern remained unchanged. There was a great reduction in the percentage of filled pods and a significant increase in the percentage of unfilled pods under pot culture conditions in comparison to field. As a result of the above situation, the effective pod set also considerably reduced more under pot culture conditions.

4.2 EFFECT OF DATES OF SOWING IN CHICKPEA

4.2.1 Effect of different dates of sowing on time, intensity and duration of flowering and fruiting in relation to crop duration in chickpea cultivars JG-62, L-550 and BG-209 under field and pot culture conditions (Experiment No.2) :

Table 9 shows the days from sowing to first flower, peak flowering, last flower, first pod and final harvest in 3 chickpea cultivars viz., JG-62, L-550 and BG-209 as affected by different dates of sowing during 1980-81.

It will be observed from the same table that the time of appearance of first flower in general is increased with increase in sowing dates in all the cultivars both under field and pot culture conditions. The days to first flower for JG-62 in field in S_1, S_2, S_3 and S_4 was 55, 60, 68 and 75 and in pot 53, 57, 70 and 75 days respectively. In L-550, S_1, S_2, S_3 and S_4 field was 60, 65, 70 and 75 days, and in pot 65, 62, 70 and 75 days respectively. In BG-209 it was for S_1, S_2, S_3 and S_4 80, 84, 83 and 95 for field and 74, 78, 83 and 90 for pot culture respectively. However, the time of peak flowering and duration of flowering decreased with increase in sowing dates. Time for peak flowering in JG-62 in field for S_1, S_2, S_3 and S_4 was 135, 120, 105 and 95 days and in pot 135, 110, 105 and 105 days respectively. For L-550 time for peak flowering in S_1, S_2, S_3 and S_4 in field was 135, 125, 120 and 105 days and in pot culture 125, 110, 115 and 105 days respectively. For BG-209, it was for S_1, S_2, S_3 and S_4 130, 130, 110 and 110 days in field and 130, 115, 110 and 105 days in pot respectively. Duration of

Table 9. Effect of different dates of sowing on time, intensity and duration of flowering and fruiting in relation to crop duration in chickpea cultivars JG-62, L-550 and BG-209 under field and pot culture conditions during 1980-81.

Cultivars	Field												Pot culture											
	JG-62				L-550				BG-209				JG-62				L-550				BG-209			
Time of sowing	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
Days to first flower	55	60	68	75	60	65	70	75	80	84	83	95	53	57	70	75	65	62	70	75	74	78	83	90
Days to first pod	80	90	95	90	125	115	105	95	125	125	110	100	80	90	95	95	125	105	100	90	125	115	105	103
Days to peak flowering	135	120	105	95	135	125	120	105	130	130	110	110	135	110	105	105	125	110	115	105	130	115	110	105
Flower duration	110	90	62	45	105	85	65	50	80	74	47	28	107	78	55	45	90	73	65	43	84	67	47	35
Crop duration	186	168	147	137	186	170	147	133	186	170	147	143	173	155	145	131	170	156	145	132	173	156	145	132

flowering decreased with delayed sowing. The duration in JG-62 in field for S_1, S_2, S_3 and S_4 was 110, 90, 62 and 45 days and in pot culture 107, 78, 55 and 45 days respectively. For L-550 in field for S_1, S_2, S_3 and S_4 it was 105, 85, 65 and 50 days and in pot culture 90, 73, 65 and 43 days respectively. For BG-209, it was for S_1, S_2, S_3 and S_4 80, 74, 47 and 28 days and in pot culture 84, 67, 47 and 35 days respectively. Similarly days to maturity also decreased with increase in sowing dates. For JG-62 it was 186, 168, 147 and 137 days in field and 173, 155, 145 and 131 days in pot for S_1, S_2, S_3 and S_4 respectively. For L-550 it was in field for S_1, S_2, S_3 and S_4 186, 170, 147 and 133 days and in pot culture 170, 156, 145 and 132 days respectively. For BG-209 the days to maturity in field for S_1, S_2, S_3 and S_4 was 186, 172, 147 and 133 days while in pot it was 173, 156, 145 and 132 days respectively.

Days to first pod formation were increased with increase in sowing dates upto S_3 in case of JG-62, both under field and pot culture conditions. For S_1, S_2, S_3 and S_4 in field it was 80, 90, 95 and 90 days and in pot culture it was 80, 90, 95 and 95 days respectively. Both under field and pot culture conditions L-550 and BG-209 took same time for appearance of first pod (125 days) for S_1 while for S_2, S_3 and S_4 it showed a decrease with increase in sowing date.

Under pot culture conditions both these cultivars showed a decrease in the number of days required for the appearance of first pod with an increase in sowing time. The number of days taken for both the cultivars were same for the first sowing (125 days) but from S_2 onwards, the L-550

took lesser days in comparison to BG-209 for the appearance of first pod. In case of L-550 for S_2, S_3 and S_4 it was 105, 100 and 90 days, while for BG-209 it was 115, 105 and 103 days respectively.

4.2.2 Influence of different dates of sowing on the morphological attributes of chickpea cultivars :

The data on the effect of different dates of sowing on the morphological attributes of chickpea cultivars viz., JG-62, L-550 and BG-209 grown in field and pot culture are given in table 10, 11 and 12 respectively. These are expressed on per plant basis.

The morphological attributes like height, branch number and leaf number increase with time upto a certain stage in all the cultivars and in all the sowings. These parameters showed low values when grown in pot irrespective of sowing dates or cultivars.

JG-62

Plant height :

Plant height increased with age in all the sowings both under field and pot culture conditions. The height was comparatively more under field condition. There was a general decrease in height at all the stages with an increase in sowing time both under field and pot culture conditions. The only exception was in case of 2nd sowing at 90 and 120 days in pot culture, where a slight increase was observed. Maximum height is realised at first sowing (83.6 and 59.2 cms respectively in field and pot culture) and difference between S_1 and S_2 was not much marked. The decrease in

Table 10. Effect of different dates of sowing on the morphological attributes of chickpea Cv. JG-62 grown in field and pot culture.

Days after sowing	Field					Pot culture				
	30	60	90	120	150	30	60	90	120	150
Time of sowing										
1	2	3	4	5	6	7	8	9	10	11
					Plant height (cm)					
S_1	23.0	39.8	51.2	68.4	83.6	19.0	29.6	35.6	42.2	59.2
S_2	17.2	27.0	42.4	61.0	66.0	15.6	27.2	42.8	49.6	x
S_3	14.2	23.8	39.2	48.6	x	12.8	23.2	38.6	39.4	x
S_4	13.8	25.6	42.0	43.8	x	11.0	20.6	36.4	38.0	x
SEm ±	2.07	0.76	1.81	3.17	-	0.60	1.14	1.36	1.49	-
CD(0.05)	4.51	1.65	3.94	6.91	-	1.31	2.47	2.97	3.25	-
					Number of primary branches/plant					
S_1	1.6	4.8	5.1	5.2	5.2	1.0	2.8	2.8	3.2	3.2
S_2	1.0	3.4	3.8	4.2	4.2	1.0	2.6	2.6	3.0	x
S_3	1.0	2.6	2.6	2.8	x	1.0	2.8	2.8	2.8	x
S_4	1.0	2.2	2.4	2.6	x	1.0	2.4	2.6	2.6	x
SEm +	0.17	0.46	0.82	0.35	-	-	0.33	0.47	0.50	-
CD(0.05)	0.37	0.99	0.78	0.76	-	-	-	-	-	-

contd...

Table 10 contd....

1		2	3	4	5	6	7	8	9	10	11
						Number of secondary and tertiary branches/plant					
S_1		5.0	31.0	36.0	48.6	65.2	2.8	6.4	16.2	32.6	38.8
S_2		4.0	8.6	32.0	64.8	67.4	3.2	4.8	14.8	24.4	x
S_3		3.8	6.0	17.2	23.0	x	3.4	5.6	19.0	19.0	x
S_4		2.0	3.8	18.4	18.8	x	2.0	4.4	13.8	13.8	x
	SEm ±	0.43	1.21	1.72	2.24	-	0.26	1.19	3.11	4.40	-
	CD(0.05)	0.94	2.64	3.75	4.88	-	0.57	2.76	6.79	7.76	-
						Total number of branches / Plant					
S1		6.6	35.8	41.1	53.8	70.4	3.8	9.2	19.0	35.8	42.0
S_2		5.0	12.0	35.8	69.0	71.6	4.2	7.4	17.4	27.4	x
S_3		4.8	8.6	19.8	25.8	x	4.0	8.4	21.8	21.8	x
S4		3.0	6.0	20.8	21.4	x	3.0	6.8	16.4	16.4	x
	SEm ±	0.52	0.62	2.14	1.95	-	0.32	0.91	2.12	2.62	-
	CD(0.05)	1.17	1.35	4.66	4.23	-	0.70	1.98	4.62	5.71	-
						Total number of leaves / plant					
S_1		38.4	237.4	294.8	495.0	388.6	28.8	60.6	145.3	245.2	298.6
S_2		26.0	68.4	204.0	631.0	369.0	22.6	46.6	152.6	227.8	x
S_3		22.8	74.8	160.4	181.8	x	16.0	45.8	130.8	165.6	x
S_4		14.6	40.4	145.2	149.4	x	10.8	46.2	138.6	86.4	x
	SEm ±	1.90	17.56	26.99	86.81	-	1.70	9.70	16.74	34.93	-
	CD(0.05)	4.14	38.27	47.80	189.16	-	3.72	21.12	-	76.07	-

heights is of much greater magnitude for 3rd and 4th sowing in comparison to 2nd sowing.

Number of primary branches :

The number of primary branches attained the maximum in all dates of sowings under field condition by 120 DAS while in pot culture condition the same was attained earlier at 90 DAS in case of S_3 and S_4.

Under pot culture conditions there was no significant difference in the number of primary branches with reference to sowing date at a particular stage. But S_1 tended to have a higher number of primary branches. However, under field conditions there were comparatively lesser number of primary branches at any one particular stage from 60 DAS. In both field and pot culture S_1 recorded the maximum number of primary branches (5.2 and 3.2 respectively).

Number of secondary and tertiary branches :

Number of secondary and tertiary branches also increased with age of plant in all dates of sowing. The maximum number of secondary branches were observed in S_2 (67.4) under field condition, while under pot culture condition this was observed in case of S_1 (38.8). Least number of branches were found in case of S_4 both under field and pot culture conditions. At any particular stage of growth upto 90 DAS the number of secondary and tertiary branches decreased with an increase in sowing date in the field. However, the same trend was not seen under pot culture condition.

The trend which was observed for the number of secondary and tertiary branches was again reflected in total number of branches.

Number of leaves :

The number of leaves/plant increased with age upto 120 DAS under field condition, while under pot culture they increased upto 150 DAS in S_1, upto 120 DAS in case of S_2 and S_3 and only upto 90 DAS in case of S_4. Between the sowing dates a general trend of decrease with an increase in sowing date was observed under field condition. However, under pot culture the trend was less clear.

L-550

Plant height :

Between the sowing dates at any particular stage there was a decrease in plant height with an increase in sowing date upto 3rd sowing. Under field condition there was not much difference between S_3 and S_4 with respect to height.

Under pot culture condition, the decrease in height with increase in sowing date was observed only upto 30 days. Thereafter no reduction in height was noticeable with an increase in sowing date.

Number of primary branches :

Maximum number of primary branches found was 5.8 under field condition and 3.2 under pot culture condition observed in case of first sowing.

Table 11 . Effect of different dates of sowing on the morphological attributes of chickpea Cv. L-550 grown in field and pot culture.

Days after sowing	Field					Pot culture				
Time of sowing	30	60	90	120	150	30	60	90	120	150
					Plant height (cm)					
S_1	22.0	37.8	48.0	68.2	87.6	19.0	27.8	39.6	47.0	47.8
S_2	18.0	28.6	40.0	60.4	66.0	17.4	23.2	40.0	51.0	55.4
S_3	15.4	24.6	38.8	49.0	x	13.6	23.6	38.0	49.6	x
S_4	13.0	24.2	42.2	49.8	x	11.8	20.2	37.0	40.0	x
$SE_m \pm$	0.47	0.74	1.84	2.42	-	0.60	0.86	2.34	0.91	-
CD(0.05)	1.03	1.60	4.00	6.88	-	1.32	1.88	-	1.99	-
					Number of primary branches					
S_1	2.8	5.8	5.8	5.8	5.8	1.0	2.2	2.8	3.2	3.2
S_2	2.0	4.2	4.2	4.2	4.2	1.0	2.4	3.0	3.2	3.2
S_3	2.0	3.0	4.0	4.0	x	1.0	3.2	3.3	3.4	x
S_4	1.0	2.0	3.0	3.0	x	1.0	2.8	2.8	3.0	x
$SE_m \pm$	0.26	0.55	0.29	0.45	-	-	0.30	0.33	0.24	-
CD(0.05)	0.58	1.19	0.64	0.99	-	-	0.66	-	-	-

contd....

Table 11 contd...

1	2	3	4	5	6	7	8	9	10	11
					Number of secondary and tertiary branches / plant					
S_1	7.8	21.2	38.8	40.0	60.2	3.4	4.0	18.4	23.0	34.4
S_2	4.1	7.2	18.0	24.8	25.0	4.0	4.6	17.2	19.0	26.6
S_3	4.0	4.8	21.0	21.0	x	4.0	8.8	11.8	13.6	x
S_4	3.0	8.0	14.4	17.0	x	3.0	3.8	12.4	14.2	x
SEm ±	0.58	2.82	4.02	5.60	-	1.17	1.42	2.42	3.56	-
CD(0.05)	1.26	6.14	8.77	9.99	-	0.37	3.09	5.28	6.99	-
					Total number of branches / plant					
S_1	10.6	27.0	44.6	45.8	66.0	4.4	6.2	21.2	26.2	37.6
S_2	6.1	11.4	22.2	29.0	29.2	5.0	7.0	20.2	22.0	29.8
S_3	6.0	7.8	25.0	25.0	x	5.0	12.0	15.1	17.0	x
S_4	4.0	10.0	17.4	20.0	x	4.0	6.6	15.2	17.2	x
SEm ±	0.56	0.69	2.12	6.30	-	0.93	0.63	2.17	0.71	-
CD (0.05)	1.22	1.50	4.42	13.17	-	2.03	1.37	4.73	1.55	-
					Number of leaves / plant					
S_1	54.2	206.0	297.8	411.6	395.6	31.2	69.6	154.0	254.2	195.2
S_2	28.4	68.2	148.0	223.0	256.0	30.0	52.0	176.0	242.8	168.2
S_3	28.4	57.0	158.0	172.0	x	23.0	53.0	126.4	143.3	x
S_4	17.8	66.2	140.2	145.0	x	15.0	47.6	118.8	132.2	x
SEm±	6.33	49.85	35.69	31.49	-	1.45	7.07	15.55	24.82	-
CD (0.05)	13.79	108.62	77.77	68.63	-	3.17	15.40	33.87	54.08	-

Under field condition the more number of primary branches were present. The maximum number was achieved by 60 DAS in case of S_1 and S_2 while by 90 DAS in case of S_3 and S_4. In general, with an increase in sowing date there was a decrease in number of primary branch under pot culture condition. The maximum number is attained in all the sowings by 120 DAS. The final number of primary branches did not vary significantly between the sowing dates.

Number of secondary and tertiary branches :

These increased with increase in age both under field and pot culture in all dates of sowing. The maximum number of branches were found in case of S_1 i.e., 60.2 and 34.6 under field and pot culture respectively. Least number of branches were found in case of S_4 under field condition and in case of S_3 under pot culture condition. By and large, there was a decrease in the number of these branches with an increase in sowing dates at a given stage.

Under pot culture condition the decrease in number of branches with increase in sowing date could not be observed before 90 DAS with the exception of S_3 where the values are not significantly different from S_4 from 90 days onwards.

Total number of branches :

The total number of branches were highest in S_1 both under field and pot culture conditions i.e., 66 and 37.6 respectively. A significant

reduction in the number of branches was found in rest of the sowings. The variation between the sowings was not much marked at any particular stage under field condition.

Under pot culture condition the differences between S_1 and other dates of sowing were not that great as found for field condition. Only the differences became sharp at 150 days.

Number of leaves :

The increase in number of leaves was noticed upto 120 DAS both under field and pot culture conditions for all the sowings, with the exception of S_2 under field condition. There was not much variation among the leaf number in case of S_2, S_3 and S_4 under field condition upto 90 days. However, a general decline was noticed with increase in sowing dates at 120 DAS in field, the same was noticed from 90 DAS onwards in case of pot culture. The highest number of leaves, 411 and 254 were noticed in case of S_1 and least in case of S_4 (145 and 132) both under field and pot culture conditions.

BG-209

Plant height :

There was an increase in plant height, number of primary branches, total number of branches with increase in time. The final plant height was significantly very high under field condition in case of S_1 as compared to rest of the sowings viz., 72.6 cms against 53.6 cms, 41.6 cms, 37.6 cms in S_2, S_3 and S_4 respectively. However, under pot culture condition the

Table 12 . Effect of different dates of sowing on the morphological attributes of chickpea Cv. EG-209 grown in field and pot culture.

Days after sowing	Field					Pot culture				
Time of sowing	30	60	90	120	150	30	60	90	120	150
					Plant height (cm)					
S_1	20.0	34.0	35.6	65.4	72.6	15.5	25.0	31.4	36.4	42.6
S_2	18.4	24.6	35.4	51.4	53.6	17.4	20.4	37.0	42.0	42.8
S_3	14.2	23.4	37.8	41.6	x	12.2	20.0	31.6	37.0	x
S_4	11.4	21.8	34.0	37.6	x	12.8	16.0	29.6	31.0	x
SEm ±	0.41	1.03	1.73	1.13	-	0.74	3.14	2.07	6.8	-
CD (0.05)	0.90	2.23	3.77	2.77	-	1.60	6.84	4.52	3.19	-
					Number of primary branches/plant					
S_1	2.6	4.8	5.1	5.2	5.2	1.6	3.0	3.0	3.0	3.0
S_2	1.0	3.0	3.6	4.0	4.0	1.0	2.2	2.8	2.8	2.8
S_3	1.0	3.0	3.0	3.0	x	1.0	3.0	3.0	3.0	x
S_4	1.0	2.0	2.8	2.8	x	1.0	2.6	2.6	3.0	x
SEm ±	0.28	0.39	0.97	1.47	-	0.17	0.19	0.20	0.14	-
CD (0.05)	0.62	0.85	-	-	-	0.37	-	-	-	-

contd...

Table 12 contd...

1	2	3	4	5	6	7	8	9	10	11
					Number of secondary branches / plant					
S_1	7.0	19.0	32.4	44.4	94.2	2.2	3.6	14.8	25.8	46.2
S_2	4.0	5.4	22.4	33.2	44.8	3.2	4.0	18.0	27.8	35.0
S_3	3.8	7.2	24.8	32.8	x	3.4	6.8	13.8	32.6	x
S_4	2.4	8.0	28.0	30.8	x	2.2	4.0	19.2	32.0	x
SEm ±	0.66	1.95	4.02	6.87	-	0.41	0.94	3.16	4.70	-
CD (0.05)	1.45	4.26	8.76	-	-	0.90	2.05	6.90	7.24	-
					Total number of branches / plant					
S_1	9.6	23.8	37.5	49.6	99.4	3.8	6.2	17.8	28.8	49.2
S_2	5.0	8.4	26.0	37.2	48.8	4.2	6.8	20.8	30.6	37.8
S_3	4.8	10.2	27.8	35.8	x	4.4	9.8	16.8	35.6	x
S_4	3.4	10.0	30.8	33.6	x	3.2	6.6	21.8	35.0	x
SEm ±	1.73	2.21	3.98	7.21		0.63	0.51	1.71	2.81	
CD (0.05)	3.76	4.32	8.67	1576		1.37	1.55	3.73	5.03	
					Leaf number / plant					
S_1	35.0	155.0	225.8	436.4	600.4	24.2	45.2	108.6	225.6	268.8
S_2	33.4	54.4	115.4	201.6	245.0	19.6	39.6	102.0	232.4	168.0
S_3	20.2	57.4	115.2	152.0	x	15.6	57.4	101.0	149.4	x
S_4	12.0	53.4	177.2	175.0	x	15.0	32.6	118.8	190.6	x
SEm ±	3.36	11.16	17.52	39.49	-	1.22	5.55	20.43	31.28	-
CD (0.05)	7.32	24.32	38.18	86.05	-	2.65	12.10	44.52	61.25	-

height did not vary considerably between the different sowing dates except in case of S_4. A reduction in plant height was observed with increase in sowing date at 30 DAS. However, at 60 DAS the reduction was only in comparison to S_1. At 90 DAS there was no variation between the sowing dates. At 120 days there was a gradual decrease in height with an increase in sowing date.

Under pot culture condition these variations were not observed. Values observed for S_4 were comparatively lowest almost at all stages.

Number of primary branches :

The maximum number (5.2) of primary branches was seen in case of S_1 followed by S_2, S_3 and S_4 under field condition. The maximum number was attained at 90 DAS in case of S_1, by 120 days in case of S_2 and 60 and 90 DAS in case of S_3 and S_4 respectively.

Under pot culture, the differences were not much marked between the different sowing dates except in case of S_1, which had comparatively higher number at 30th day.

Number of secondary and tertiary branches :

These increased with time both under field and pot culture, the order of increase being $S_1 > S_2 > S_3 > S_4$. It will be observed that under pot culture condition, the plants were harvested between 120 and 150 days, while S_1 and S_2 they continued growth after 150 DAS. Although the total number of branches found more or less same under pot culture at 120 days

in S1 and S_2 in comparison to S_3 and S_4, yet the final number at 150 days was much higher. This may be due to the fact that the plants were harvested between 120 and 150 days, while in S_1 and S_2 they were harvested beyond 150 DAS.

The similar pattern described for the number of secondary and tertiary branches was noticed with respect to total number of branches.

Number of leaves :

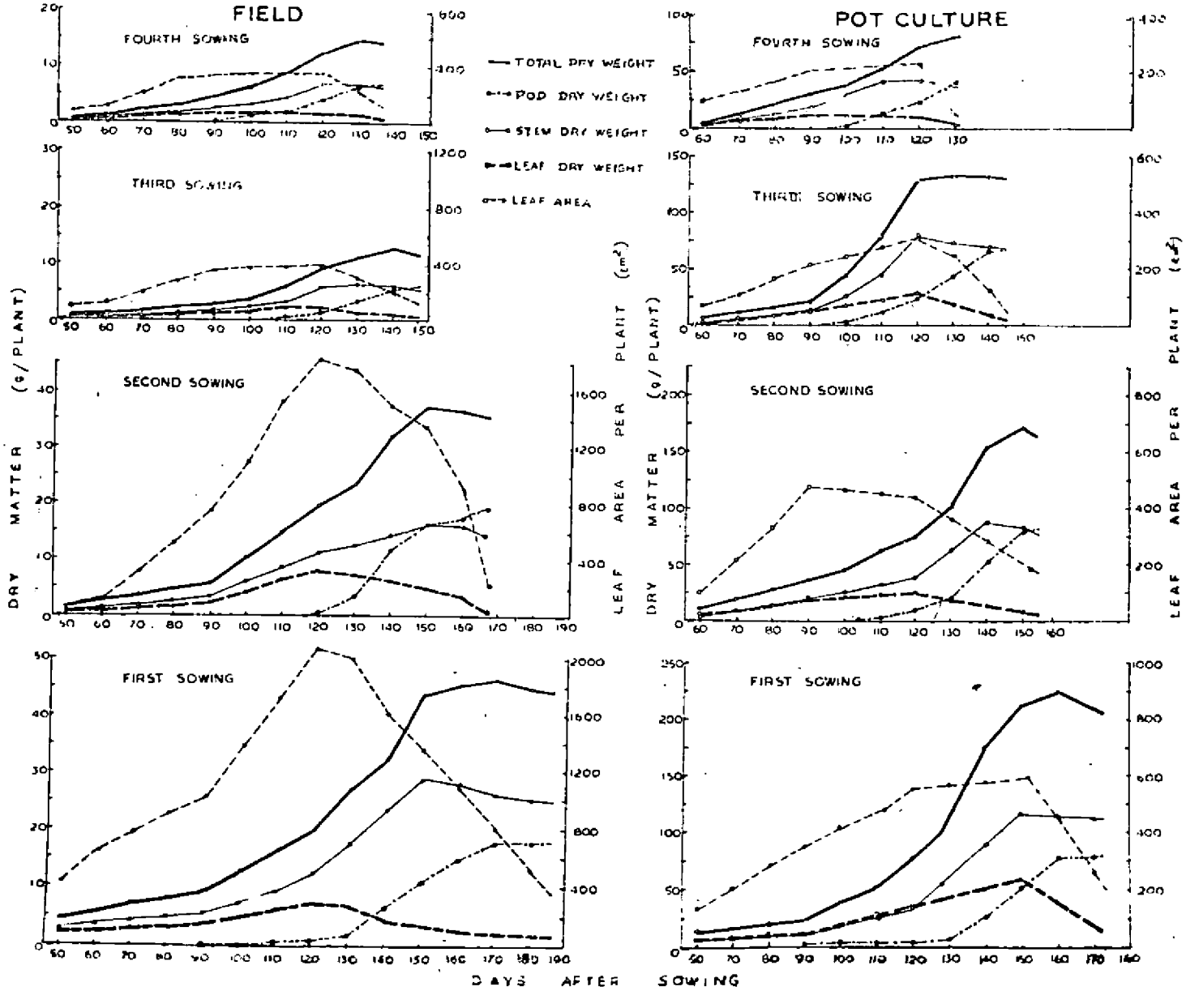
Leaf number increased with time in almost all stages both under field and pot culture conditions, with exception of S_2, where it registered a decline at 150 days. The maximum number was again noticed in case of S_1. The order was $S_1 > S_2 > S_4 > S_3$ both under field and pot culture conditions. At any given stage the differences were more marked with respect to S_1 under field condition, which had a higher number of leaves in comparison to the rest of the sowings, however, these were less marked in pot culture.

4.2.3 The influence of different dates of sowing on leaf area and dry matter production in chickpea cultivars :

The influence of different dates of sowing on leaf area and dry matter production of chickpea cultivars JG-62, L-550 and BG-209 grown under field and pot culture conditions is presented in figure 2, 3 and 4 and in table 13 to 18 respectively. The figures represent the changes from the start of flowering till final harvest at an interval of ten days, for each date of sowing. For convenience of representation the flower weight has been included in the stem weight.

FIG.2

CHANGES IN LEAF AREA AND DRY MATTER PRODUCTION IN DIFFERENT PLANT PARTS FROM FLOWERING TO HARVEST IN CHICKPEA cv. JG-62



JG-62

First sowing :

It will be seen from the figure 2 for the first sowing, under field condition (Table 13) leaf area increased with time till 120 DAS and thereafter showed a gradual decline till the time of harvest. The maximum leaf area (1969 cm^2/plant) was attained 10 days before peak flowering. The total dry matter production followed typical sigmoid curve. There was a slow increase upto 90 DAS and thereafter the increase was greater. The maximum dry weight (46.250 g/plant) was attained at 170 DAS. Stem weight also followed a typical sigmoid curve and the maximum stem weight was attained at 150 DAS (28.012 g/plant), afterwards there was a slow decline in stem weight till the time of harvest. The highest dry weight of leaf (7.438 g/plant) coincided with the attainment of maximum leaf area. The pods did not show much variation in weight until 120 DAS, however from 130 DAS onward there was a linear and sharp increase in dry weight until 170 DAS. Thereafter it maintained a constant level.

Under pot culture conditions (Table 14), also, the leaf area increased linearly upto 120 DAS. After that the rate of increase was slowed down till 150 DAS and then showed a very sharp decline until harvest. Although the increase at 120 DAS was more or less similar to that observed under field condition, yet, the increase was extended till 150 DAS and the maximum area (598 cm^2/plant) was observed at this stage and a sharp decline was seen after 150 DAS. The pattern of dry matter production in pot culture condition was similar to that of field, however, since the maturity of plants was attained earlier, the maximum dry matter and pod weight were attained at 160 DAS.

2nd sowing :

During the second sowing the leaf area showed a sharp increase from 60 DAS. It attained its maximum area (1813 cm^2/plant) at 120 DAS. Thereafter it showed a gradual decline until 150 DAS and from thereon registered a sharp decline. The total dry weight showed a typical sigmoid pattern. A slow increase upto 90 DAS and sharp increases thereafter till 150 days were noted and at 150 DAS it attained the highest dry matter (37.205 g/plant). The stem weight in the second sowing increased at a slower rate until 90 DAS, and thereafter it increased sharply till 120 DAS and then went up steadily at a slower rate until 160 DAS where the highest (16 g/plant) was recorded, afterwards it declined gradually till harvest. The increase in leaf weight was gradual till 90 DAS, from thereon the increase was linear till 120 DAS to attain the maximum (8.201 g/plant) and from 120 DAS till the time of final harvest there was a gradual decline until harvest. The increase in dry weight in pod was registered from 120 DAS and followed a typical sigmoid curve.

Under pot culture condition the leaf area increased linearly to attain the maximum (483 cm^2/plant) upto 90 DAS and more or less the same level was maintained till 120 DAS and then it declined gradually till harvest. The total dry matter increased upto 150 DAS and attained the maximum (17.125 g/plant) by this stage. The increase between 120 and 150 days was appreciably greater than the increase between 90 and 120 DAS. The stem weight also showed a parallel trend upto 140 DAS and afterwards

a slow decline was seen till the time of final harvest. The leaf dry weight increased till 120 DAS. It attained its highest (2.595 g/plant) at this stage and thereafter it declined gradually till harvest. A linear increase in pod weight was noticeable upto 130 DAS at a slower rate and at a higher rate from 130 to 150 days.

3rd sowing :

In the 3rd sowing in field the leaf area increased linearly till 90 days linearly and thereafter upto 120 DAS at a slower rate and attained by this time its highest area (400 cm^2/plant) and from thereon a linear decline was observed. The total dry matter produced was comparatively less in S_3. Significant increase occurred in dry matter between 110 and 120 DAS. The highest dry matter accumulation (12.775 g/plant) was noted at 140 DAS. Stem weight also showed a similar trend till 120 DAS. There was no appreciable increase in stem dry weight from 120 DAS onwards and it attained its highest (6.500 g/plant) at 140 DAS. Leaf weight gradually increased upto 120 DAS and then it declined. Pod weight increased linearly till 140 days.

Under pot culture condition the leaf area increased linearly upto 120 DAS and also declined linearly thereafter. The highest area of 299 cm^2/ plant was recorded at 120 DAS. The total dry matter followed a typical sigmoid curve. It increased upto 90 DAS at a slower rate and at rapid rate upto 120 DAS. The highest dry matter was recorded at 140 DAS (14.375 g/plant). The same trend was observed in case of stem and it reached its highest weight at 120 DAS (7.555 g/plant). The leaf weight and pod weight

showed the same trend as observed under field conditions. However, the highest dry weight was observed for leaf and pod at 120 and 140 DAS respectively.

4th sowing :

In case of 4th sowing in field, the leaf area increased linearly from 60 to 80 DAS. There was no further change till 120 DAS, it declined thereafter. The highest leaf area was found at 120 DAS (354 cm^2/plant). The dry matter production upto 90 DAS was slow and from 90 to 120 DAS it was rapid and attained the highest at 130 DAS (14.350 g/plant). Same trend was observed in case of stem, however, the increase was noted only upto 120 DAS, when it attained the highest dry weight (7.0 g/plant). Leaf weight increased slowly till 90 DAS, further it remained constant till 110 DAS. The highest leaf weight recorded was 1.750 g/plant at 110 DAS. The pod weight increased linearly from 100 days onwards till it stabilised at 130 DAS.

Under pot culture conditions by and large the picture remained the same, except that the linear increase was observed between 60 and 90 DAS.

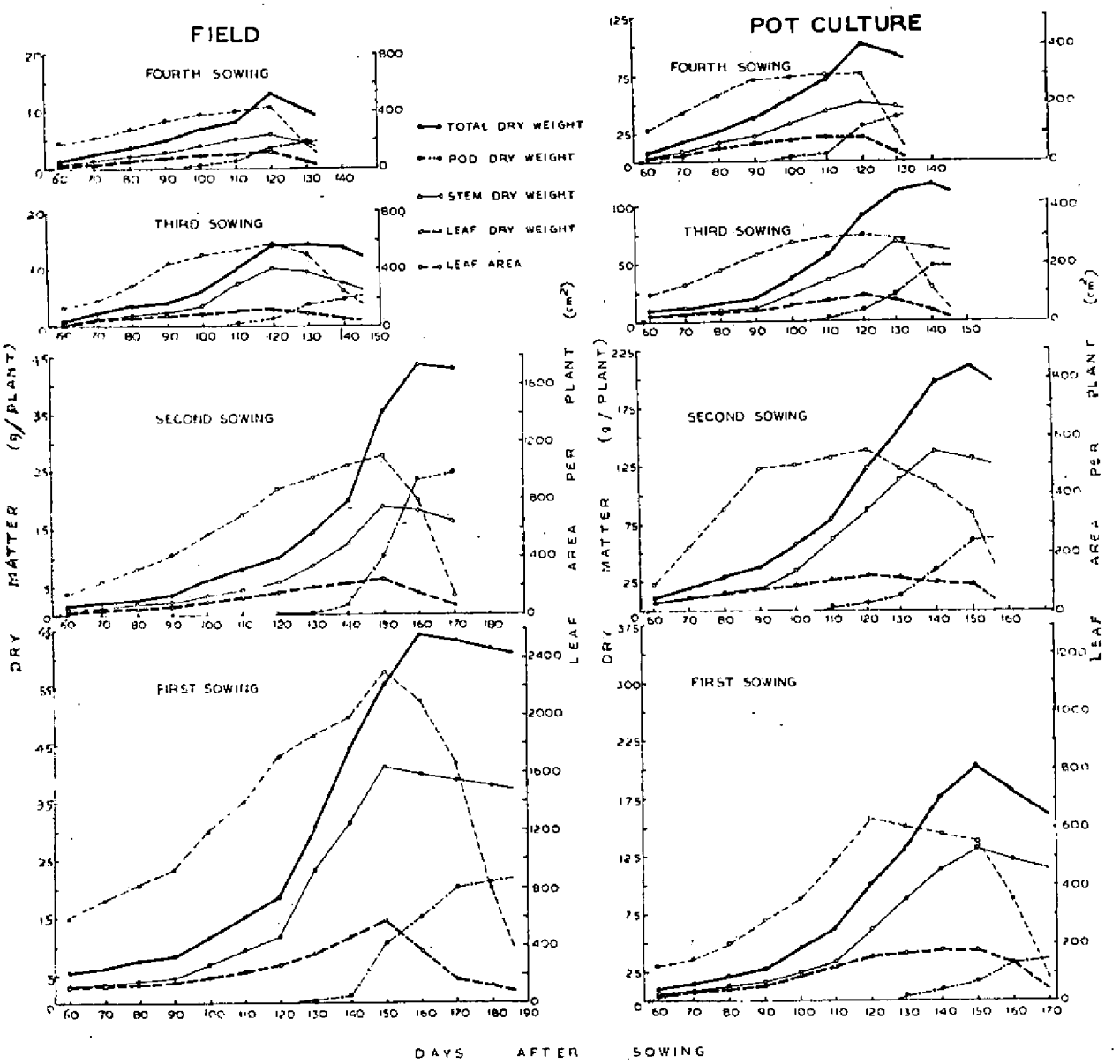
L-550

Ist sowing :

It will be noted from figure 3 and table 15 that the leaf area under field condition increased upto 150 DAS and thereafter showed a sharp decrease. The highest area recorded was 2300 cm^2/plant was at 150 DAS. The total dry matter production followed a typical sigmoid curve. The dry

FIG. 3

CHANGES IN LEAF AREA AND DRY MATTER PRODUCTION IN DIFFERENT PLANT PARTS FROM FLOWERING TO HARVEST IN CHICKPEA cv. L 550



matter production was slow till 90 DAS, then it increased upto 120 days and afterwards showed a sharp increase till 160 DAS and then attained the highest weight (64 g/plant) and declined steadily till harvest. The stem dry weight followed the same trend. Leaf weight also showed a similar pattern till 150 DAS, however, it declined sharply thereafter. The increase in pod weight was slow upto 140 DAS and increased rapidly between 140 and 170 days.

Under pot culture condition (table 16) the leaf area registered a similar trend till 120 DAS. Between 120 and 150 DAS it remained almost constant and then declined rapidly. The pattern with respect to total dry weight and stem weight was similar as observed under field condition. Leaf weight, however, showed a similar pattern only upto 120 DAS. Between 120 and 150 DAS no appreciable increase in leaf weight was observed and it declined thereafter. Pod weight increased linearly with time until it stabilised at 170 DAS.

2nd sowing :

The leaf area during the second sowing in the field increased linearly till 150 DAS and then declined sharply. The total dry matter showed a typical sigmoid curve. The highest weight was attained at 160 DAS (43.500 g/plant). The stem dry weight increased slowly until 150 DAS and from thereon increased rapidly until 150 DAS, and it recorded the highest weight of 18.750 g/plant at this stage. The leaf dry weight increased till 100 DAS and declined sharply. Pod dry weight increased in a typical

sigmoid fashion in parallel to stem weight.

Under pot culture condition the leaf area increased upto 120 DAS, then declined gradually till 150 DAS and very sharply after 150 days. The total dry weight followed a typical sigmoid curve and the highest weight of 21.462 g/plant was noted at 150 days. The leaf dry weight increased steadily till 120 days and no further increase was noted after that, however, a sharp decline was only noticed just before at the time of harvest. Pod weight paralleled the stem weight and followed a sigmoid curve.

3rd sowing :

The leaf area under field condition increased linearly upto 90 days and slowly between 90 and 120 days and then decreased linearly. The total dry weight increase was more pronounced between 90 and 120 days, the highest being recorded at 130 days (14.225 g/plant). Stem dry weight closely paralleled the total dry weight. However, it declined from 130 days onwards Leaf dry weight increased upto 120 DAS. Pod weight increased with time until harvest. Increase in pod weight was slow upto 120 days but the same increased rapidly between 120 and 130 days.

Under pot culture conditions the picture was more or less remained similar except the highest total dry weight (11.825 g/plant) was found at 140 days and the stem maintained a constant level in it weight from 120 days onwards.

4th sowing :

The results of fourth sowing show that the leaf area increased upto 120 days and thereafter declined sharply. The total dry matter increased linearly till 110 days and rapidly between 110 and 120 days. The highest dry weight (13.225 g/plant) was seen at 120 DAS. Stem and leaf dry weight increased till 120 days, however, the decline in leaf weight was more sharp in comparison to stem. The pod dry weight paralleled the stem dry weight. It also showed a rapid increase between 110 and 120 days, after which increase in weight was of low order. Similar trend was observed under pot culture.

BG-209

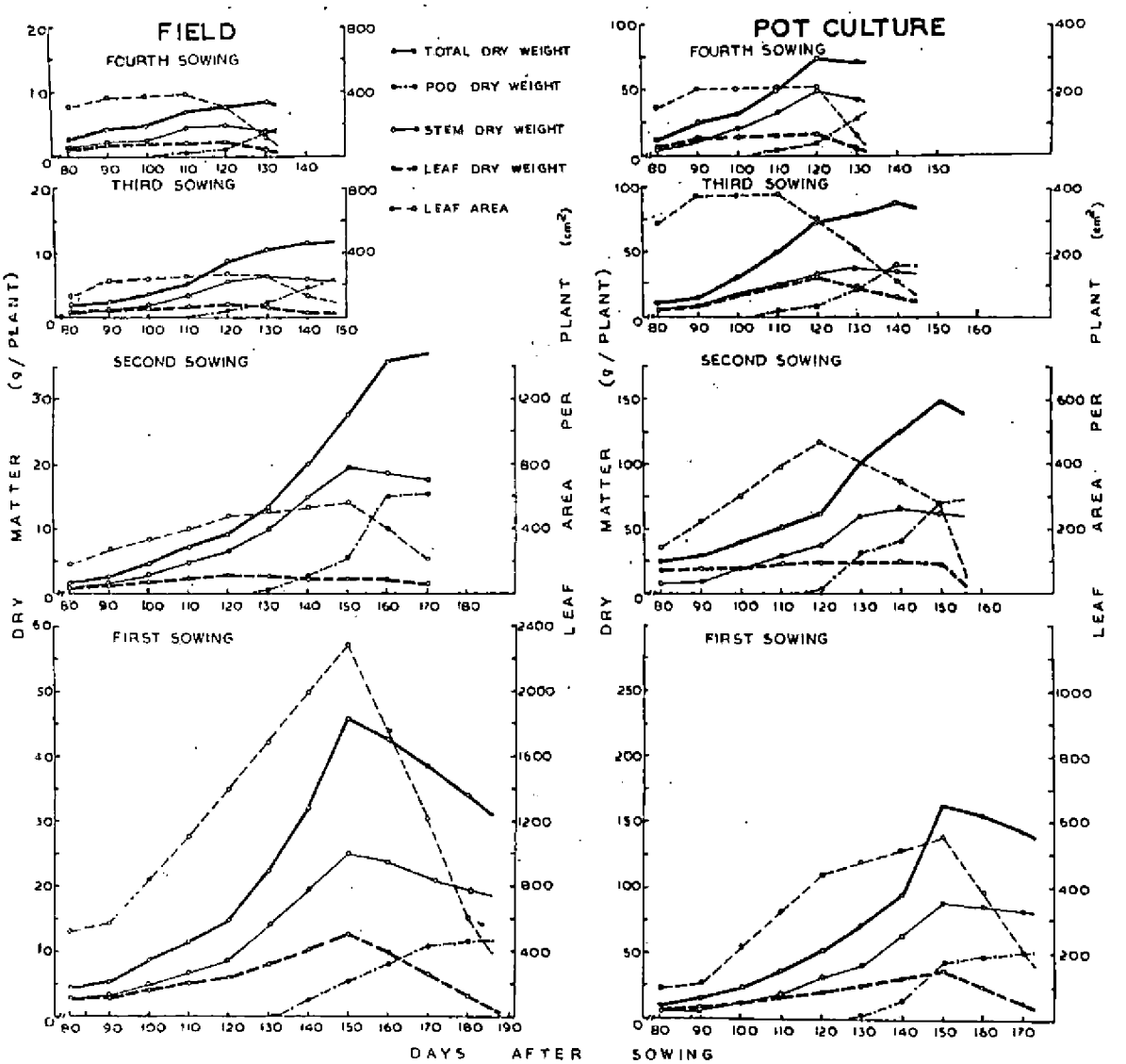
Ist sowing :

It will be seen from the fig. 4 that the leaf area increased rapidly from 90 DAS till 150 DAS and thereafter declined very sharply under field conditions (Table 17). The highest area recorded (2292 cm^2/plant) was on 150 DAS. The total dry weight increased with time at 150 DAS and declined gradually. The increase between 120 and 150 days was greatest as compared between 90 and 120 days. It attained its highest at 170 days (46.250 g/plant). Almost similar pattern was observed with stem dry weight. The leaf dry weight increased upto 150 days to record its highest weight of 12.573 g/plant and then declined linearly till harvest.

Under pot culture condition (Table 18) changes in leaf area and leaf

FIG. 4

CHANGES IN LEAF AREA AND DRY MATTER PRODUCTION IN DIFFERENT PLANT PARTS FROM FLOWERING TO HARVEST IN CHICKPEA cv. BG-209



weight, were of same order as obtained in field, however, the increase was of lower magnitude. The total dry weight increased linearly until 140 days, rapidly between 140 and 150 days. Highest dry weight was attained at 150 days (16.1 g/plant). Stem dry weight closely paralleled the pattern of total dry weight. The pod weight increased with time, however, there was a significant increase between 140 and 150 days.

2nd sowing :

The leaf area generally increased until 130 DAS sharply to record the highest of 600 cm^2/plant and declined thereafter. The total dry weight increased with time, but the increase was more marked between 130 and 160 days. The highest weight (37.202 g/plant) was recorded at harvest. Stem weight paralleled the change in total dry weight upto 150 days only. By and large, the leaf weight remained constant after registering the increase from flower initiation to 110 days, but decreased significantly at harvest.

Under pot culture condition, leaf area increased till 120 days, then slowly decreased upto 150 days. Total dry weight increased upto 150 days, larger increases were observed between 120 and 150 days. Stem dry weight closely paralleled the total dry weight changes upto 130 days and thereafter the weights tended to stabilise, however, the highest weight was obtained (6.440 g/plant) at 140 DAS. The leaf dry weight remained almost constant between 90 and 150 days.

3rd sowing :

In the third sowing the leaf area increased sharply between 80 and 90 days and remained constant till 120 days when it attained its highest area (268 cm^2/plant). Then it declined slowly. The total dry weight increased with time, howwver, it showed a rapid increase between 110 and 120 days. The stem dry weight also increased with time till 130 days. The leaf dry weight by and large remained constant between 90 and 130 days and then declined sharply.

Under pot culture condition an initial increase in leaf area between 80 and 90 days was noted. From thereon there was little decrease in leaf area upto 120 days. Thereafter it declined sharply. The changes in total dry weight and stem weight were of similar nature as in field. In contrast to the changes in field, the leaf weight increased and decreased linearly, attaining its maximum at 120 days. The change in pod dry weights were more or less of similar order.

4th sowing :

During fourth sowing, by and large, leaf area remained constant till 120 days, however, the highest leaf area (372 cm^2/plant) was observed at 90 days. The total dry weight increased till 130 days (8.5 g/plant) and then slowly declined. By and large, the leaf area, leaf dry weight and stem dry weight remained constant between 90 and 120 days. An increase was noted between 80 and 90 days and a decline from 120 days to harvest with exception of stem weight. The pod weight increased with time, but

more rapidly between 120 and 130 DAS.

Under pot culture conditions similar trend was observed with respect to leaf area, leaf weight and total dry weight, however, the stem dry weight showed an increase with time upto 120 days.

4.2.4 Effect of different dates of sowing on the percentage dry matter distribution in various plant parts in chickpea :

The data pertaining to the effect of sowing dates on the percentage dry matter distribution in various plant parts of chickpea cultivars JG-62, L-550 and BG-209 at various stages of growth in field and pot culture are given in table 19, 20 and 21 respectively, from 30 days after sowing until final harvest at 10 days interval.

Since a very small percentage of total dry matter was present in flowers, no separate data was given for flowers and their weights were included in the stem for convenience. One common observation was that the percentage of dry weight in pod increased with time in all the cultivars both under field and pot culture and therefore these are not described individually.

JG-62

Data for JG-62 under field and pot culture conditions are presented in table 19. From the same it will be noted that in field during the first sowing (S_1) at 30 days the leaf had 66 % dry matter of total dry matter as compared to 34 % in stem. The percentage dry matter in leaf decreased with

time. However, it was noticed that there was marked reduction in leaf at two different periods during the crop duration. The first was between 30 and 40 DAS and the second was between 120 and 130 DAS, while the first decrease was accompanied by an increase of comparable order of stem. The same was not between 120 and 130 days. Moreover, it will be noticed that, by and large, the reduction in percentage of leaf dry matter was of comparable degree in relation to increase in percentage dry matter present in stem at any given stage.

The changes during second and third sowings were found to be of similar nature. One interesting point was that in all the sowings the stem gains weight by 70-80 DAS.

The picture in case of S_4 was different when almost equal percentage of dry matter was present between leaf and stem and no marked reduction in leaf dry weight percentage in rest of the sowings between 30 and 40 days could be observed. However, with increase of time, the stem began to gain and percentage dry matter increased till 90 DAS.

Under pot culture condition, a similar trend was observed as found in field, however, the marked reduction was observed between 40 and 50 DAS in S_1 and between 50 and 60 days in S_2 and 30 and 40 days in S_3.

L-550

In field, L-550 also showed the same behaviour as observed for JG-62 with respect to S_2 and S_3, however, percentage of dry matter present in

leaf at 30 DAS was comparatively less (61.8 %). In case of S_4, although, by and large, the pattern was the same, yet, the percentage of stem dry weight was more as compared to JG-62.

Under pot culture condition, a similar trend was seen with respect to S_1, S_2 and S_3. Only in case of S_1 the period of maximum reduction was noticeable at a later time interval. A marked difference was noted in case of S_4 in comparison to field. The trend in S_4 was more like the S_3 of pot culture and the observed percentage distribution at 30 DAS was also of comparable order.

BG-209

In field at 30 DAS the percentage dry matter in leaf was 84.6 and in stem it was 15.4 in S_1. At this stage amongst the cultivars BG-209 recorded the highest percentage of dry matter of leaf. A sharp reduction occurred between 30 and 40 DAS and similar increase could be noted in stem. Unlike other cultivars, by and large the distribution between stem and leaf was more or less equal upto 110 DAS. Appreciable increase in percentage dry matter in stem was noted from thereon until 130 DAS and declined gradually thereafter. The above trend was seen maintained by S_2, however, the marked decrease in percentage dry weight in leaf was observed between 40 and 50 DAS. Another difference from S_1 was the fact that the stem weight was comparatively always very high at any given stage.

In case of S_3 at 30 DAS the percentage dry weight present in leaf

and stem was 62 and 38 respectively, hence the percentage dry matter in stem was greater at this stage in comparison to S_1 and S_2. Moreover, the decline in percentage dry weight in leaf was gradual with time. The percentage dry weight in stem also increased gradually till 110 days and thereafter decreased slowly. By and large, the trend in case of S_4 was seen similar, except that the percentage dry weight in leaves, although initially lower, was otherwise, comparatively higher at a given time.

The pattern under pot culture condition was found different from the field. The sharp reductions observed in the case of field at specific time period were not observed under pot culture condition. Stem weight also was comparatively higher at initial stages. Otherwise, by and large, the picture remained the same with respect to S_1 and S_2.

Another observation was that in S_2 the percentage of leaf dry matter fluctuated considerably upto 60 DAS.

The pattern shown by S_3 in field more or less remained unchanged under pot culture conditions, however, in the S_4, although the general trend was similar yet the quantitative value until 90 DAS at given time were higher for leaf and lower for stem respectively.

4.2.5 Effect of different dates of sowing on the relative growth rate (RGR), crop growth rate (CGR) and leaf area index (LAI) :

The data pertaining to the RGR, CGR and LAI for the chickpea cultivars viz., JG-62, L-550 and BG-209, as affected by different sowing dates are presented in table 22, 23 and 24 respectively. The data are given for field only.

JG-62

Relative growth rate (RGR) :

The RGR values are presented from 30 DAS upto maturity for four dates of sowing. Between 30 and 40 DAS the RGR decreased as the dates of sowing increased. Thereafter, it fluctuated both within the growing periods and between the sowing dates. However, during S_1 an increase in RGR value was observed from 60 to 100 DAS. It declined between 100 and 110 days, but again increased to more or less constant value upto 100 days, thereafter it fluctuated and sharply declined between 150 and 160 days.

For S_2 the RGR fluctuated and no definite pattern could be seen. For S_3 the RGR declined sharply till 70 DAS and thereafter sharp inclines and declines were noted between regular intervals of 10 days. During S_4, the RGR, although initially low, increased considerably between 40 and 50 days and thereafter declined with time.

Crop growth rate (CGR)

CGR varied greatly within the sowing dates and between the sowing. CGR increased with time upto 50 DAS in first sowing and it declined thereafter in the next time interval of 50 to 60 days. Between the sowing dates, during this period the values for S_1 were always found to be highest and this was markedly different from other sowings. In case of first sowing the CGR values increased with time until 150 days and declined sharply thereafter. Highest CGR value was found between 140 and 150 DAS (36.6 g/m^2). The CGR value in the second sowing increased in a more or less similar

manner upto 100 days and thereafter remained almost constant and then again increased between 130 and 140 days, during which highest CGR (28.38 g/m^2) was recorded. For S_3, the increase in CGR values was restricted between the time interval from 90 to 120 days and the highest CGR value was recorded at 120 DAS (12.24 g/m^2). In S_4, the increase in CGR values were from 70 to 120 days.

Leaf Area Index (LAI)

The leaf area index in general was highest for any given time interval for S_1 from 30 DAS onwards. It increased till 130 DAS and declined gradually thereafter. S_2 although showed a similar trend as shown by S_1 yet, certain important features can be observed. Initially the values in comparison to S_1 were very low. However, as the time interval increased these differences were narrowed, so that by the time the maximum values were attained, there was no appreciable difference between S_1 and S_2. In case of S_3 and S_4 the leaf area decreased with time until 130 DAS and declined further. It is interesting to note that the values for S_3 and S_4 for any given time interval between 30 and 60 DAS were always greater than S_2 and in the following interval the differences in values were almost nil. Thereafter S_2 values were always higher than S_3 and S_4. However, the differences were not very great.

Leaf Area Duration (LAD)

Leaf area duration was reduced with delayed sowings and the order was $S_1 > S_2 > S_3 > S_4$ and the values for S_1, S_2, S_3 and S_4 were 50.30, 40.35, 9.45 and 7.46 respectively.

L-550

Relative growth rate (RGR) :

RGR values for S_1 and S_2 to a certain extent were comparable upto 140 DAS. The values increased upto 60 DAS in S_2, then declined and remained low until 90 DAS and from there onwards it fluctuated, however, between 100 and 140 DAS the values for the S_1 and S_2 were more or less of the same magnitude. In S_3 and S_4 considerable fluctuations were observed in RGR values.

Crop Growth Rate (CGR) :

No specific trend in CGR was noticed either within the sowing dates or between the sowing dates. However, by and large the values before 90 DAS were comparatively lower and higher after 90 DAS.

Leaf Area Index (LAI) :

The leaf area index increased in all the sowings upto a certain time and declined thereafter. The maximum LAI noticed was 7.56, 1.98, 0.85 and 1.22 between 150-160, 120-130, 110-120 and 90-100 DAS in case of S_1, S_2, S_3 and S_4 respectively. Between the sowing dates for any given time interval upto 80 DAS the values for S_1 were highest.

Leaf Area Duration (LAD)

The leaf area duration decreased significantly with delayed sowings, however, there were no marked differences between S_3 and S_4. The values for LAD were 51.47, 14.29, 5.93 and 4.10 for S_1, S_2, S_3 and S_4 respectively. The order was $S_1 > S_2 > S_3 > S_4$.

BG-209

Relative Growth Rate (RGR) :

RGR varied considerably within the sowing date. However, it could be observed that between the sowings, the RGR values were more or less of the same order at certain time intervals, for e.g., between 40 and 50 DAS, between 90-and 100 days and between 100 and 110 days, with the exception of 4th sowing between 90 and 100 days. The values for S_2 were of comparable order with S_3 between 40 and 70 days and also between 110 and 120 days but beyond 120 days only with S_1.

Crop Growth Rate (CGR) :

During first sowing CGR was seen fluctuating considerably till 90 DAS and increased thereafter. The values from 150 and 180 days were low. In the second sowing it increased upto 60 DAS and slightly declined till 80 days and then increased with time upto 160 DAS. Both S_3 and S_4 showed increases upto 110 days and declined thereafter, however, the decline in S_3 was comparatively slower.

Leaf Area Index (LAI)

The LAI increased upto a specific time in all the sowings and declined thereafter. The maximum LAI of 7.58, 1.98, 0.88 and 1.22 were found on 150, 130, 120 and 90 days after sowing for S_1, S_2, S_3 and S_4 respectively. At any given time between the sowings the values for S_1 were always higher but did not vary much from the rest of the sowings until 60 days, whereupon

the values for S_4 were found to be higher upto 100 days and from 100 days onwards in case of S_2.

Leaf Area Duration (LAD) :

The values of LAD can be compared with that of L-550 for all the sowings, as they are more or less of same order, as a 346 % increase was seen in S_1 compared to S_2 in both the cultivars. However, the variation in LAD between S_3 and S_4 was not so marked. The values for LAD are 51.41, 14.82, 5.96 and 7.09 for S_1, S_2, S_3 and S_4 respectively and the order was $S_1 > S_2 > S_4 > S_3$.

4.2.6 Influence of different dates of sowing on the reproductive behaviour of chickpea :

The influence of different sowing dates on the reproductive behaviour both under field and pot culture conditions in cv. JG-62, L-550 and BG-209 is graphically represented in figs. 5, 6 and 7 respectively.

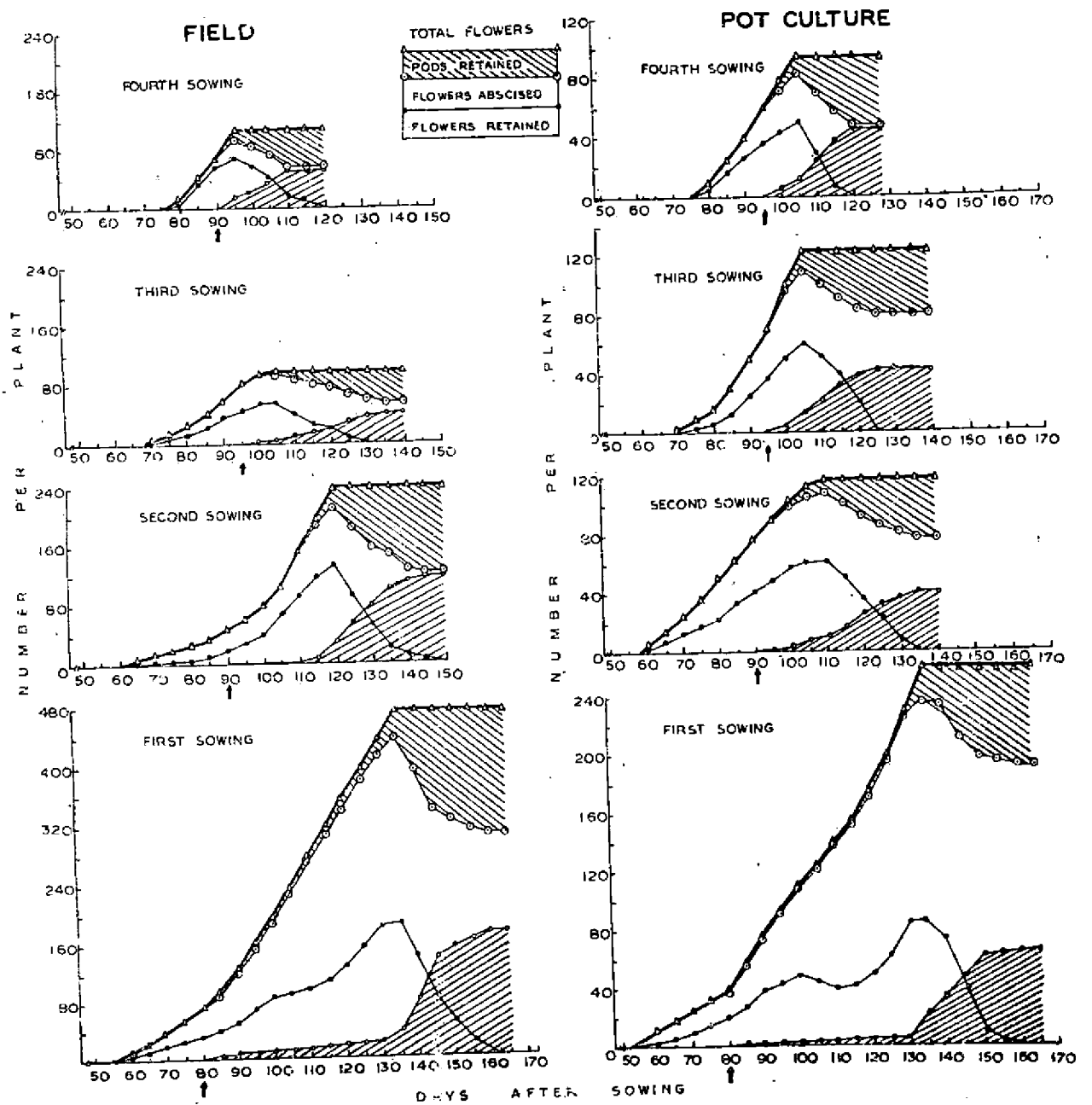
In order to have a comparative evaluation of reproductive behaviour under different sowing dates same scale has been used for all cultivars, however, different scales have been used for field and pot culture in order to highlight the patterns under these conditions. The results are presented separately for each cultivar.

JG-62

From figure 5.it will be evident that the time, intensity and duration

FIG. 5

EFFECT OF DIFFERENT DATES OF SOWING ON THE REPRODUCTIVE BEHAVIOUR OF CHICKPEA cv. JG-62



of flowering is greatly altered under the influence of different dates of sowing. With delayed sowing, the appearance of first flower is also delayed. The intensity of flowering was generally reduced with delayed sowing. The duration of flowering was also considerably reduced with increase in sowing dates.

Similar pattern was observed under pot culture conditions. In general, the flowering occurred earlier with an increase in sowing dates.

Ist sowing :

Flowering started at 55 DAS in S_1 and continued upto 165 days. Hence the total duration of flowering observed was 110 in the case of first sowing. The peak flowering was observed at 135 DAS. The total number of flowers increased in a sigmoid fashion till 135 DAS. There was an initial rapid rise in the number of retained flowers upto 100 days. Further rapid increase is noted from 115 to 130 days. Thereafter the number of retained flowers declined sharply. The abscission also increased with time upto 100 days but thereafter it increased rapidly. 252 flowers had abscised at the time of peak flowering. The pod formation was initiated at 80 days. The number of pods formed did not increase appreciably until 130 days. There was a marked and significant increase in the number of pods found between 135 and 145 DAS. Thereafter the increase was considerably less and no further increase in pod number was recorded after 160 days. A total of 170 pods were formed.

More or less a similar trend was observed under pot culture condition

also except for an early initiation and peak afterwards. The magnitude of flowering was considerably less. As compared with 475 flowers under field condition, there was only 260 flowers under pot culture conditions.

2nd sowing :

In the second sowing the flowering initiated from 60 DAS and total duration was 90 days. The peak flowering occurred at 120 days. The number of retained flowers increased steadily and thereafter declined sharply until 135 days and gradually till 150 days. Out of a total of 240 flowers, 117 pods were formed. The pod formation started at 90 DAS, but the rapid increase in pod number started from 110 days to 140 days. The pod number stabilised by 145 DAS. By the time of attainment of peak flowering 76 flowers had been abscised.

Under pot culture flowering started from 57 DAS onwards and continued till 135 DAS. Hence the total duration of flowering was 78 days. The total number of retained flowers increased until 100 days and more or less same number of flowers were retained till 110 days. Thereafter, it declined sharply. 46 flowers had been abscised at the time of peak flowering. Pod initiation was noted at 90 DAS. It increased at a very slow pace upto 100 days and thereon increased rapidly until it attained a constant number by 135 days. Although by and large, the same general trend is maintained under pot culture condition, yet, the flowering peak was not sharply demarkated and it extended over a larger number of days. A total of 117 flowers were formed out of which 40 pods developed.

3rd sowing :

In 3rd sowing days to first flower were 68 and the flowering ceased by 130 days. A shorter duration of 62 days was obtained under field in comparison to S_1 and S_2. The peak flowering was recorded between 100 and 105 days. The decline in flowering was gradual. By peak flowering 42 flowers had abscised. Pod formation was initiated 95 DAS and there were very few pods till 105 days, from thereon the pod number increased steadily upto 130 days and then tended to stabilise. A total number of 96 flowers were formed and final retained pods were 40.

Under pot culture condition the flowering was initiated at 70 DAS and ended by 125 days. Duration of flowering was 55 days. A sharp peak of flowering was observed at 105 DAS. 49 flowers were seen abscised by this time. The pods initiated by 95 DAS and pod formation stabilised by 125 DAS. The increase between this period was rapid. The total number of flowers formed were 124 and total pods realised were 43.

4th sowing :

75 days were taken during the 4th sowing for the appearance of Ist flower. The flowering lasted upto 120 DAS. Total duration was 45 days. The peak flowering occurred at 105 DAS. By the time 26 flowers had abscised. The first pod was seen on 95 DAS. The pod formation increased rapidly upto 120 DAS and the final number was achieved by 110 days. In total 106 flowers were formed of which 50 turned out as pods.

Under pot culture conditions the picture was similar with respect to

time and duration of flowering and peak flowering. After peak flowering there was a rapid fall in the number of retained flowers until 115 DAS. 33 flowers had abscised by the time of peak flowering. The total number of flowers and pods formed were 95 and 47 respectively.

L-550

Ist sowing :

Under field conditions flowering started at 60 DAS and lasted till 165 days. Duration of flowering was 105 days. The total number of flowers produced per plant was 594 and total number of pods formed were 138. The peak flowering occurred between 130 and 135 and during 100-130 DAS there was a rapid increase in number of retained flowers. 389 flowers had abscised by the time of peak flowering. The pod formation started at 125 DAS but no appreciable increase in number of pods took place until 140 DAS. Between 140 and 160 DAS there was a sharp increase in the number of pods formed with time.

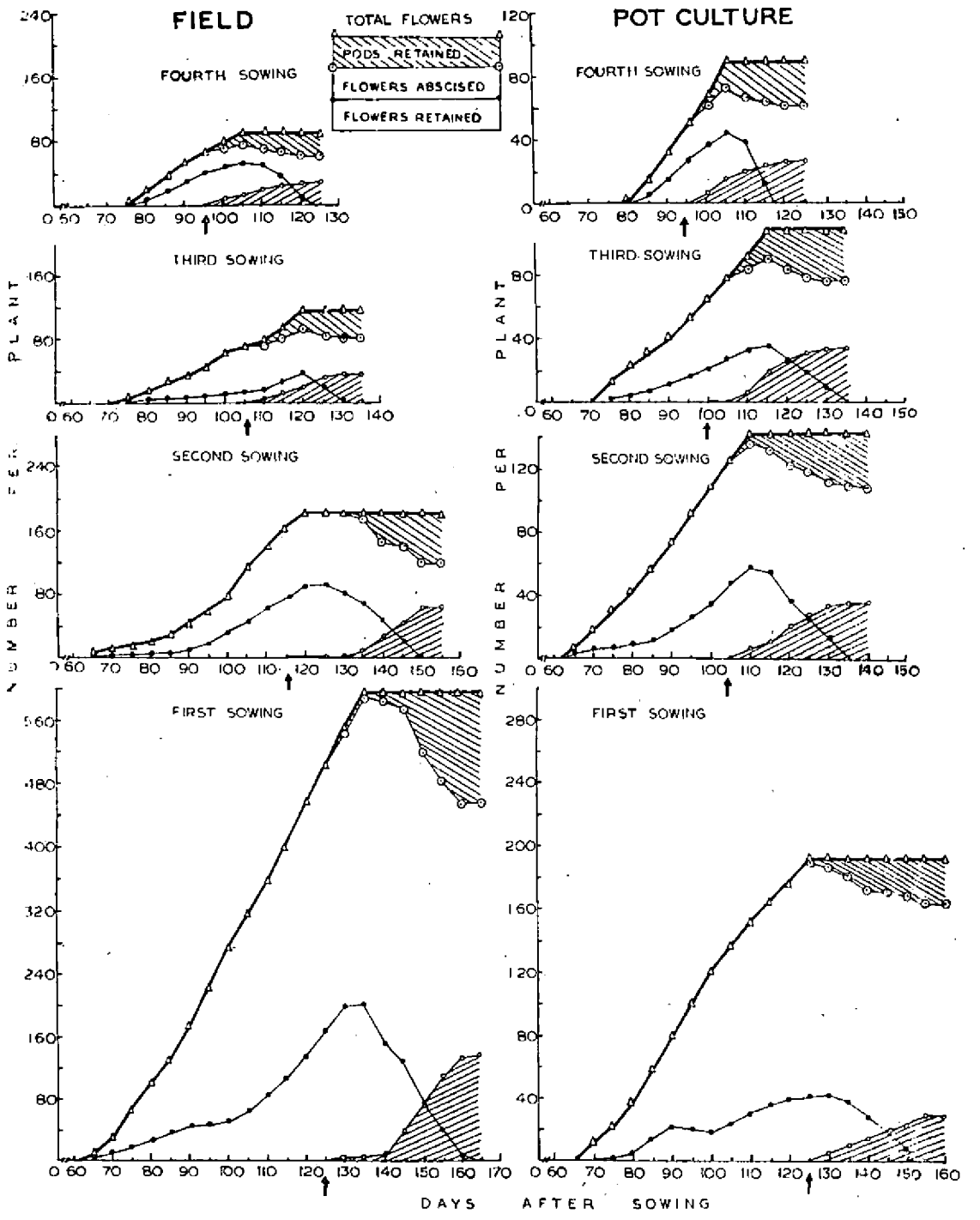
Under pot culture condition although the trend was similar, the total number of flowers were reduced to 1/3. Only 193 flowers were formed and from this 29 pods were obtained. Time of pod initiation and peak flowering was found to be earlier. The cumulative abscission at the time of peak flowering was found as 145. Pod formation started at 125 DAS and increased steadily till 155 days.

2nd sowing :

The first flower appeared at 65 days and flowering continued till 150

FIG. 6

EFFECT OF DIFFERENT DATES OF SOWING ON THE REPRODUCTIVE BEHAVIOUR OF CHICKPEA cv. L-550



DAS. The total duration was of 85 days. The peak flowering occurred at 125 DAS, By this time 99 flowers had fallen. Of the total of 118 flowers formed and the final pod realisation from these was 62. Pod formation started at 115 DAS, but the number increased rapidly only between 135 and 150 DAS.

Under pot culture condition, by and large a similar picture was obtained, however, flowering was earlier (62 DAS) and the last flower appeared at 135 DAS, hence flower duration was 73 days. The peak flowering reached at 110 DAS. At harvest 34 pods were picked although the total number of flowers was 142. First pod appeared at 100 DAS. Pod formation rapidly increased from 105 to 130 days and no further increase was noticed thereafter. The number of flowers abscised at peak flowering was 78.

3rd sowing :

Under field condition it took 70 days for the appearance of first flower. The total duration of flowering was 65 days. Peak flowering occurred 120 days and the cumulative abscission at this time was 58. Pod formation started by 105 DAS and increased till 130 DAS. 35 pods formed out of a total of 118 flowers.

Under pot culture condition although the time intensity and duration and total number of flowers and pod were found almost the same, yet the peak flowering and pod formation were earlier by 5 days.

4th sowing:

The flowering started 75 DAS and ended by 125 DAS. Duration of flowering was 50 days. There was no sharp peak of flowering and a broad peak period of flowering between 100 and 110 days was seen with the maximum at 105 DAS. The number of flowers abscised by the time of peak flowering was 23. The pod formation started at 95 DAS and stabilised by 120 DAS. The total number of flowers were 90 and final pod number was 28.

Under pot culture condition the pattern was identical, except that duration of flowering was shorter.

BG-209

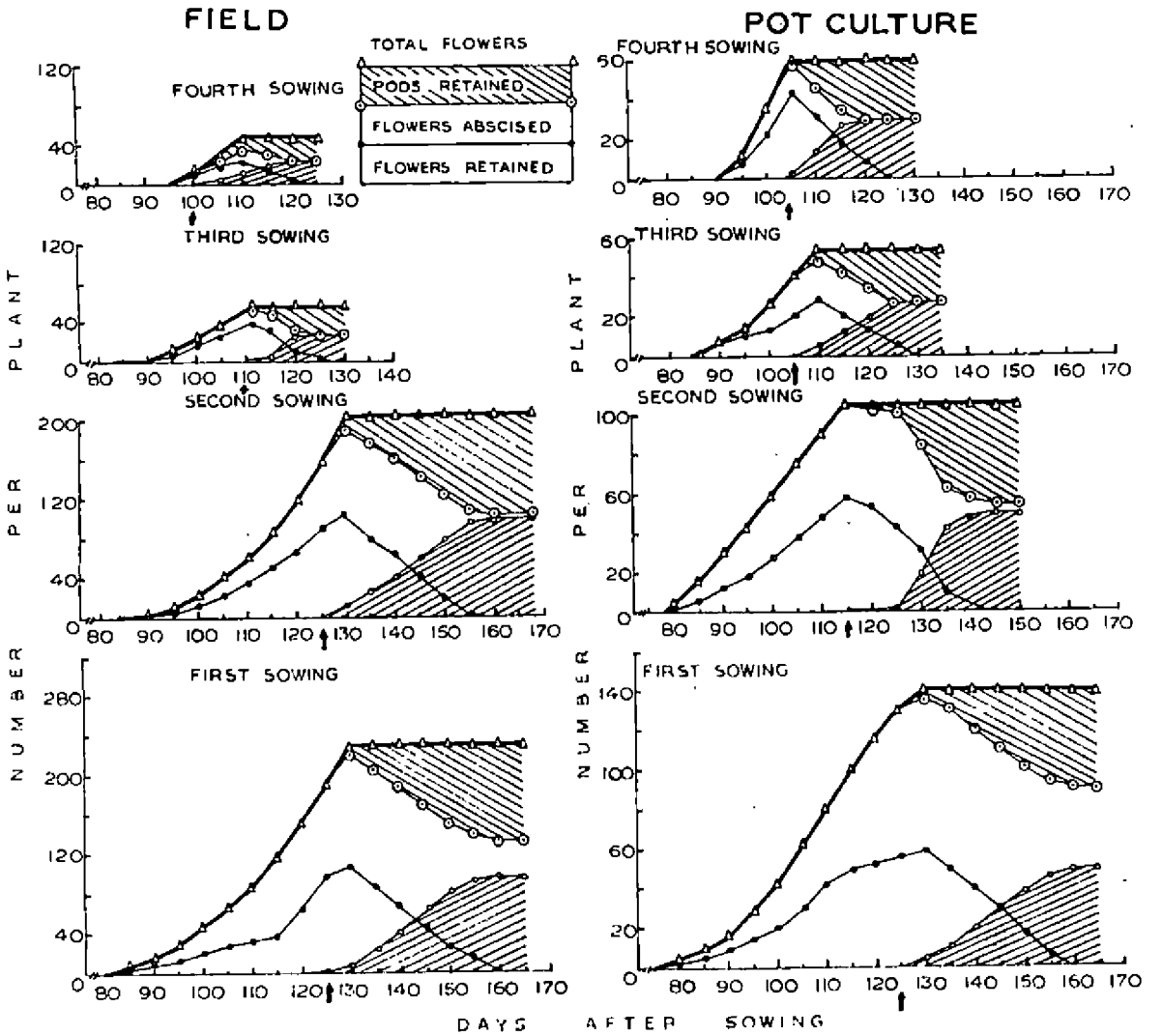
Ist sowing :

In the first sowing flowering started at 80 DAS and lasted till 160 DAS. The total duration was 80 days. The peak of flowering came at 130 DAS. By this time 115 flowers had abscised. The pods started at 125 DAS. A steady increase in pod formation was seen till 160 DAS and then it became stable. The total number of flowers formed were 230 from which 97 pods were formed.

Under pot culture condition, the flowering started 5 days earlier than field and duration was less by 4 days. The peak flowering was attained on the same day as in field. A total number of 77 flowers had fallen by this time. The first pod appeared at 125 DAS and pod formation continued till 160 DAS. A total of 140 flowers were found of which 50 pods were harvested.

FIG. 7

EFFECT OF DIFFERENT DATES OF SOWING ON THE REPRODUCTIVE BEHAVIOUR OF CHICKPEA cv. BG-209



2nd sowing :

The first flower appeared by 84 DAS under field conditions. Flowering lasted for 158 days and hence duration was 74 days. The peak flowering was at 130 DAS. The total number of flowers abscised by this time was 98. The pod initiation took place by 125 DAS and steadily increased upto 160 DAS. From a total of 204 flowers only, 100 pods were realised at harvest.

Under pot culture condition, flowering started 78 DAS and lasted for 67 days. The peak flowering was at 135 DAS. By this time 47 flowers had fallen down. The pods started on 115 DAS. The pod formation continued till 145 DAS after which it became stable. Out of 105 flowers produced, only 50 developed into pods at harvest.

3rd sowing :

Flowering started at 83 DAS and continued till 130 DAS, hence flowering duration was 47 days under field condition. The peak flowering was noted at 110 DAS and cumulative abscission during this time was 16. The pod initiation was noted at 110 DAS and continued till 125 DAS and thereafter it stabilised. The total flowers formed was 56 out of which 28 turned into pods.

Under pot culture condition first flower was seen at 83 DAS, hence five days earlier than field. The total flowering duration of 47 days and the peak flowering was attained on the same day as observed in the field. By this period 21 flowers had abscised. First flower appeared 5 days earlier.

than in field. Pod formation lasted till 125 days and then became stable. 27 pods were formed out of a total of 54 flowers.

4th sowing :

In field the first flower appeared at 95 DAS and flowering lasted till 123 DAS. The peak of flowering was at 110 DAS. 14 flowers had abscised by that time. The first pod appeared at 100 days and pod formation ceased by 120 DAS. Total flowers formed were 48 out of which 24 turned into pods.

In pot culture flowering started 5 days earlier and lasted till 125 DAS, the flowering duration being 35 days. Peak flowering was also earlier by 5 days. A total of 15 flowers had fallen down by that time. 30 pods were harvested from a total of 60 flowers formed. Pod formation started at 103 DAS and increased rapidly till 120 DAS. The pattern was similar to that of field.

4.2.7 Influence of different dates of sowing on the retention, and abscission of flowers and pods

Data on the effect of different sowing dates on the percentage of retention of flowers and pods both under field and pot culture conditions in cultivars JG-62, L-550 and BG-209 are given in table 25, 26 and 27 respectively.

JG-62

A. Flowers retained during a specific period as a percentage of total flowers

In all the four dates of sowing the rate of flower retention, as

percentage of total flower, increased with time till peak flowering and thereafter declined. 38.7 %, 49.1 %, 52.0 % and 62.7 % were the respective maximum retention in S_1, S_2, S_3 and S_4 respectively.

In late sowing the percentage of retention increased sharply in comparison to earlier sowings. A decline in percentage of retention was noticed in all the sowings after peak flowering. This decline in the 2nd sowing was the highest as compared to the other sowings. Although a very high percentage of flowers were retained in late sowings, the duration of such retention was comparatively very short in contrast to S_1 and S_2.

Under pot culture condition almost similar trend was found and the peak retention did not vary much with the exception of 4th sowing. The important difference is that during the second sowing percentage of retention exceeds about 2-3 fold under pot culture during a specific period even after giving due discount to 5 day early flowering. Another feature was that in case of late sowing, when a given specific period was compared upto 95 DAS under field and pot culture, the percentage retention was always lower under pot culture condition.

B. <u>Pods retained during a specific period as percentage of total pods at harvest</u>

In all the sowings the pods retained as percentage of total pods at harvest increased with time in field. 100 % of total harvest were realised in S_1, S_2, S_3 and S_4 between 155-160, 140-145, 130-135 and 105-110 DAS

respectively. Active realisation of harvestable pods could be observed between 135-145 days in S_1 where 23 to 57 % pods were retained. In the second sowing the retention of pods was increased by 20 % at every five days interval between 115-135 DAS and by about 15 % at every 5 day interval between 105 and 130 days. In case of 4th sowing about 20 % increase in retention was seen at the very start of the pod realisation which increased with time.

Under pot culture conditions more or less similar picture was obtained for S_1 only. The retention of pods was noticed in S_2, S_3 and S_4 simultaneously between 90 and 95 days. However, 100 % pods were realised at different periods. It was shortes in case of S_4 and longest in case of S_2. The rate of realisation was not regular as found in field. However, the increase in retention percentage is greater in case of S_4 compared to S_3. In S_2 the 20 % increase in retention as found in field is noticeable but between 110 and 115 DAS. Table 28 shows the shedding behaviour in JG-62 under field and pot culture conditions. In general, the low retention of pods at the early stage of pod formation could be attributed to the shedding behaviour which can be visualised from fig.5.

In S_1, there was greater shedding by 115 DAS in comparison to number of flowers retained during that period. In the case of S_2 the rate of abscission was initially high upto 80 DAS and then there was an appreciable decrease in shedding, however, retention of flowers increased until peak flowering, which could be the cause of increased pod number at later stages. In the 3rd sowing abscission was low or equal to retention except between

90 and 95 DAS. In S_4, abscission was always at a much lower rate as compared to retention.

By and large, the picture in pot culture was more or less similar.

L-550

A. Flowers retained during a specific period as percentage of total flowers

Flowers retained during a specific period as % percentage of total flowers increased until peak flowering and thereafter declined (Table 26). The maximum percentage retained at peak flowering was 33.7, 44.4, 32.2 and 60 for S_1, S_2, S_3 and S_4 respectively. The difference between S_1, S_2, S_3 and S_4 were comparatively less marked. Maximum percentage varied from 32 to 44. The retention was seen spread over a longer period in first sowing and comparatively reduced with increase in sowing dates. The increase in flower retention between increasing periods was most gradual and decline in retention was also gradual.

Under pot culture condition a similar picture was obtained, however, the maximum percentage realised between first and fourth sowing was comparatively less than found in the field. The S_4 comparatively had a greater retention percentage, when compared at a given specific period from 85 DAS to peak flowering, both under field and pot culture conditions.

B. Pods retained during a specific period as percentage of total pods at harvest

The data pertaining to this indicate that the values increase with

time in all sowings both under field and pot culture. The initiation of pod retention was very late in this cultivar in the case of S_1 and S_2 i.e, between 125 and 130 days. However, for S_3 and S_4 it was comparatively early and was between 100 and 105 days and 90 and 95 DAS respectively. The cent per cent retention of the final pod number was achieved by 165, 150, 135 and 135 days after sowing in S_1, S_2, S_3 and S_4 respectively. Very active pod retention was between 145 and 150 days in S_1 and between 135 and 140 days in S_2, while for S_3 the percentage of retention increased more with increasing period of time. In case of S_4 there was a sharp increase between 95 and 100 DAS, thereafter it was 15 % increase with increasing period of 5 days.

Under pot culture condition the picture was not the same, however, the magnitude of percentage increases were of comparable order. Since pod formation in pot culture in the second sowing was much enhanced with time, it has realised almost its maximum, by the time the pod retention in field had commenced. In S3 and S_4, however, similar pattern as that of field was seen. But in S_4 a greater percentage was realised at identical periods.

It will be evident from the table 29 that the number of retained flower was comparatively much less compared to those abscised in a given period until 105 DAS, thereafter equal number of flowers retained or abscised till 115 DAS. From thereon the number of retained flowers was always higher as compared to abscised till near peak flowering. In the S_2 more or less similar picture was obtained until 105 DAS. In addition to it, abscission was more till 110 DAS, from 115 DAS onwards the retention was more, as compared

to abscission. In third sowing the rate of retention was always less than rate of abscission upto 100 DAS. Thereafter the retention was increased and abscission was reduced markedly. In the initial ten-days of S_4 the abscission was greater and thereafter the retention exceeded the abscission and almost the abscission was nil in the later phase of peak flowering.

Under pot culture condition the abscission was always higher at a given period and only at the time of peak flowering equal number of flowers were retained or abscised. It is interesting to note that the peak flowering was in the same time as the case of field between 90 and 100 DAS and that was also the period of highest shedding for JG-62 for S_1. In case of S_2 a similar picture emerged upto 95 DAS in field and pot culture conditions. Thereafter the retention under pot culture condition was greater as compared to field. In S_3 more or less equal number of flowers were retained over an increasing interval of time until just prior to peak flowering. The number of flowers abscised was always more than the retained except 10 days before peak flowering period. During the S_4, the abscission was by and large, less.

BG-209

A. Flower retained during a specific period as a percentage of total flowers

The maximum increase was noticed at peak flowering, where 49.9 %, 46.0 %, 67.0 % and 45.8 % in S_1, S_2, S_3 and S_4 respectively were noticed (Table 27). The order was $S_3 > S_1 > S_2 > S_4$. The decline was gradual

in S_1 and S_2, however, it was sharp in case of S_4. The 3rd sowing registered a sharp decline between 115 and 120 DAS i.e., just after peak flowering. There was not much variation between maximum percentage of retained flowers between S_1, S_2 and S_4 sowings. At any given period the percentage of flower retained was greater for 3rd sowing upto 115 DAS. It was interesting to note that in case of fourth sowing although the maximum percentage was almost same for S_1 and S_2, yet the percentage retained from 95 days onwards was comparatively very high (about 3 to 4 fold) and it was only next to S_3 during that period.

In pot culture condition also same trend was observed where maximum percentage of retention was at peak flowering except for S_4, where maximum value was obtained 5 days in advance to peak flowering, however, the values for maximum percentage were found to be different from field, for respective sowing dates. In comparison to field the maximum percentage values were comparatively less for S_1 (41.4 %) and more for S_2 (55.2 %) and the same was greatly reduced or increased in case of S_3 and S_4 by 16 % and 25.8 % respectively. The values for S_1 increased and decreased generally, but in case of S_2, although the values increased by 10 % from 95 DAS till peak flowering, yet, the decrease was only by 4 % after peak flowering until 125 days and a sharp decline was noticed thereafter. In case of S_3 there was a rapid increase in percentage until peak flowering and decline was also comparatively of same magnitude. However, in S_4 there was a rapid increase till 105 DAS and thereafter it declined also with the same rate.

B. Pods retained during a specific period as percentage of total pods at harvest :

Both under field and pot culture conditions the values increased with time. The first sign of retention was evident between 120 and 125 DAS for S_1 and S_2. For S_3 and S_4 it was between 105 and 110 and 100 and 105 DAS respectively. The 100 % realisation of final pods took place in case of S_1 and S_2 at the same time between period of 155-160 and for S_3 and S_4 between 120-125 and 115-120 DAS respectively.

At S_1 retention of pods was greater at the rate of 20 % increase over a period of 5 days interval from 135 days onwards. In S_2, the same trend and magnitude as found in S_1 could be noticed. In case of S_3, about 70 % of pods were retained between a very short span since the values found between 110 and 115 DAS were 21.4 % and that found between 115 and 120 DAS were 92.8 %. In S_4, initial percentage was 25 and it increases in same rate until final realisation.

Under pot culture condition similarities were only in case of S1. In the second sowing, the retention was earlier than in field, but there was a sudden increase between 125-130 DAS. During this period an increase of 40 % is noted over the earlier period. In case of S_3 the sudden increase during the short span was not noticed and the increase in percentage was at more or less by about 25 % during each time interval. In S_4, a great increase was noticed from an initial value of 6.6 % to 43.3 % and 86.6 % in the following time intervals.

It will be noted from table 30 that the number of flowers abscised was always greater during a given period until 115 DAS. Thereupon the retention was much above than the number of abscised flowers upto 125 DAS. However, at peak flowering period the abscission was greater than retention. During S_2 the retention in general was more over abscission and until 115 DAS and thereafter equal number of flowers were retained or abscised during the next 10 days. During the peak flowering period (125-130 DAS) number of flowers abscised were more than the number retained. In S_3, the abscission was still less as compared to S_2 till peak flowering. S_4 also showed a similar trend except that abscission was higher between the period 105 and 110 DAS.

The picture under pot culture condition was different for S_1 only, since under field condition more flowers were retained prior to peak flowering. While in case of pot culture abscission was always equal or greater at all periods with exception between 105 and 110 DAS, and at initial start. Rest of the sowings showed similar trend under pot culture condition.

4.2.8 Effects of different dates of sowing on the reproductive attributes in different chickpea cultivars under field and pot conditions

Effect of different sowing dates on the reproductive attributes in different chickpea cultivars under field and pot culture conditions is shown in Table 31.

The flower number is highest both under field and pot culture conditions in all the cultivars. The order was $S_1 > S_2 > S_3 > S_4$. Rest of the

reproductive attributes also, in general, maintained the same trend between the sowings, as far their number was concerned, but this trend was not always maintained under pot culture conditions with respect to all the attributes, however, S_1 sowing values, by and large, were highest and between S_3 and S_4 the differences were narrowed down.

A closer examination of the table will reveal that it was the limitation of the flower number in S_3 and S_4 that limited the number of other reproductive attributes, which fell in sequence. The reduction in reproductive attributes in case of S_3 and S_4 as compared to S_1 were of comparable order in all the cultivars with the exception of the developed pod number in case of JG-62 at S_4. The above observations were more projected under field condition, since the pod number realised under pot culture condition did not differ much between the sowings.

When S_2 was compared with S_1, it was noted that all the three cultivars behaved differently. JG-62 at S_2 showed marked reduction in all the reproductive attributes both in field and pot culture, while L-550 showed appreciable increases in many of the attributes in pot culture. BG-209, on the other hand showed this trend in field. Although, L-550 showed heavy reduction in all the attributes at S_2 under field conditions, yet reductions could be noticed in pot culture only with respect to number of flowers formed and shed. An opposite picture emerged with BG-209, however the increases recorded over S_1 in field were of low order. The shedding was highest in L-550, and therefore, the pod number realised for L-550 were also less. The reductions in developed pod number in L-550 and JG-62 were 35 % and 20 %

respectively, however, BG-209 instead recorded an increase of 11 % with respect to developed pod number. The reduction of underdeveloped pods was seen highest in L-550 followed by JG-62 and BG-209 and the differences between the varieties were significant. It will also be noted that ~~also~~ the reduction in pod number at S_2 was very high in case of JG-62 and BG-209, yet, the reduction in seed number was comparatively very less and were 31.6 and 15.6 % respectively. In L-550, the reduction in seed number did not differ significantly from pod number. Seed number per pod remained unaffected by sowing dates.

As far as the weight of the reproductive attributes was concerned, the pod weight was always highest for S_2 both under field and pot culture conditions followed by S_1, S_2 and S_4. This observation was irrespective of variety or growing condition. Similarly seed weight was also highest for S_2. However, 100 seed weight did not always follow the same trend and in most of the cases the 100 seed weight was highest for the first sowing.

When compared to S_1, the reductions in pod weight and seed weight of S_3 and S_4 were highly significant and 63-69 %, 75-80 % and 49-67 % reductions in these attributes were noticed in JG-62, L-550 and BG-209 respectively, however, these reductions were of low magnitude under pot culture condition, where these ranged between 15 to 50 % only in case of JG-62 and BG-209. L-550, on the contrary at S_3 registered an increase of 23 % over S_1 with respect to these parameters. However, in case of S_4 these remained unchanged. As compared to S_1 marked increases in pod weight and seed weight were noticed at S_2. The increases in JG-62, L-550 and BG-209

were about 6-8 %, 16-17 % and 61-67 % respectively. It will be noticed that while the increase at S_2 over S_1 remained same both under field and pot culture, but it was altered in case of L-550 and BG-209. While the increase under pot culture condition was higher in L-550, the opposite was seen with BG-209, which recorded higher increases in the field.

Reproductive efficiency:

Reproductive efficiency is determined sequencially from the number of flowers produced to number of pod set and then the number of pods fully developed and the seed number therein and finally the weight gained by the seed. In other words, initial start is from flower number and final expression is economic yield. The various parameters determining reproductive efficiency have been calculated from the data given in table 31 and the same have been expressed as percentage. They are presented in table 32.

Loss due to shedding (%)

Loss due to shedding varied considerably between the cultivars, however, for a cultivar it was of comparable degree both under field and pot culture condition and the shedding values were higher for pot culture. The highest was noticeable in L-550, followed by JG-62 and then by BG-209. Within the sowing date, the shedding percentage did not vary much. Irrespective of the cultivar or growing condition, the percentage of shedding was always highest in S_1. For JG-62 the shedding percentage varied within 13 % amongst the different sowing dates under field conditions and about 28 % in pot culture. If S_1 was not taken into account, then, the shedding percentage

Table 32. Effect of different sowing dates on the various parameters determining reproductive efficiency of chickpea in field and pot culture.

Cultivar	Dates of sowing	Shedding loss (%)	Pod set (%)	Effective pod set (%)	Normal Effective fruiting efficiency. NORMAL developed pods / Total pods (%)	Under developed pods / Total pods (%)	Seed efficiency No. of seeds / Total No. of ovules (%)	Effective seed efficiency No. of seeds / Ovules of total pods (%)
1	2	3	4	5	6	7	8	9
				Field				
JG-62	S_1	64.2	35.8	20.4	57.0	43.0	18.4	51.4
	S_2	51.2	48.7	32.5	66.6	33.4	25.0	51.1
	S_3	58.3	41.7	28.1	67.5	32.5	21.4	50.8
	S_4	52.8	47.1	39.6	84.0	16.0	25.2	51.4
				Pot culture				
	S_1	73.8	26.1	15.4	58.8	40.2	13.1	50.2
	S_2	65.8	34.2	25.6	75.0	25.0	17.1	51.4
	S_3	65.3	34.7	23.9	67.4	32.6	17.7	51.0
	S_4	50.5	49.4	31.6	68.4	31.6	25.1	50.7

contd...

Table 32 contd..

1	2	3	4	5
L-550	S_1	76.8	23.2	12.6
	S_2	65.5	34.2	27.2
	S_3	70.3	29.6	21.2
	S_4	68.9	31.1	23.3
	S_1	84.9	15.0	8.3
	S_2	76.0	24.0	12.6
	S_3	69.1	31.0	23.6
	S_4	68.9	31.1	17.7
BG-209				
	S_1	57.8	42.1	27.4
	S_2	51.0	49.0	34.2
	S_3	50.0	50.0	41.0
	S_4	50.0	50.0	43.7
	S_1	64.1	35.7	22.8
	S_2	52.4	47.6	33.3
	S_3	50.0	50.0	42.6
	S_4	50.0	50.0	25.0

6	7	8	9
Field			
54.3	45.7	13.7	51.2
79.0	21.0	20.3	59.1
71.4	28.6	17.7	59.8
75.0	25.0	18.1	58.3
Pot Culture			
55.1	44.9	9.0	59.9
52.4	47.6	14.3	59.7
76.4	23.6	18.0	58.2
51.1	48.9	18.1	58.5
Field			
64.9	35.1	25.3	60.0
70.0	30.0	29.0	59.1
82.1	17.9	29.2	58.4
87.5	12.5	24.3	58.7
Pot culture			
64.0	36.0	21.1	59.1
70.0	30.0	27.0	58.2
85.2	14.8	28.6	57.2
50.0	50.0	28.8	57.6

was narrowed down to 7 % and 15 % under field and pot culture conditions respectively. In L-550, the variation in shedding percentage between the sowing dates was about 11 % in field and 16 % under pot culture. It is interesting to note that the percentage shedding for S_3 and S_4 remained unchanged both under field and pot culture conditions, but that of S_1 and S_2 increased about 10 % under pot culture. BG-209 registered the least loss of reproductive efficiency by shedding among the cultivars. The shedding behaviour remained more or less the same both under field and pot culture conditions. In case of S_2, S_3 and S_4 the shedding percentage recorded was 50-52 % both under field and pot culture. In case of S_1, it was 51.8 % and 64.2 % in field and pot culture respectively.

Pod set (%)

Since shedding loss is the negative expression of pod set, therefore percentage pod set showed an opposite and positive expression. Highest pod set was observed in BG-209 in all the sowings, followed by JG-62 and L-550. Within the sowing also a similar trend was observed. In all sowings S_1 gave the least values, followed by S_2, S_3 and S_4 which gave, more or less, similar values.

Effective pod set (%)

Effective pod set or fruiting efficiency is the ratio of fully developed pods at final harvest to the total number of flowers expressed as percentage. This varied greatly within the cultivars and between the sowing

dates. The effective pod set was seen considerably reduced for first sowing in comparison to the rest of the sowings both under field and pot culture conditions. Highest was generally recorded by the S_4 for all the cultivars under field condition with the exception of L-550 at S_2. Under pot culture condition it was generally S_3 which showed the highest effective pod set with the exception of JG-62 where S_4 showed the maximum effective pod set.

For JG-62 the effective pod set both under field and pot culture conditions was least for S_1 and maximum for S_4. However, it decreased by a narrow percentage (5-8 %) under the pot culture condition at respective sowing dates. In general the order was $S_4 > S_2 > S_3 > S_1$.

Effective pod set was of very lower order in L-550 in comparison to JG-62 for field, the value for S_1, S_2, S_3 and S_4 were 12.6, 27.2, 21.1 and 23.3 respectively and that for pot culture was 8.3, 12.6, 23.6 and 17.7 respectively. The variation under field and pot culture between the sowing dates was 2 to 8 %.

BG-209 had the highest effective pod set amongst the cultivars, within the cultivars and between the sowings in field and pot culture conditions. The effective pod set percentage was seen as 27.4, 34.2, 41.0 and 43.7 in field and 22.8, 33.3, 42.6 and 25.0 in pot culture in S_1, S_2, S_3 and S_4 respectively.

By and large, it could be inferred that there is a gradation in effective pod set, which is low in early sowing, medium in normal sowing and higher in late sowing.

Effective fruiting efficiency :

Effective fruiting efficiency is the ratio of fully developed pod to the final pod number (Number of normal pods/total number of pods).

It will be seen that this parameter increased with increase in sowing dates in JG-62 and BG-209 under field condition. In L-550, it increased considerably at S_2, S_3 and S_4 in comparison to S_1, however, between S_2 and S_4 there was no marked difference.

Under pot culture condition, by and large, higher increases were observed in this parameter at S_2 and S_3 as compared to S_1 with the exception of S_4, in case of L-550 and BG-209, where they showed a comparative decrease.

Underdeveloped pods to total pods ratio :

Since the above is the ratio of underdeveloped pods to total pods the results were negative or opposite in nature to those obtained for the effective fruiting efficiency.

Seed efficiency

It is the ratio of the number of ovules ~~number~~ realised as seed over the total number of ovules found in the total number of flowers formed. The percentage of ovules developed into seeds was highest in BG-209 followed by JG-62 and then L-550 and the same increased considerably with delayed sowing. However, it varied very little between S_2, S_3 and S_4 except in case of S_4 in L-550.

Effective seed efficiency

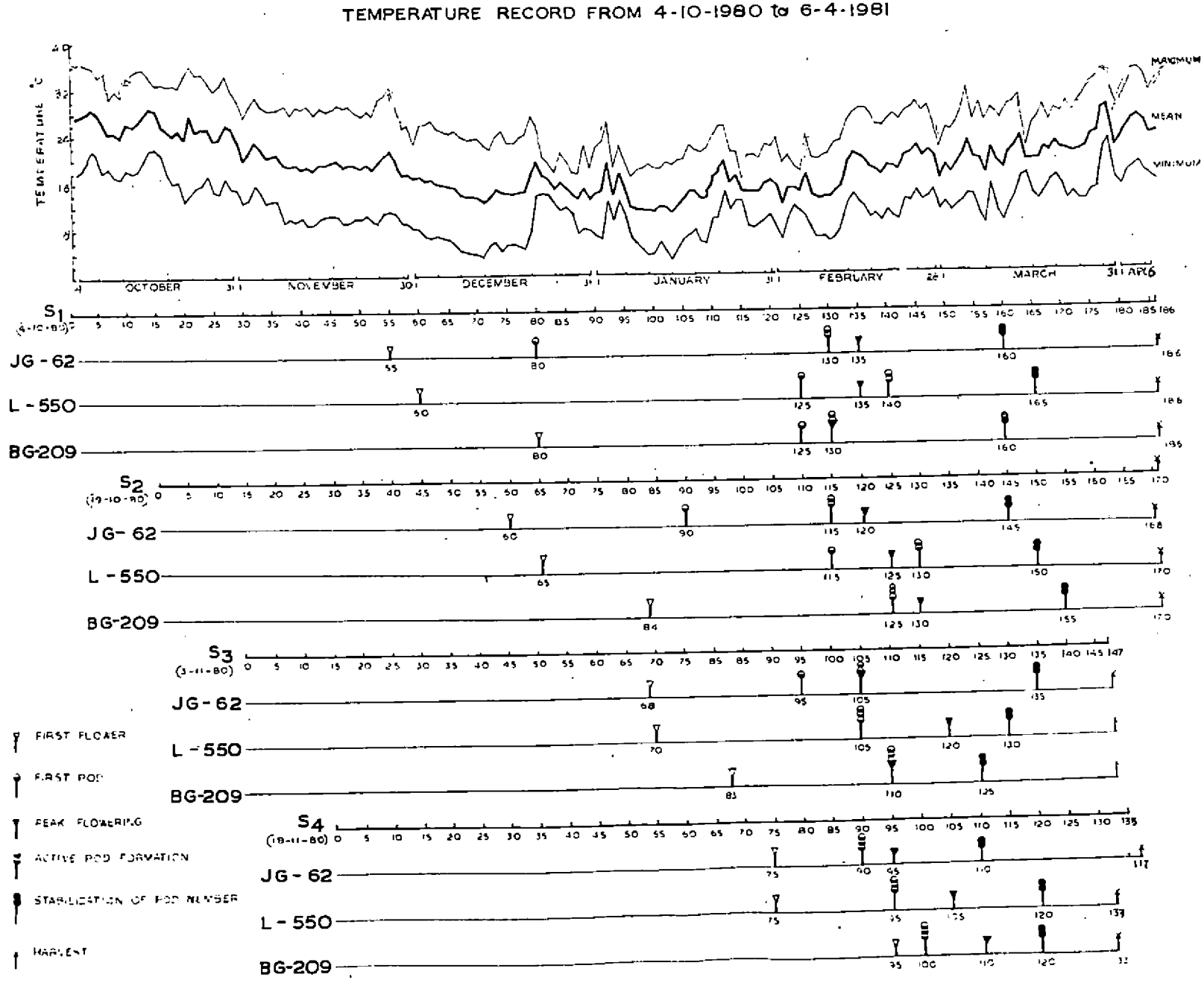
This is the ratio of the number of ovules developed into seed to the number of ovules found per carpel per pod set.

The percentage of ovules which developed into seed from total number of ovules present in final pods was highest in case of BG-209, where it was of the order of 60 % followed by JG-62 and L-550 (51 %). Between the sowing dates no significant change was observed with respect to JG-62 and BG-209 either in field or pot culture. However, in case of L-550 a considerable increase was noticed under pot culture condition at S_1. Between rest of the sowings no difference was seen either in pot or in field.

4.2.9 Temperature regimes during the different dates of sowing of chickpea cultivars during 1980-81.

Temperature record from 4th October, 1980 to 6th April, 1981 are graphically presented in fig. 8 and the same is given at 5 day interval in the temperature chart. It will be evident that maximum temperature was high from first week of October to first week of November. Thereafter, it declined by about 2-3°C until middle of December. By 3rd week of December the temperature remained more or less constant between 18-19°C with a sporadic increase between 2nd to 6th January. From middle of January to approximately middle of February the temperature remained, by and large, constant between 20-21°C with only one sporadic decrease and rise during February. The temperature rose sharply thereafter and remained more or less constant throughout March. The maximum temperature rose to 31-32°C in April.

FIG. 8


TEMPERATURE RECORD FROM 4-10-1980 to 6-4-1981
TEMPERATURE °C
MAXIMUM
MEAN
MINIMUM
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
S1
(4-10-80)
JG - 62
L - 550
BG-209
S2
(19-10-80)
JG - 62
L - 550
BG-209
S3
(3-11-80)
JG - 62
L - 550
BG-209
S4
(18-11-80)
JG - 62
L - 550
BG-209
FIRST FLOWER
FIRST POD
PEAK FLOWERING
ACTIVE POD FORMATION
STABILISATION OF POD NUMBER
HARVEST

Minimum temperature was high during October, but it decreased as the days progressed until middle of January, thereon fluctuated, however, by and large, the temperature remained between 7-8°C from 17th January to 10th February. Temperature was on constant increase from middle of March to April During the middle of March the minimum temperature was between 11-12°C.

The mean temperature remained more or less constant upto the end of October and thereafter it declined and remained more or less constant until the end of November. During December to middle of January the mean temperature remained between 13-15°C. A lower temperature was noticed between 7th January and 16th January (11-12°C). From the middle of January the mean temperature increased to around 14-15°C until 10th February. From 11th February onwards the mean temperature increased gradually until April.

Heat units :

The heat unit declined steadily until middle of November, from thereon remained constant until the end of November. There is sharp decline in heat unit from December to middle of January with occasional drop or increase, between 2nd and 3rd week of January the heat units increased appreciably and again decreased upto first week of February, thereafter increased greatly. but, by and large, it remained constant until middle of March. From middle of March to April there was appreciable increase in heat units.

Growing Degree Days (GDD)

From the chart it will be seen that growing degree days remaind more

or less constant till the end of October, then declined steeply till middle of December. GDD increased appreciably from Ist December to the end of December and thereafter declined sharply, until middle of January. GDD rose sharply from 9.4 to 24.0 and then 33.2, then declined to 18.5 by 10th February. From there upon marked increase was noted between 11-15th February, then there was gradual increase in GDD until 6th April. Sporadic decrease was noticed between 26th January and 2nd March.

II IMPROVEMENT OF REPRODUCTIVE EFFICIENCY BY CHEMICAL MANIPULATIONS

4.3 Response of chickpea cv. L-550 to different concentrations of growth regulators at preflowering, mid-flowering and post-flowering stages (1979-80) (Experiment No.3)

Data regarding the response of chickpea cv. L-550 to different concentrations of growth regulators at pre-flowering, mid-flowering and post flowering stages are presented in table 33.

Indole 3 active Acid (IAA)

It will be seen from the data that IAA had beneficial effects at all stages and increased the pod number and seed yield significantly over control. However, the flower number was decreased considerably. Lower concentrations (1-2 ppm) were more effective in comparison to higher concentrations.

Benzyl aminopurine (BA)

BA was found to be most effective at post flowering stage with 5-10 ppm

with respective to the effective pod number and seed yield.

Cycocel (CCC)

Cycocel had the most beneficial effect during the mid-flowering phase with respect to seed yield. Only lower concentrations of 2000-3000 ppm were found to have beneficial effect at mid-flowering stage.

Ethrel

All concentration of Ethrel reduced the seed yield considerably, although it did not appreciably decrease the effective pod number from those of the control. It was detrimental for yield.

4.4 Effects of stage vs growth regulators interaction on yield attributes in chickpea cultivar L-550 in pot culture and field (Expt. No.4)

The data on the effects on the application of 3 growth regulators on the interaction on yield attributes in chickpea cultivar L-550 under pot culture condition are presented in table 34.

All the parameters increased under the influence of respective treatments in comparison to untreated control plants. However, the maximum increase was noticed with reference to seed yield in case of treatment No.4 (6.043 g/plant). The order is 4 > 9 >10 > 3 >6 > 8 > 7 > 2 > 5 > 1. The percentage difference from control varied from 51 to 137. Maximum yield was found to be associated with maximum pod number, however, in case of Tr.9 and 10, which followed Tr. 4, the higher yield was not due to the

increase in total number of pods but due to an increase in total number of developed pods and lower number of underdeveloped pods.

The harvest index (H.I) was found to be maximum for Tr 4 (35.8) followed by treatment 9 >10>3 >6 >7 >8 >2 >1 >5. One interesting observation was, whenever the seed yield had increased considerably, the stem weight also showed a parallel increase.

Under field condition the seed yield was found to be comparable as to pot culture (Table 34). In field also Tr. 4 recorded the maximum grain yield, but the percentage increase over control was found to be much below (55.5 %) than that obtained for pot culture. The order of increase of seed yield was 4 > 9 >10 >3 >6 >2 >8 >7 >1 > 5. Although, the changes in harvest index were of comparable order, yet, the percentage was much higher in field than pot. The total dry matter also closely paralleled the seed yield.

III. BIOCHEMICAL STUDIES IN RELATION TO REPRODUCTIVE EFFICIENCY OF CHICKPEA

4.5 A comparative study of the biochemical change in fresh and abscised plant parts (Expt. No.5)

Results of the comparative study of the biochemical changes in fresh and abscised plant parts are described under the respective biochemical parameters.

4.5.1 Amount of total nitrogen, total proteins, soluble proteins and soluble sugars in normal and abscised flowers and pods of chickpea

Table No.35 presents the amount of differences in total nitrogen, total protein, soluble proteins and soluble sugars expressed as percent dry weight in normal and abscised flowers and pods in chickpea cultivars viz., JG-62, L-550 and BG-209 grown under field condition.

Table 35. Change in total nitrogen, total proteins, soluble proteins and soluble sugars in normal and abscised flowers and pods of chickpea.

Cultivar	Reproductive organ	Percent dry weight			
		Total nitrogen	Total protein	Soluble proteins	Soluble sugars
JG-62	Normal flower	2.9	18.5	1.8	5.2
	Abscised flower	2.7	17.3	1.6	2.8
	Normal pod (0.4 x 0.9 mm)	3.0	19.0	1.1	5.4
	Abscised pod (0.4 x 0.9 mm)	3.3	20.7	1.4	7.9
L-550	Normal flower	3.3	20.7	1.6	7.3
	Abscised flower	2.1	13.3	1.4	5.7
	Normal pod(0.4 x 0.9 mm)	2.8	17.9	2.9	8.7
	Abscised pod(0.4 x 0.9 mm)	3.5	21.9	3.2	9.8
BG-209	Normal flower	3.3	21.0	1.1	10.3
	Abscised flower	2.9	18.1	1.0	7.1
	Normal pod (0.4 x 0.9 mm)	2.7	17.1	2.2	3.6
	Abscised pod (0.4 x 0.9 mm)	3.0	18.8	1.1	5.0

It will be noticed that irrespective of the cultivar, the abscised flowers and pods always had a lesser and higher contents of above mentioned parameters, as compared to normal flowers and pods respectively.

There was not much difference in the various parameters within the cultivars, however, the percentage of nitrogen was highest in case of BG-209 and hence protein content was also highest amongst the cultivars. The soluble protein content was higher for flowers in JG-62 but for pods it was higher in case of L-550. The soluble sugars was found to be highest in case of L-550.

4.5.2 Changes in nucleic acid content in normal and abscised flowers and floral parts in chickpea cultivars

Table 36 presents the changes in nucleic acid content in normal and abscised flowers and floral parts in chickpea cultivars viz., JG-62, L-550 and BG-209 grown under field condition.

It will be seen from the table 36 that as compared to normal flowers the RNA content as μ g/g fresh weight decreased significantly. The DNA content as μ g/g remained unchanged in the normal and abscised flowers of all the cultivars. The nucleic acid contents among the cultivars showed the following order

L-550 > BG-209 > JG-62

The site of the decreased amount of RNA content could be traced to

Table 36. Nucleic acid content in normal and abscised flowers and floral parts of chickpea

(µg/g fresh weight)

Cultivar	JG-62				L-550				BG-209			
Floral part	Normal		Abscised		Normal		Abscised		Normal		Abscised	
	RNA	DNA	RNA	DNA	RNA	DNA	RNA	DNA	RNA	DNA	RNA	DNA
Peduncle	188	3	186	5	64	16	54	15	50	11	36	13
Pedicel	148	12	87	10	26	18	44	10	43	17	54	10
Calyx	84	4	146	4	21	5	69	14	48	12	73	16
Corolla	156	17	222	13	62	12	69	12	66	18	70	20
Androecium and Gynoecium	1594	239	1259	243	2675	590	2087	591	2193	204	1752	203
Whole flower	2150	275	1900	275	2848	641	2323	642	2400	262	1985	262

marked reduction in the reproductive structures viz., androecium and gynoecium. It is interesting to note the degree of reduction in RNA content in reproductive structures is almost of same order in all the cultivars.

Among the floral parts calyx recorded appreciable increase in RNA content in abscised flowers.

4.5.3 Pigment content in normal and abscised flowers and floral parts of chickpea

The data on variation in pigment content in normal and abscising flowers and flower parts in chickpea cultivars, JG-62, L-550 and BG-209 grown under field condition are given in Table 37.

Chlorophyll

The total chlorophyll content was reduced markedly in abscised flowers in all the cultivars. The reduction was 24 %, 38 % and 31 % in JG-62, L-550 and BG-209 respectively. Reduction was observed both in chlorophyll a and b, however, the reduction was marked in chl. b as compared to chl. a.

The changes in different flower parts showed the pigment content was markedly reduced in case of calyx and reproductive parts.

It was noted that L-550 had a higher chl. b content as compared to chl. a. The ratio of chl. a/b was found to be same in case of normal and abscised flowers, except for JG-62 where this was higher for abscised flowers.

Carotenoid

The carotenoid content increased in the abscised flowers of the cultivars, but did so more in cv. L-550 and in floral parts it fluctuated considerably.

Anthocyanin

The data on changes in the anthocyanin contents in normal and abscised flowers of chickpea cultivars viz., JG 62, L-550 and BG-209 grown under field condition are given in Table 38.

Table 38. Anthocyanin content in normal/abscised flowers and floral parts of chickpea

Cultivar	JG-62		L-550		BG-209	
	Normal	Abscised	Normal	Abscised	Normal	Abscised
	← OPTICAL DENSITY →					
Peduncle	0.35	0.22	0.02	0.02	0.14	0.12
Pedicel	0.61	0.45	0.11	0.09	0.29	0.16
Calyx	0.08	0.09	0.03	0.02	0.17	0.17
Corolla	0.34	0.25	0.02	0.02	0.27	0.16
Andrœcium and gynoeceium	0.08	0.08	0.03	0.03	0.25	0.20

From the observed optical density values in L-550, it can be seen that it had low anthocyanin content, which did not alter much during abscission, however, in JG-62 and BG-209 anthocyanin content decreased significantly

in the abscised flowers. The decrease was more marked in pedicel, corolla and peduncle of JG-62 and only in pedicel and corolla of BG-209.

4.6 Changes in organic contents of leaves under the influence of temperature (different dates of sowing) in chickpea (Expt. No.6)

Changes in organic acid contents of leaves under the influence of temperature (different dates of sowing) in chickpea cultivars JG-62, L-550 and BG-209, grown under field condition are given in Table 39.

Table 39. Changes in organic acid content in leaves of chickpea as influenced by temperature (different dates of sowing)

Cultivar	Time of sowing	Time in hours			
		08.00 (Fore-noon)	12.00 (Noon)	16.00 (After-noon)	20.00 (Night)
		mg. eqv. maleic acid/g dry weight			
JG-62	S_1	0.63	3.07	6.62	1.84
	S_2	2.01	2.65	4.89	3.20
L-550	S_1	1.21	3.38	4.40	2.42
	S_2	1.90	3.43	4.54	3.30
BG-209	S_1	0.62	2.26	3.69	2.63
	S_2	3.51	3.94	5.48	4.06

The most striking feature was that in all the cultivars the acid content in leaves increased during the night during 20.00 hours and declined

during the day time, thus showing a rhythemic changes in organic acid with time of the day and night. Temperature altered this rhythemic pattern considerably by narrowing down the differences in level of organic acids at the time of peak accumulation during night and disappearance during day times, in all the cultivars.

5. DISCUSSION

Information on the major limitation to the reproductive efficiency in chickpea is meagre. An integrated approach regarding the influence of temperature (based on different date of sowing) on time, intensity and duration of flowering and reproductive efficiency in relation to growth and development of chickpea is completely lacking. In the present investigation, efforts were, therefore, made to investigate and understand the same. In addition to the above, biochemical studies in relation to reproductive efficiency were also carried out mainly to understand the biochemical basis of flower shedding. Experiments were designed to meet the above objectives and discussion below will be an effort to project the various points emerging out from the results obtained. Experiments were conducted both in field and pot culture and it was noticed that although quantitative values under pot culture conditions differed considerably from field conditions, yet qualitative pattern remained essentially the same. The quantitative difference in pot culture may be largely due to variation in soil moisture. Since the qualitative pattern obtained under field condition remained by and large similar under pot culture condition, hence no effort is made to discuss the results of pot culture experiments separately and the results obtained are discussed collectively.

5.1 Evaluation of reproductive efficiency

Two experiments were conducted in order to evaluate the reproductive efficiency and the results of the respective experiment will be discussed individually.

5.1.1 Evaluation of the reproductive efficiency in different genotypes of chickpea

The study to the genetic variability and diversity with reference to flowering behaviour and shedding of flowers during reproductive stage was carried out in order to evaluate peak period of flowering, shedding percentage and reproductive behaviour. In field the peak flowering in most of the genotypes was noted between 120 and 125 days, however, for BG-209 it was at 130 days after sowing (DAS). Under pot culture, the peak flowering ranged between 118-120 days amongst majority of the cultivars. It was evident that the peak flowering period did not alter within the cultivars. The shedding percentage was found to be very high and it ranged from 67-90 %. The least was found in BG-209 and highest in L-550. From the result obtained in this experiment, amongst the 12 genotypes examined it was found that BG-209 had the highest reproductive efficiency in terms of number of pods, filled pods, total seed number, pod weight and seed yield. This was closely followed by BG-226. The lowest reproductive efficiency was observed in case of L-550, in terms of lower number of pod set, normal filled pods and total seed number however, the 100 seed weight was found to be highest for the cultivar. By and large, the BG lines had better number of total pod set, as well as normal filled pods and seed number, but there was considerable variation between genotypes with respect to pod weights and seed yields, as compared to their number. If we examine closely the characteristics which affects the reproductive efficiency e.g, shedding percentage, it will be noted that the genotypes having the highest reproductive efficiency has the least shedding

percentage and vice-versa. The cause of low reproductive efficiency of L-550 can be largely attributed to high percentage of shedding. It would be noted that although seed number was comparatively higher than JG-62, L-550 and C-235, yet, some of the BG-lines (BG-203, BG-212 and BG-216) recorded lower weights in pod and seed, so that final reproductive efficiency in terms of yield was lower for these in comparison to JG-62 or L-550. Since the seed number per pod, by and large, did not vary much between different genotypes, it could be visualised that the seed abortion might be the major cause of low reproductive efficiency in those BG-lines which recorded higher number of pods than JG-62, but had lower seed yields. However, by and large, it can be concluded that higher reproductive efficiency can be attributed to low shedding percentage, higher seed yield and higher effective pod set.

5.1.2 The influence of temperature (based on different dates of sowing) on time, intensity, duration of flowering and reproductive efficiency in relation to growth and development of chickpea.

In order to understand the influence of temperature on flowering, reproductive efficiency, growth and development, important reproductive stages in addition to pre-flowering vegetative phase have been identified and these are examined. These are summarised below :

Time, intensity and duration of flowering

Time, intensity and duration of flowering is greatly altered under

Table Important events and stages identified during the crop duration.

Cultivars		JG-62				L-550				BG-209			
Stage	Time of sowing	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Days to first flower		55	60	68	75	60	65	70	75	80	84	83	95
2. Days to first pod		80	90	95	90	125	115	105	95	125	125	110	100
3. Initiation of active pod		130	115	105	90	140	130	105	95	130	125	110	100
4. Stabilization of pod number		160	145	135	110	165	150	130	120	160	155	125	120
5. Harvest		186	168	147	137	186	170	147	133	186	170	147	133
1. Vegetative (preflowering)		55	60	68	75	60	65	70	75	80	84	83	95
2. Pod initiation (First flower to first pod 2-1)		25	30	37	15	65	50	35	20	45	41	27	5
3. Lag phase of pod formation (First pod to active pod formation 3-2)		50	25	10	0	15	15	0	0	5	0	0	0

contd....

Table contd....

1	2	3	4	5	6	7	8	9	10	11	12	13	14
4.	Active pod formation (4-3)	30	30	30	20	25	20	25	25	30	30	15	15
5.	Stabilization of final pod number (5-4)	26	23	12	27	21	20	17	13	26	15	22	13
Other Important stages and their duration.													
Peak flowering		135	120	105	95	135	125	120	105	130	130	110	110
Pod duration		80	55	40	20	40	35	25	25	35	30	15	20
Total reproductive duration		131	108	79	62	126	105	77	58	106	86	64	38

the influence of different dates of sowing, while the days to first flower increased; the intensity and duration of flowering was markedly reduced with an increase in sowing date from S_1 to S_4. The final crop duration was also markedly reduced with the consequence that the pre-flowering or vegetative period was longest in late sowing. These findings are in agreement with the earlier results of Eshel (1967), who also observed a reduction in growing period, flower production and reproductive activity by delayed sowings. In the present study the order of formation of flowers was $S_1 > S_2 > S_3 > S_4$, irrespective of the cultivar, however, the reduction in the number of flowers formed during S_2 as compared to S_1 to be very little in case of BG-209 (11 %) as compared to 49-69 % in JG-62 and L-550. Highest number of flowers (except in S_2 and S_4) were found in L-550, followed by JG-62 and least in BG-209. It will be evident from the temperature chart that no relation with temperature could be found either for appearance for first flower or first pod. However, it can be noticed from the temperature indices summarised in table presented, at peak flowering the mean temperature was within the range same for JG-62 and L-550 for all the sowings (Mean temperature 18-20°C), but for BG-209, it was comparatively lower and also fluctuated considerably. The maximum temperature did not vary for JG-62 or L-550 at this stage and it was identical for both. Between the sowings, the temperature varied slightly in case of JG-62, but it remained constant for L-550. The minimum temperature were also identical or similar for JG-62 and L-550 in all the sowings (10.5 - 12.2°C). However, the same varied considerably for BG-209. It can be concluded that the mean temperature of 20°C and a minimum temperature of 10-12°C

seems to favour flower initiation. Since in the case of BG-209, the minimum temperature was considerably low and fluctuated, it could be the possible cause for lower flower number. Such a relation was also noticed by van der Maesen (1972) and this also support the contention of Summerfield et al. (1981) that warmer night temperature favour flowering in chickpea.

The temperature, at first pod formation, was not indicative of any pattern. The maximum temperature declined with sowing dates upto S_3 in case of JG-62 and rose at S_4. For L-550 and BG-209, between the sowing, rise in temperature was found to be associated with the appearance of first pod. The minimum temperature fluctuated considerably between the sowings at S_1 and S_2 in case of JG-62 and L-550, otherwise, the minimum temperature remained almost stable between 10.4 - 12.2°C. At the time of active pod formation, mean temperature remained 18.3 - 21.6°C except for S_1 and S_2 of JG-62 and S_1 of BG-209. The minimum temperature also remained around 12.2 - 14°C, but for the above mentioned exceptions. We can conclude that a mean temperature of 18 - 21°C and a minimum of 12 - 14°C are conducive for active pod formation. Although optimal temperature for flower formation and dry matter production has been reported by van der Maesen (1972) and confirmed by Summerfield et al. (1980), yet no such information is available with respect to pod formation.

At the time of stabilization of the final pod number, the mean temperature remained unchanged between 18.3 - 19.4°C for all the sowings, however, both the maximum (25-28°C) and minimum (12-13°C) did not vary much

with the exceptions already mentioned above for active pod formation.

In the end, we can conclude that the mean optimal temperature for flower formation is about 20°C and minimum about 12°C, however, a higher maximum temperature of about 22°C is more conducive for flower formation. Irrespective of cultivar or date of sowing a mean, maximum and minimum temperature of 19°C, 25.5°C and 12.5°C respectively, may be optimal temperature for active pod formation. From stabilization to harvest the mean temperature remained, by and large, same around 22-24°C, the maximum temperature around 30-32°C and the minimum temperature remained between 14-15°C for JG-62 and L-550 but were considerably higher for BG-209. The respective duration of important stage indicated that in JG-62 the days from first flower to first pod (stage 2 - pod initiation) increased upto S_3 in case of JG-62 only, but the same decreased in L-550 and BG-209, with an increase in sowing date. The increase in JG-62 was by 5-7 days and the decrease in L-550 was by 15 days at each consecutive sowing date. However, in BG-209, the decrease was only 5 days between S_1 and S_2, 14 days between S_2 and S_3 and 23 days between S_3 and S_4. It will be observed that in JG-62 the active pod formation commenced very late than other cultivars and there was a lag (stage 3 : lag phase of pod formation) of 50 and 25 days at S_1 and S_2 respectively, but the same commenced early at S_3 and at S_4, when the active pod formation started with the formation of first pod itself. In L-550 both S1 and S_2 took 15 days for commencement of active pod formation and in BG-209, this period was further reduced to five days. Thus, the lag to active pod formation at S_1 and S_2 was greatest in case of JG-62 and least on absent in case of BG-209. At S_3

and S_4 (except S_3 of JG-62), there was no time gap between pod initiation and active pod formation and the active pod formation commenced with the initiation of first pod itself. It is worthwhile to note that irrespective of the date of sowing or cultivar, the duration of active pod formation (stage 4) remains largely constant (20-30 days) with the exception of S_3 of BG-209.

Duration between stablisation of final pod number to harvest (Stage 5: stablization), by and large, remained same for different dates of sowing, but varied within cultivars. For JG-62, it was longest between 23-27 days (exception S_3 = 12 days), between 13-21 days in L-550 and between 13-26 in BG-209. The duration between respective stages has been worked out as percentage of either total crop duration or the 'reproductive duration'. Although during post flowering period both vegetative and reproductive phases overlap, yet predominantly most of the reproductive activities takes place during the period. Hence the reproductive duration will be referred to the duration between first flower and stabilization of final pod number. Reproductive duration is used for convenience only in order to demarkate it from pre-flowering vegetative period. From now on these phases will be referred in the text as vegetative and reproductive, however, the former is the pre-flowering vegetative phase.

It was observed that the duration of following stages increased with an increase in sowing dates.

1. Pre-flowering duration in relation to post-flowering duration.

2. Vegetative duration in relation to total crop duration.
3. Days to peak flowering in relation to reproductive duration.
4. Days to first pod in relation to reproductive duration (except S_4 of L-550).
5. Pod duration in relation to reproductive duration.

It was also noticed that the following remains almost unchaged with the increase in sowing dates.

1. peak flowering in relation to crop duration
2. pod duration in relation to reproductive duration (by and large)
3. active pod duration in relation to reproductive duration (except L-550)
4. active pod duration in relation to crop duration
5. pod duration in relation to crop duration (except JG-62, which can also be broadly categoried with the exception of S_4)

The active pod duration in relation to total pod duration was also increased in JG-62 with increase in sowing date. In L-550, the active pod duration in relation to total pod duration was shoerter at S_1 and S_2 as compared to S_3 and S_4 where the total pod duration is itself the period of active pod duration. In case of BG-209 the active pod formation was the total pod duration at S_2, S_3 and S_4 and even at S_1 it was comprised of 86 %. It can be concluded that the duration of stage which remains more or less stable with different dates of sowing are those which are least affected by temperature and we can term as temperature insensitive stages.

However, those which are altered greatly under different sowing dates can be termed as temperature sensitive stages. The temperature sensitive stages were found to be the vegetative and the active pod formation stages. In case of latter, it is the percentage of the period counted towards active pod formation in relation to total pod duration which matters. We can further conclude that a cultivar classified as early flowering e.g., JG-62, is not necessarily destined to mature early or to enjoy only a short reproductive period. Conversely, cultivar taking much longer time to come into flower e.g., BG 209 can have shorter reproductive period and so can come to maturity in more or less same time depending upon the environmental conditions. Such a suggestion was made earlier by Summerfield et al.(1980).

The flower formation in JG-62 and L-550 took place at S1 when temperatures were decreasing, however, peak flowering was recorded with an increase in temperature. In contrast, peak flowering only occurred when minimum temperature increased appreciably from 4.8°C to 11.8°C, therefore, higher minimum temperature seem to be more conducive for flower formation.

During active pod formation the temperature remained more or less the same, the mean between 17-19°C, the maximum between 24-27°C and the minimum between 10-12°C in all the cultivars. This might be the possible reason to almost similar duration in all cultivars. During earlier sowings, in JG-62 the active pod formation took place at lower temperatures and it is tempting to suggest this is one of the possible reasons for more number of under-developed pods.

In an effort to compare the temperature indices with the stages, the heat units (HU), growing degree days (GDD) and cumulative minimum temperature (CMT) values have been calculated (Refer Appendix). The results will be discussed in the light of the same.

During vegetative phase :

The HU, GDD and CMT showed similar order as $S_1 > S_2 > S_3 > S_4$ and amongst the cultivars for all the sowings following order BG209>L-550> JG-62.

During reproductive phase :

i) HU values declined with increase in sowing dates. The order was $S_1 > S_2 > S_3 > S_4$, and between cultivar the order was L-550> JG 62 > BG 209. The difference between L-550 and JG-62 were not large, however, in case of BG 209, there was a marked reduction in HU between sowings and the order was $S_1 = S_2 > S_3 > S_4$.

ii) The GDD decreased with increase in sowing dates and however, for each sowing, it varied with the cultivar.

S_1 L-550 > JG-62 > BG 209

S_2 L-550 > BG-209 > JG 62

S_3 JG 62 > L-550 > BG-209

S_4 L-550 > JG 62 > BG-209

Almost similar values of GDD were observed for all the cultivars at S_2.

iii) The CMT had, by and large, the following trend.

$S_1 > S_2 > S_3 = S_4$ and among the cultivar it was BG-209 > L-550 > JG-62 at all the sowing dates.

Relative values in vegetative and reproductive stages between the sowings are given below :

First sowing :

Heat Unit : Vegetative < Reproductive in JG-62 and L-550

Vegetative > Reproductive in BG-209

Growing Degree Days : Vegetative > Reproductive in JG-62, L-550 and BG-209

Cumulative minimum temperatures : Vegetative < reproductive in JG-62 and L-550

Vegetative > reproductive in BG-209

2nd Sowing

Heat Unit : Vegetative = reproductive in JG-62 and L-550

Vegetative > reproductive in BG-209

GDD : Vegetative > reproductive in all the cultivars

CMT : Vegetative < reproductive in JG-62 and L-550

Vegetative > reproductive in BG-209

3rd and 4th sowings :

HU : Vegetative > reproductive in all the cultivars

GDD : Vegetative > reproductive in all the cultivars

CMT : Vegetative < reproductive for L-550 and JG-62

Vegetative > reproductive phase for BG-209

The GDD decreased with the increase in sowing dates in all the cultivars.

The cumulative minimum values were higher during reproductive phase and the values at vegetative and reproductive phase were found to be similar for JG-62 and L-550. On the other hand, BG-209 had comparatively lower values during the reproductive phase as compared to vegetative phase.

At S_4, the reproductive values remained the same for JG-62 and L-550, however, there was a short reduction in reproductive phase in CMT in comparison to S_3. A slight increase in CMT was observed at S_4 and BG-209.

From the above, it can be concluded that BG-209 in comparison to others accumulate more HU, GDD and CMT during vegetative phase. However, during reproductive phase these values are least for this variety. The other conclusion is that JG-62 and L-550 accumulate more heat unit during reproductive phase at S_1 and S_2 but equal or less during S_3 and S_4. The GDD, however, are lower during reproductive phase. The CMT, however, are higher during reproductive phase at S_1 and S_2 in these cultivars and lower at S_3 and S_4.

The proportion percentage in relation to the temperature indices during the total crop duration already indicated that each cultivar had a fixed percentage of total crop duration proportioned at preflowering vegetative stage phase and this remained largely unaffected by temperatures,

however, in case of reproductive phase marginal variations were observed at extremes of temperature (e.g., S_4). Amongst the cultivars, during the vegetative phase the order of proportion percentage is BG-209 > L=550 > JG-62.

It appears that since flower initiation always follow a period of vegetative growth and events may be viewed as a transition of the apical meristems from leaf products to the sequential formation of floral parts. The balance between vegetative and flowering is thus between the factors tending to direct appendicular structures into pathway leading to various parts of flowers. Therefore, transition to flowering is a part of a rather inflexible developmental programme, governed in its essential by attonomous control. What is the nature of the endogenous control of gene expression on development ? Events seem to be directed according to predetermined programme and plants seem to time it in accordance with the changing environments. In other words, whether a plant accumulates more or less of temperature indices the proportion percentage of duration between vegetative and reproductive phase remain the same, however, the degree of accumulation does effect its capacity to produce biomass and its partitioning.

5.1.3 Morphological attributes :

The morphological and growth attributes decreased with an increase in sowing dates, $S_1 > S_2 > S_3 > S_4$. The most striking feature of the effects of different dates of sowing on growth and development of chickpea was the marked reduction observed in S_3 and S_4 as compared to S_1. The average reduction in plant height and number of branches was found to be

45 and 65 per cent respectively. Similar reduction with late sowing were reported by Sen et al. (1964), Eshel (1967) and Sharma et al.(1967). The average reduction in leaf number, leaf area, leaf area duration and leaf weight was 69 %, 80 %, 86 % and 79 % respectively. The average reduction in stem weight showed 81 % and that in total dry matter 75 %.

At S_1, in all the cultivars a major proportion of morphological characters were gained during the vegetative phase and the rest of the growth attributes, by and large, were gained either during pod initiation (L-550 and BG-209) or during the lag phase of pod formation (JG-62).

In JG-62, plant height, branch number and leaf number were gained more during vegetative, pod initiation and lag phase respectively. However, with respect to other attributes, the pattern was similar with that found for S_1. In L-550, both at S_1 and S_2, the leaf area, leaf weight, stem weight and total dry weight were gained more during the pod initiation stage. In BG-209 the pattern was similar to L-550, except that at S_2 93 % of the leaf weight was found during the vegetative phase.

It will be observed that in all the cultivars at S_3 and S_4 the pattern remained same with respect to morphological attributes, leaf area and leaf weight and their major proportion was gained during the vegetative phase, which rarely deviated at S_3, where occasionally the major proportion was realised during the combined vegetative and pod initiation stage. However, larger proportion of stem weight and plant weight were gained very late during the active pod formation with the exception of BG-209 at S_4, where it was during the vegetative phase.

The time of fall in leaf area varied with the cultivars. In JG-62 at S_1, the same was noticed during the lag phase, at S_2 at beginning of active pod formation and in S_3 and S_4 during and after the active pod formation. In L-550, at S_1 and S_3 it was noticed at beginning of active pod formation which in S_3 and S_4 it was almost in the end of active pod formation. The leaf area duration decreased as the dates of sowing increased. The decreases were higher for L-550 and BG-209, about 72 % at S_2 and 86-92 % in S_3 and S_4 as compared to S_1. In case of JG-62, like BG-209 and L-550 the reduction in S_3 and S_4 was greater (82-86 %) but at S_2 25 % reduction was noticed. From the above observation, it can be concluded that the vegetative phase is very important with respect to morphological characters in all the cultivars. Although at S_3 and S_4 for all the cultivars the vegetative phase was found to be most important with respect to the proportion percentage of majority of attributes, yet the fact remains that the biomass production was restricted significantly. The reduction in biomass production in comparison to S1 was found to be 75 - 80 %. The restriction on biomass production itself at later sowing may be due to lower accumulation of heat units and lower values of growing degree days as a result of which the energy transductions are affected and lower energy is available to be converted into biomass that may be the possible reason for higher biomass production at S_1. In addition to this, the morphological attributes were also restricted in number and length significantly because of lower biomass production.

The other important point is that the stem weight was gained during a

later phase as compared to S_1 or S_2. The total dry weight increased at stage 4, were largely due to pod formation. Thus in S_3 and S_4 major growth activities of plant were confined either during vegetative or at active pod formation. This was largely due to the fact that a lag phase was not present at S_3 and S_4 with the exception of JG-62 at S_3. The lag phase was found to be important in case of S_1 and S_2 of JG-62 and L-550, during which period the stem gained major percentage of its weight. However, in BG-209 we find that the lag phase is absent (except S_1 where it is only 5 days) in all the sowings and hence the major gain in leaf or stem weights is either at vegetative or pod initiation. Hence in S_3 and S_4 as well as in S_1 and S_2 of BG-209 the active pod formation or pod initiation are not separable, while JG-62 and L-550 at S_1 and S_2 are separated by a lag phase. Since the number of flowers formed were very high for JG-62 and L-550 at S1 and S_2 as compared to BG-209, it is suggested that increase in stem weight during the flowering period may be an important factor in realisation of more number of flowers and this may be one of the major limitation of reproductive efficiency, because at S_3 and S_4 the limitation to the reproductive efficiency is the flower number itself and not the latter sequence.

The leaf area duration does not seem to be important factor since at S_2 with lower LAD, higher yields are obtained, however, the presence of certain % of leaf area during active pod formation stages seem to be very important. In late sowing although leaf area is lower yet it remains stable for a very long time, this might be important factor for better pod set. RGR and CGR fluactuations are explained in view of the fact that varied

proportion (%) are directed at different stages and differ with both cultivars and between sowings.

5.1.4 Reproductive attributes :

Flower number, in general, decreased with an increase in sowing date in all the cultivars. In other words, the flowering was delayed with late sowings. Similar results were reported by Sen et al. (1964), Eshel (1967) and with those obtained by van der Maesen (1972), under controlled environment where he observed that at low temperature range flowering was delayed by few days, who finally concluded that both flower initiation and development can be influenced by temperature. However, the present findings indicate that the major effect of temperature is on flower formation rather than an initiation of flowering, which seems to be governed largely by internal factors. It will be noticed that the largest number of flowers are formed in S1, while the reduction ranged between 49 and 69 % in JG-62 and L-550 respectively. It was only 11 % in BG-209 under the influence of similar temperature at S_2. Further at S_3 and S_4 the reduction in flower number was to the extent of 80-85 %. Therefore, the limitation in flower number itself is the major cause of low efficiency at late sowings. Eshel (1967) attributed reduction in number of flowers by delayed sowings as a result of shorter flowering period. Similar relationship between temperature and flowering period is also noticed in the present study, however, it is stressed that shorter flowering period may not be the only reason for the reduction in flower number, because the flowering duration of S_4 in BG-209 is only 38 days as compared to 64 days at S_3, yet the flower number is almost similar. The same is true for JG-62 also.

The lowest flower number at S_1 is recorded by BG-209, where the number is approximately reduced to half of JG-62 and more than half of L-550. The restriction in BG-209 could possibly be attributed to the fluctuating temperature during the flower formation as the first flower was initiated in this variety at 80 DAS, as compared to 55 to 60 DAS, in other cultivars.

The major cause of low reproductive efficiency is shedding of flowers and fruits. This was very high in all the cultivars. Greater number of flowers were shed at S_1 and the order of shedding behaviour between sowings, by and large, was $S_1 > S_2 > S_3 > S_4$. Although higher number of flowers were formed at S_1, the same were also shed in greater numbers. The advantage of highest number of flowers at S_1 was therefore, offset to a larger extent by shedding.

The results obtained with respect to abscission rate at any given time interval of 5 days from start of flowering is of following order : $S_1 > S_2 > S_3 > S_4$. The magnitude of abscission within the cultivar was L-550 > JG-62 > BG-209. The number of abscised flower over retained flowers was comparatively very low at S_4 and to a lesser extent at S_3. Although the number of flowers formed were considerably low, yet those retained were comparatively higher. The shedding was found to be higher between 90-125 days, where the temperature fluctuated considerably, however, maximum temperature fluctuated between 17-21°C, mean between 13-16°C and the minimum between 4-11°C. The cause of shedding is generally attributed to high

temperatures and long photoperiods, but in present study during the perid of active shedding of flowers the temperature regimes were found to be lower but the minimum temperature fluctuated considerably. The number of flowers retained during a specific period as percentage of total flowers also supports that the shedding is greater at S_1 because, retention is lowest at S_1 and highest at S_4 or S_3, and for S_2 it is usually greater than S_1.

Since the duration of flowering is long at S_1 and shortest at S_4 plant might be having its own mechanism to retain more flowers in shorter duration or else shedding might be a necessity during longer reproductive duration because if all the ovules formed are developed into seeds, the plant cannot afford to support them, hence it might be allowing shedding till favourable temperature for pod formation prevail. The maximum retention in JG-62 is 31 % at S_1 and 50-63 % in rest of the sowings. Similarly, in L-550 at S_1 maximum retention was 31 % at S_1 and 60 % at S_4. In case of BG-209 about 50 % was retained at S_1, S_2 and S_4 and 67 % at S_3. It is evident that in BG-209 the percentage of retention of flower was greater and less variable between the stages. Hence, the total number of flowers formed was comparatively low. In all the cultivars the decline in percentage of flower retention was noticed after peak flowering from where active pod formation commenced. Although, very high percentage of flowers were retained in late sowings, the duration of such retention was comparatively very short in contrast to S_1 and S_2.

The number of pods retained during a specific period as percentage of total pods indicated that, although, the duration of retention was decreased with an increase in sowing date, yet the larger percentage of pods were retained at S_3 and S_4. It can be concluded from the above that the abscission is lowest at late sowings because larger number of flowers are actively turned into pods during shorter duration. The duration of retention is longest in JG-62, because the first pod appeared early at 80 days. Yet the pods are not retained actively and there is a lag phase before active pod formation.

The present study gives the first information regarding retention of flowers and pods, which was not so far available for chickpea. A similar study, however, has been made in soybean (Thomas and Rafer, 1976). In chickpea, the pod wall grows to a larger extent before seed development proceeds. Lag period lasts about 15 days after the anthesis and thereafter it is followed by a linear period of increase in growth, during which seed accumulates a vast proportion of dry matter (Saxena and Shaldrake, 1980). In the present study regarding pod retention, no distinction was made between filled and unfilled pods, however, since the percentage of unfilled pods was found highest at S_1 and lowest at S_4 in all the cultivars under field condition, it can be concluded that seed development was hampered more at S_1 in comparison to S_4. Future studies should be carried out in order to find out the stage at which those pods fail to fill and also the cause of the failure should also be identified.

Seed number/pod remained largely unaltered by different dates of sowing and was comparatively higher for BG-209. The total seed number was highest for S1 and S2 and lowest at S_3 and S_4. The values are largely the reflections of total pod number, however, if due discount is given for unfilled pods, the seed number per pod is high. In JG-62 at S_1, it is 2.0 and at S_2 and S_3 it is 1.6, while S_4 gives the least i.e., 1.6 seeds/pod. In L-550, it is 2.2 at S_1, 1.3 at S_2 and 1.6 to 1.7 in S_3 and S_4. In case of BG-209, it is 1.9 to 2 for S_1 and S_2, 1.6 for S_3 and 1.3 for S_4. We can conclude indirectly that higher seed number is realised comparatively at S_1 in the filled pods of the cultivars, which generally decreases with increase in sowing dates. In other words seed setting is higher at S_1 and the pods which remained unfilled before or later to seed setting, perhaps, may be due to abortion of ovules. So far the seed number/pod has been indirectly taken as number of total seeds formed with respect to total number of pods, however, no consideration of unfilled pods have been taken into account, which is essential in order to know the extent of seed setting.

Azeez et al. (1960) concluded that high air humidity and low temperature adversely affected seed setting. The causes of low seed setting listed by van der Maesen (1972) were self incompatability, failure of ovule to develop and cleistogamy.

In the present study, pollen viability was not the cause of low seed setting, as artificial pollination resulted in normal filled pods. Since, there is a lag phase of 15 days before the seed development, it can be

inferred that the seed development had taken place during active pod formation stage and one of the possible reasons of better seed number/pod after due discount of unfilled pod at S_1, may be due to a stable temperature, with a mean about 18-19°C.

Increase in pod or seed weight was highest in S_2 followed by S_1, S_3 and S_4. There was a significant reduction to the extent of 80 % at S_3 and S_4, Sheldrake and Saxena (1979) noted that pod filling was limited by supply of assimilate or nutrients in case of late formed pods. They observed that 25-30 days was the time to reach physiological maturity by individual pods.

According to Summerfield and Wein (1979), chickpea is unique among legumes as it can sequester assimilates effectively from a branch (whether reproductive or vegetative mode) and pods at nodes with leaves, no preferential advantages to those at nodes without leaves. Whether the increase in stem dry weight is closely associates with this phenomenon needs further investigation.

5.3.5 Various parameters determining reproductive efficiency

The reproductive efficiency in pulses is determined sequentially from number of flowers formed to number of pods set, the number of effective pods or completely filled pods realised, and the seed number therein and finally the seed weight. The various components have been studied sequentially in few crop plants like soybean and cotton (van Schaik and Probst, 1958; Thomas and Rafer, 1976). No such study has been reported for chickpea, however, pod set/shedding have been reported as percentages, although can

can be taken as an index of reproductive efficiency, yet, neither they project sequential determination, nor the limitations to reproductive efficiency. There is no report except that of Eshel (1967), where the effect of environmental factor on reproductive efficiency in relation to growth and development has been determined sequentially. Other sporadic attempts are first reports of pod set on shedding. The work of Eshel (1967) is the only detailed study carried out under field condition, where the effect of temperature based on different sowing dates has been seen with respect to flower number, pod number, seed number and seed weight. However, he has not tried to explain the effects in relation to temperature indices and has taken no account of the ovule number. Neither he has made an integrated approach with respect to flowering behaviour, growth and development at specific shorter intervals in relation to temperature.

The present study is the first with respect to following :

1. The flowering behaviour has been traced from the very first flower to the last flower periodically at a shorter interval of 5 days and simultaneously correlated with concurrent growth and development changes occurring at specific time intervals in a sequential and integrated manner.
2. The temperature indices have been calculated for chickpea in order to have a better understanding of the influence of temperature on growth and development in relation to reproductive efficiency.
3. The number of ovules (theoritically) have been incorporated for the sequential determination of reproductive efficiency in chickpea.

Although the number of flowers formed were highest at S_1 but the shedding was also greatest at S_1. Therefore the percentage of the pod set was lowest for S_1 in comparison to rest of the sowings.

The number of flowers formed are reduced to a marked extent at S_3 and S_4, but the shedding percentage is of same order as noted at S_2, therefore, by and large, the pod set is not greatly altered between the sowings by temperature. However, within the cultivars, the shedding is least for BG-209 and highest for L-550, while JG-62 is intermediate. Therefore, it becomes imperative to consider that flower shedding is genetical and external factors influence it least and only in limits of extremes they influence it to a certain extent. This is contrary to the general belief that higher temperatures are responsible for higher shedding. van Shaik and Probst, as early as 1958 reported the inheritance of inflorescence type, peduncle length, flower per node and percentage of flower shedding in soybean. They provided evidence that percentage of flower shedding in soybean was inherited genetically with dominance and complementary gene effect towards long peduncle, high flower number and high shedding. They also concluded from the studies that shedding of reproductive organs is generally considered to be affected largely by environment, but there are strong indications that considerable genetic control is present. They found that a relationship existed between flower number and shedding even in the progenies of these crosses and these were all positive and highly significant. Heritably estimates for peduncle length were found to be relatively high. They suggested polygenic control of shedding in soybean. A similar striking

parallel is observed with chickpea; the nature of shedding seems to be genetical and if it is inherited quantitatively like soybean with dominance, then perhaps the conclusions of van Schaik and Probst can be extended to chickpea, where they pointed out highly significant positive correlation and regression coefficients between flower number and shedding, indicated a difficulty of incorporating high production capacity and low shedding percentages into one strain.

The average pod set was 49 %, 44 % and 29 % in BG-209, JG-62 and L-550 respectively. Sinha and Co-workers (1980) suggested that the cause of low pod setting during winter in Delhi is largely due to poor pollen germination, however, the present findings do not lend support to the above contention in view of the fact that the pod set was not greatly altered between the sowings. Moreover, van der Maesen (1972) had ruled out the possibility of pollen viability as a cause of low fertilization, since he observed that 20 % germinated pollen grains were more than sufficient for adequate fertilization.

The number of effective pods or filled pods was always lowest for S_1 and highest for S_4 and vice-versa.

The seed efficiency or number of seeds developed as percentage of total number of ovules present, in flower formed was lowest at S_1 and, by and large, did not vary in rest of the sowings.

However, the effective seed efficiency i.e., the number of seeds developed from the number of ovules present in final pod number did not

vary between the sowings (except S_1 of L-550 = 51 %) and the same was about 51 % in JG-62, 58 % in L-550 and BG-209.

If the effective seed efficiency is calculated by giving due discount for unfilled pods, it will be observed that it varies with the cultivar and for JG-62 it is greatest at S1 (90 %), and lowest at S-4 (61 %). For S_2 and S_3 it is 76 and 78 % respectively. In L-550 it is again highest at S_1 and identical at S_2 and S_4 (78 %) and at S_3 84 %. For BG-209 also the highest is at S_1 (93 %), followed by S_2 (84 %) and the same for S_3 and S_4 is 59 %. So it can be concluded that the restriction on seed setting or curtailment of seed development results in loss of 40 %, 49 % and 33 % at S_1, 25 %, 19 % and 25 % at S_2, 27 %, 24 % and 1 % at S_3 and 10 %, 20 % and 0 % at S_4 for JG-62, L-550 and BG-209 respectively. It can also be inferred that BG-209 has the highest effective seed efficiency while L-550 has the lowest. In addition, the seed efficiency of BG-209 is less affected by temperature variations.

5.2 Improvement of reproductive efficiency by chemical manipulations

5.2.1 Stage vs concentration :

In an effort to improve the reproductive efficiency of chickpea by chemical manipulations, response of chickpea to different concentrations of growth regulators was investigated. Further an attempt was made to study the stage vs concentration effects of the growth regulators.

5.2.2 Auxin

From the results obtained, it was evident that auxin (IAA) was effective at all the stages at lower concentrations. This suggest that auxin is normally present in organ like flower and is an important factor in inhibiting the abscission and thus increasing the pod set and therefore a decrease in the auxin level preceeds or accompanies abscission. Such a relationship has been clearly demonstrated with respect to leaf abscission. However, no such attempt has been made with respect to floral abscission. As early as 1951, Shoji et al. had suggested that in leaves there exists an auxin gradient in the abscission zone, while the leaf is active. The same gradient is lost preceeding abscission and therefore, auxin gradient, rather than the absolute amounts of auxin, controlled abscission. The possibility of an auxin gradient across the flower pedicel, which determines whether a flower remains attached or is shed remains to be investigated for chickpea. There is another possibility that abscission of flower is related with an accumulation of some auxin antagonist as found in case of cotton (Lad, 1976). It is quite possible that the biosynthesis of auxin itself is involved as found by Lund (1956) for tobacco. If so, then stimulation of auxin formation from precursors present in a style tissue (by the enzymes) occurring in the descending pollen tubes may also support the early development of a pod. If subsequently, the pods are abscised because of deficiency of further auxin production during seed development. Further research is required to investigate the role of growth hormones in flower and pod shedding of chickpea, as well as on fruit development.

5.2.3 Cycocel

Cycocel was found to be more effective at a lower concentration during the mid-flowering stage. It will be seen from the effects of sowing dates on morphological attributes that, about 41-46 % of plant height was achieved during vegetative phase and further increases are , by and large, recorded during the mid-flowering phase. It is quite likely that the plant height is retarded by cycocel, if applied at mid-flowering stage, when increase in stem is taking place. A reduction in height may therefore, not only lead to inhibition of apical dominance, hence an increase of more number of lateral branches at later stage, but would also reduce the competition between vegetative phase and reproductive phase and thus thereby promoting reproductive growth and better pod set.

5.2.4 Benzyal amino purine

BA was found to be more effective at lower concentration at post flowering stage. Like other cytokinins BA (synthetic) might be acting by delaying the senescence of the leaves at this stage, thereby maintaining the integrity of chloroplast membranes and thus photosynthetic apparatus of the leaves, due to which the reduction caused in the supply of assimilates due to advancing senescence is checked and as a result better pod set is achieved.

5.2.5 Ethrel

The active principle, which is ethylene was found to have a deleterious effects at all the concentrations at each stage. Ethylene, in minute quantities can cause dramatic changes in physiological activities of plants.

It could not be ascertained whether the concentrations used in present investigation were too high and hence injurious, or ethylene has a negative role in pod set. However, ethylene is a powerful inhibitor of bud growth.

From the present study, it was obvious, that a specific growth regulator had a specific effect, either at specific stage or stages and, by and large, the lower concentration were more effective as compared to higher concentrations.

5.2.6 Stage vs growth regulator interaction

Stage vs growth regulator interaction was studied in the light of the results obtained from the above. The response of chickpea in relation to different growth regulators clearly, in fact, indicated that there was a stage vs growth regulator interaction. In support of the contention, an eleborate field as well pot culture trial was organised in order to substantiate further evidence in this regard. From the results obtained from the stage vs growth regulator interaction, where various concentrations of IAA, cycocel and BA were made with respect to this influence on particular stage, for e.g., cycocel at mid-flowering, BA at post-flowering and IAA at all stages. It was evident from the results that the highest yield was obtained where IAA was given at pre-flowering and combined with cycocel at mid-flowering and BA at post-flowering stages and this was followed by those concentrations, which had IAA at pre and mid-flowering stages or in addition to this BA at post-flowering stage. In the light of the results obtained, the contention is further strengthened that more organised stage vs growth

regulator interaction should be further investigated in order to make recommendation to the farmer, so that consistant result could be achieved for improvement of reproductive efficiency.

The other important point which emerged from the above study was that the total plant weight was increased considerably and this increase was also associated with an increase in stem weight. It is likely that an interaction of the various hormones under study at different stages contributed to an overall better biomass production and also to the better partitioning of the same to the economic parts as evident by the harvest index data, where an increase of 2-10 % was found both under field and pot conditions. Since these findings could be substantiated and supported by field trial, it can be adopted for improving reproductive efficiency of chickpea.

5.3 Biochemical studies in relation to reproductive efficiency

One of the major causes of low reproductive efficiency is the flower and pod shedding. Comparative study of the different biochemical parameters was done with a view to find out the relative difference between fresh and abscised flower and pod.

5.3.1 Total nitrogen, soluble protein and soluble sugars in normal and abscised flowers/pods

The relative amount of total nitrogen, total protein and soluble proteins were found to be lower in case of abscised flowers in comparison to fresh normal flowers. Since, there is no literature available as such

a comparison has never been made, we are left to speculate with a few reports available on the changes in nitrogen content during growth and development or the nitrate assimilation during the various stages. Saxena and Krishnamurthy (1979) observed that nitrogen contents in general commenced to decline progressively for 20 days after sowing both in stem and leaf till the time of flowering and this decline was more steep in leaf than in the stem. It is quite likely that the supply of nitrogen becomes limiting and results in abscision of flowers. Pokhriyal and Abrol (1980) working with cv. BG-209 found that soil derived nitrogen accounted for 15 %, 83 % and 72 % of total reduced nitrogen at preflowering (I), profuse flowering (II) and seed filling stages (III) respectively. Out of the total soil derived nitrogen 10.1 %, 59.3 % and 30.6 % was reduced during the stages I, II and III respectively. They observed that maximum accumulation of reduced nitrogen took place during stage II. They concluded that a high incidence of flower and pod shedding may be related to the fact that the supply may not be able to cope with the demand. This can be one of the possible reasons of low nitrogen percentage in case of abscised flowers. The abscised pods, on the other hand, had higher amounts of total nitrogen, total protein and soluble sugars than the normal developed pods. In view of the findings of Pokhriyal and Abrol (1980) that Cicer plants at final harvest contained 88281 ± 10228 μ mols reduced nitrogen, much of which was present in the seed. It can, therefore, tentatively be suggested that the plant has some kind of mechanism to draw from various organs during unfavourable times in

favour of most essential developing organ per se and it was due to such likelihood that more of these compounds were sequestered into the seeds of the abscised pod before the final abscission.

The relative amount of soluble sugars was less in case of abscised flowers as compared to normal fresh flower. Singh et al. (1981) have shown on L-550 that the soluble sugars as percentage of dry weight considerably decreased upto 28 days after anthesis and then remained unchanged till the grain matured. However, changes inlevels of starch, expressed as percentage of seed dry weight, show rapid increase during this period and further that intense biochemical activity took place during this period. The low level of soluble sugars in flowers could either be because of lower synthesis of these or due to increase conversion of these into starch during this period. The abscised pods on the contrary, showed an increased level of soluble sugars. The values are also much higher in comparison to the normal pods, therefore, it could be infered that the conversion of starch is because of this abscised pods have a higher level of soluble sugars, in comparison to normal pod.

5.3.2 Nucleic Acids contents in normal and abscised flower and floral parts

Relative amount of nucleic acids present in fresh and abscised flowers indicates that the total RNA content in flower decreased. However, DNA content per flower remained unchanged. Therefore, the changes in the nucleic acids are due to the change in RNA content that could be traced to

marked reduction in their reproductive structures viz., androecium and gynocium. Besides these, there are two other important observations e.g., increase of amount of RNA in pedicel and calyx in comparison to normal flower. It is known that the abscission takes place at the junction of pedicel and peduncle. The possibility of a nucelic acid gradient across the flower pedicel, which determines whether a flower remains attached or shed, could not be ruled out. There are indications which tempts to suggest of such a possibility. In the normal flower, the peduncle has a higher content of RNA as compared to the pedicel, which has comparatively lower amount of RNA. In the abscised flowers pedicel recorded higher nucleic acid as compared to the amount noted in the normal flower, with the exception of JG-62. However, it should be borne in mind that JG-62 has a double podded character and that there is every possibility that this character which arises at the same junction, may be the factor responsible for the differences observed in case of JG-62. The possibility of the existance of a gradient is highlighted by the decreased amount of RNA in the reproductive structure and an increased amount of the calyx. The role of calyx also needs to be evaluated in future studies because of its close connecting link between the reproductive structures and pedicel and also because of its larger expanded green surface among the floral parts.

It was shown by Lund (1956) that in tobacco the stimulation of auxin formation from precursors present in the style tissues by the enzyme occurring in the descending pollen tubes was responsible for the increased growth of ovary, which also supports the early development of pods. Whether the

much of the auxin formation is involved in normal flower which influence growth activities requiring increased amounts of nucleic acids for protein synthesis in normal flowers ? Whether failure of the same is related with the decrease and thereby decrease in nucleic acid is a matter of conjecture and it remains to be investigated in chickpea.

5.3.3 Pigment content in normal and abscised flowers and floral parts

The pigment, chlorophyll, has so far been analysed in leaves or pods, but no reference pertains to floral parts of the flower stalk. All the floral parts contain pigments (chlorophyll/anthocyamin/carotenoid) and therefore, a comparative study was made in order to have an idea about the relative contents of these in the different floral parts. The total chlorophyll content of abscised flower was reduced considerably to the extent of 24-38 %. Reduction was observed both in amounts of chl. a and chl. b, however, there was comparatively more reduction in chl. b. But the ratio of chl. a to chl. b per flower was found to be same in fresh and abscised flowers in L-550 and BG-209 and it was higher for abscised flowers of JG-62. The amount of chlorophyll present in flower part was greatly reduced in the abscised flowers, since peduncle, pedicel and calyx are important structures, besides the basal part of the gynoecium, which is also green. It is likely that these may be accounting with certain limits to the photosynthesis of the developing pods in order to achieve independence to a certain extent of the developing pods from the assimilate supply from the leaves. Whether the failure to become independent photosynthetically

is associated with the abscission of developing pods ? The amount of ch. b. is reduced comparatively in relation to chl. a. Although it has not been conclusively proved, most investigators believe that chl. b is prevalent over chl. a (Bourdvan, 1966) and there exists convincing evidence that immediate precursor of chl. a is chlorophyllide a. It is quite likely that the biosynthesis of chlorophyll is affected during abscission of flowers. The ratio of chl. a/b remain unaltered in L-550 and BG-209. This indicates that rate of photophosphorilation is not altered in these cultivars.

Carotenoids

The total carotenoids content per flower increased considerably in the abscised flower, in comparison to the normal flower. Carotenoids like chlorophyll are located in the chloroplast and on the chromatophore (Veir and Stocking, 1952) occurring there as water insoluble protein complexes. Goodwin (1960) suggested that chlorophyll and carotenoids may be attached to some protein, forming a complex known as photosynthin. It is thought by many investigators that the specific orientiation of carotenoids in relation to chlorophyll within the lamellar system of chloroplast is an important aspect of photosynthetic process. Besides this, two distinct role of carotenoids in photosynthesis have been established; i) they protect against the photo-oxidation of chlorophyll ii) they absorb and transfer light energy to chl. a. Whether the carotenoids are increased to offset the reduction in chl. b. or to protect chlorophyll from oxidation. In either way they seem to be imparting a protective mechanism to offset the

reduction in photosynthesis due to a reduction in chlorophyll pigment. Since the values fluctuated in the different floral parts and also the values of chl. b. fluctuated with the floral parts, it is suggested that carotenoids may also be acting by transfering energy to chl. a. in event of reduction in chl. b.

Authocyanin

The authocyanin contents in abscised flower in general decreased in all the floral parts examined. In L-550, the quantity this pigment is very low and the pedicel only carries a little amount. The role of authocyanins is not fully understood. A decrease in this pigment was noticed by Abbas (personal communication) which was accompanied by a parallel decrease in peroxidase activity. In event of such a relationship, the importance of pigment become enhanced, since, in general, the perodixase activity is related not only to activities of certain important enzymes like IAA oxidase, but also in relation to phenol content. Similar association was also observed by Srivastava and Lalcraya (1976). Within the limited scope of the present study, it is not possible to assign any specific reason for its decrease and this needs further investigation.

5.3.4 Changes in the organic acid contents in the leaves of chickpea as influenced by different dates of sowing

The rhythmic pattern or organic acid accumulation during night and disappearance during day was observed in leaves of S_1 in all the cultivars, but

the same was greatly altered in the leaves collected from S_2 in all the cultivars. In other words, the temperature altered the rate of accumulation of maleic acid according to the rhythemic pattern in leaves during S_1. Ramdas (1979, personal communication) had reported that chickpea is the only field crop with the crassulacean type of metabolism, however, Sinha and co-workers (1980) reported that chickpea is a C_3 plant. They further found that the maleic acid present on the surface of leaf and fruit walls of chickpea progressively increased in the order of vegetative, pre-flowering, pod setting and seed development stages. They further found that maleic acid increases by 2.5 fold with an increase of temperature from 5 to 30°C. Since the leaves were washed well before analysing for the organic acid, there is no possibility that the increase in maleic acid was due to its presence in the glands on the surface of the leaves. Moreover, the leaves at S_1 showed clear rhythmic pattern and recorded the diurnal fluctuation in organic acids (later identified as 80 % maleic acid) and the same rhythmic pattern was not observed at S_2, therefore, it is too tempting to suggest that depending upon the temperature that the chickpea plant may behave either as a crassulacean type as reported by Ramdas or as a C_3 type as found by Sinha and co-workers. The temperature at S_1 was comparatively higher and it is likely that the plant has a mechanism to switch to a better alternative pathway in relation to its environment. However, such a suggestion at this stage is merely speculative. Further research in this direction, however, is desirable.

From the foregoing discussion, it is evident that the BG-209 had the highest reproductive efficiency, largely due to higher growth rate during vegetative phase, low shedding, higher seed number per pod and better pod set. L-550, on the other hand, had the lowest reproductive efficiency, since it had low rate of growth during vegetative phase, lower pod set and higher shedding, however, its yield is high as it had more seed weight. JG-62 was found to be intermediate with respect to rate of growth during vegetative phase, medium pod set, medium shedding and more seed weight per pod.

The components on the seed yield and reproductive efficiency are given in the scheme presented.

The scheme is a modification of the original scheme of Summerfield et al. (1980) for legumes. The modifications give importance to the following :

i) Biomass production and its accumulation into stem as a pre-requisite for flower formation.

ii) Importance to seed number per filled pod.

iii) Influence of cumulative temperature on crop duration.

iv) The percentage proportion of cumulative temperature accumulated during pre-flowering phase.

The limitations to reproductive efficiency in the present study was largely found to be due to :

1. flower formation which is chiefly under the influence of temperature.

A modified scheme of the components on seed yield and reproductive efficiency in chickpea

1. Vegetative growth rate x duration of preflowering period
2. Biomass production and its accumulation in the stem
3. % of nodes that become reproductive

A 1 x 2 x 3 = Vegetative potential

4. Number of flowers per reproductive node (F)
5. % of F that sets pods
6. % of P that are retained
7. % of P that are filled

Number of pods per reproductive node (P)

8. Number of seeds set per pod
9. Number of seeds per pod

Number of seeds per developed pod (s)

B. 4 x 5 x 6 x 7 x 8 x 9 = Reproductive efficiency

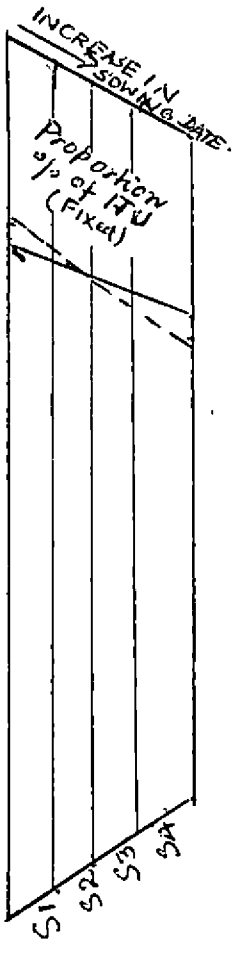
10. % of seed that attain maturity (Carbon supply nitrogen supply)
11. Mean seed weight = Mean seed growth rate x duration of pod filled

C. 10 x 11 = Yield culmination.

Yield per plant = A x B x C

Post flowering ← Duration → Preflowering (Temp. sensitive)

TOTAL CROP DURATION
Influenced by cumulative temperature units



------ influence of extreme temperature

2. the production of biomass which is determined both by genetical and phenological potentials.
3. Restriction in the biomass accumulation in the stem before or during lag phase of pod formation.
4. Higher shedding of flower/pods.
5. Development of pod and seed.
6. Failure of pod to become photosynthetically independent.

The biochemical differences in fresh and abscised flowers indicate that the flower abscission is largely due to deficiency of nitrogen compounds, sugar and nucleic acids and pigments.

However, the low reproductive efficiency can be largely improved by chemical manipulations, using growth regulators.

SUMMARY

The average yield of chickpea in India is as low as 700 kg/ha. One of the major causes for this low yield can be attributed to the low reproductive efficiency. The cause for low reproductive efficiency is mainly due to heavy shedding of reproductive structures. The present investigations were, therefore, initiated with the following objectives :

i) To study the genetic variability and diversity with reference to the flowering behaviour and shedding of flowers during the reproductive stage in order to evaluate the peak periods of flowering, shedding percentage and reproductive efficiency.

ii) To study the influence of temperature (based on different dates of sowing) on time, intensity and duration of flowering and reproductive efficiency in relation to growth and development of chickpea.

iii) To study the possibility of improving the reproductive efficiency by chemical manipulations using growth regulators.

iv) To investigate the biochemical changes associated with abscission of flowers and fruits.

To meet the major objectives of present investigation, experiments were categorised in three groups viz., 1) evaluation of reproductive efficiency of various genotypes, 2) improvement of reproductive efficiency by chemical manipulations and 3) biochemical studies in relation to reproductive efficiency.

The experiments were conducted both in field and pot culture under natural day light conditions during 1979-80 and 1980-81, in order to have

a comparative idea of reproductive efficiency under these conditions. It was observed, although, plants grown in pot culture gave quantitatively low values for all the attributes, yet closely paralleled the general pattern observed in field with reference to flowering, growth and yield behaviour.

Evaluation of reproductive efficiency in twelve genotypes were carried out during 1979-80 in order to select suitable genotypes for detailed study during the subsequent year. The genotypes were, JG-62, C-235, nine BG-lines and the Kabuli cv. L-550. In the field the experimental lay out was randomised block design with three replications. The crop was sown in field and pot culture on 19.10.1979.

It was observed that peak flowering period in these genotypes was between 120-130 days. The shedding percentage was found to be very high and it ranged from 67-90 %. The least was found in BG-209 and highest in L-550. Amongst the 12 genotypes examined, it was found that BG-209 had the highest reproductive efficiency in terms of number of pods, filled pod, total seed number, pod weight and seed yield. The lowest reproductive efficiency was observed in L-550. The cause for higher reproductive efficiency in BG-209 was attributed to low shedding %, higher pod set and higher effective pod set.

Based on the performance of different genotypes, three cultivars viz., JG-62, L-550 and BG-209 were selected for detailed studies during 1980-81. BG-209 and L-550 were selected because of their contrasting

behaviour in flower shedding. JG-62 was found to be intermediate and also it had a double podded character.

Studies on the influence of temperature (based on different dates of sowing) on time, intensity and duration of flowering and reproductive efficiency in relation to growth and development were made with the above three genotypes. Four sowings (S_1, S_2, S_3 and S_4) were done at 15 days interval commencing from 4th October, 1980.

Time, intensity and duration of flowering were greately altered under the influence of different dates of sowing. While the days for first flower increased, the intensity and duration of flowering was markedly reduced with increase in sowing dates from S_1 to S_4. In general, the days to first pod also followed the same trend. The final crop duration also markedly reduced with the consequence that the pre-flowering or vegetative period was lowest in late sowings. The temperature records indicated that, in general, the mean optimal temperature of about 20°C, a minimum about 12°C and a maximum about 20°C were conducive for flower formation. Irrespective of cultivar or date of sowing, a mean maximum and minimum temperature of 19°C, 25-5°C and 12.5°C respectively was observed to be optimum for active pod formation. It was also observed that a higher mean, maximum and mean temperature was required for pod stabilization and filling.

The important stages during crop period were identifed and the duration to attain these stages were worked out. It was observed that the vegetative duration (stage 1) increased with delayed sowings in all the cultivars,

while the days to first pod (stage 2 - pod initiation) fluctuated among the cultivars and with dates of sowing. In JG-62 and L-550 a lag phase of pod formation (stage 3) was seen in earlier sowings, more being in JG-62 and L-550, while in BG-209 it was almost absent. The duration of active pod formation (stage 4) remained more or less constant (20-30 days), irrespective of dates of sowing or cultivar. Duration between stabilisation of pod number to harvest (stage 5), by and large, remained the same for different dates of sowing, but varied amongst cultivars. It was longer in JG-62 (23-27 days) and shorter in L-550 (13-21 days).

The computation of percentage proportion of various durations in relation to total crop and reproductive durations lead to categorise these stages as temperature sensitive or insensitive. Compared to other stages vegetative stage was most sensitive to temperature. It was seen that cultivars classified as early flowering e.g., JG-62 and cultivar taking much longer time to come into flower e.g., BG-209, more or less had the same crop duration depending upon the environment by way of an adjustment of duration in their reproductive period.

The various temperature indices, heat unit (HU), growing degree days (GDD), and cumulative minimum temperature (CMT), accumulated at different growth stages till harvest were calculated from the temperature records and this was extended to chickpea. It was seen that BG-209, in comparison to others, consumed more HU, GDD and CMT during vegetative phase over reproductive phase in all the four sowings. It was also observed that

JG-12 and L-550 accumulated more HU during reproductive phase at S_1 and S_2, but equal or less in S_3 and S_4. The GDD, however, were found higher during vegetative phase at early sowings and lower at delayed sowings in these cultivars. The proportion percentage in relation to temperature indices during total crop duration indicated that each cultivar had a fixed percentage of total crop duration proportioned at pre-flowering or vegetative phase and this remained largely unaffected by temperature, however, in case of reproductive phase marginal variations were observed at extremes of temperature (e.g., S_4). Amongst the cultivars, during the vegetative phase the order of proportion percentage was BG-209 > L-550 > JG-62. It was also observed that whether a plant accumulated more, or less of temperature indices, the proportion percentage of duration between the vegetative phase and reproductive phase remained the same, however, the degree of accumulation did affect its capacity to produce biomass and partitioning. Thus, it was observed that the temperature had influence in total crop duration, which was dependent on cumulative temperature units.

The morphological and growth attributes decreased with an increase in sowing dates in the order $S_1 > S_2 > S_3 > S_4$. The reductions were much marked in S_3 and S_4 as compared to S_1. The average height, number of branches, leaf number, leaf area and leaf area duration was 45 %, 69 %, 80 % and 86 % respectively. The average reduction in leaf weight, stem weight and total dry matter was found to be 79 %, 81 % and 75 % respectively. In all the cultivars at S_1, the major proportion of morphological characters were gained during vegetative phase and rest of the growth attributes, by

and large, during pod initiation as in L-550 and BG-209 or during the lag phase of pod formation as in JG-62. In delayed sowings, major proportion of above attributes were gained during vegetative phase. The time of fall of leaf area varied with cultivars and sowing dates from lag phase to beginning of pod formation. The biomass production was markedly restricted in late sowings as compared to early sowings. This reduction in biomass production, especially accumulation of dry matter in stem during the flowering period might have hampered the realisation of more number of flowers, since in S_3 and S_4 the limitation in reproductive efficiency could be seen as flower number itself and not the latter sequence.

A quantitative reduction in reproductive attributes viz., flower number, pod number, total seed number and seed weight was observed in all the cultivars, when sowings were delayed. The major cause of low reproductive efficiency was found to be due to heavy shedding of flower and fruit. This was noticed very high in all the cultivars and,by and large, the order was $S_1 > S_2 > S_3 > S_4$. The abscission rate at any given interval by five days from start of flowering was seen of following order $S_1 > S_2 > S_3 > S_4$. The magnitude of abscission within the cultivar was the order L-550 > JG 62 > BG 209. The number of flowers retained during a specific period as percentage of total flowers showed that shedding was greater in S_1, because retention was lowest on S_1 and highest at S_4 or S_3 and for S_2 it was greater than S_1. This was true in the case of pods also. The abscission of pods was found to be lowest at late sowings, because larger number of flower formed were actively turned into pods during a shorter duration.

The seed number/pod remained unaffected by different dates of sowing. But the total seed number was highest for S_1 and least for S_4. Increase in pod and seed weight was highest in S_2, followed by S_1, S_3 and S_4. A significant reduction in these over S_2 to the extent of 80 % at S_3 and S_4 was seen.

The parameters determining the reproductive efficiency was worked out in detail. It was seen that average pod set was 49 %, 44 %, and 29 % in BG-209, JG-62 and L-550 respectively. The number of effective pods or filled pods was always lowest for S_1 and highest for S_4.

The seed efficiency or number of seeds developed as percentage of total number of ovules present, in flower formed was lowest in S_1 and, by and large, did not vary in rest of the sowings.

However, the effective seed efficiency (i.e.,number of seeds developed from the number of ovules present in pod number) did not vary between the sowings. When effective seed efficiency was calculated by giving due discount for unfilled pods, it was observed that it varied with cultivar. It was greatest at S_1 and least at S_4 for all cultivars, ranging from 90 % to 54 %. Hence, the restriction in seed setting or curtailment of seed development resulted in loss of 40 %, 39 %, and 33 % at S_1; 25 %, 19 % and 25 % at S_2; 27 %, 24 % and 1 % at S_3; 10 %, 20 % and 0 % at S_4 for JG-62, L-550 and BG-209 respectively. Hence it was inferred that BG-209 had the highest effective seed efficiency, while L-550 had the least.

In an effort to improve the reproductive efficiency of chickpea by chemical manipulations, different concentration of growth regulators at different stages of crop growth were applied to cv. L-550 grown under pot culture condition during 1979-80. It was observed that at lower concentrations the growth substances i.e. IAA @ 2 ppm at all stages, cycocel at 2000 ppm at mid-flowering and BA at 5 ppm at post-flowering stages, were seen effective. But Ethrel in all cases gave negative result.

In the light of above findings, an experiment to investigate the effect of stage vs concentration was conducted in randomised block design with four replications in field and simulation in pot culture. It was observed that IAA at pre-flowering, combined with cycocel at mid-flowering and BA at post-flowering stages enhanced the reproductive efficiency through higher seed yield.

Biochemical changes associated with reproductive efficiency were investigated. The relative amount of total nitrogen, total proteins and soluble proteins were found to be low in case of abscised flowers in comparison to fresh normal flower. The above finding was true for soluble sugars also. The abscised pods on the contrary showed an increased level in all the above parameters.

Relative amount of RNA in abscised flowers were low, but DNA content remained unchanged. An increase in RNA content in pedicel and calyx in abscised flower was observed.

The pigments viz., chlorophyll and anthocyanin in abscised flowers and parts showed a marked reduction, while the amount of carotenoid in abscised flowers showed an increase.

A rhythmic pattern of accumulation of organic acid during night and disappearance during day was observed in the leaves of S_1 in all the cultivars, but the same was greatly altered in S_2, which was found to be due to the influence of temperature during S_1.

The present investigations revealed that BG-209 had the highest reproductive efficiency, largely due to higher growth rate during vegetative phase, lower shedding %, higher seed number per pod and better pod set. L-550 had the least reproductive efficiency and JG-62 was found to be intermediate. The reproductive efficiency was influenced by variation in temperature and in biochemical parameters. It was also seen that reproductive efficiency can be improved by chemical manipulations, using growth regulators.

BIBLIOGRAPHY

Abu-Shakara, S., Mirga, S. and Tannons, R. (1970). Chemical composition and amino acids content of chickpea seeds at different stages of development. J. Food Agric. 21 : 91-93.

Ageeb, O.A.A. and Ayoub, A.T. (1977). Effect of sowing dates and soil types on plant survival and grain yield of chickpea. J. Agric. Sci. (U.K.) 88 : 521-527.

Agrikar, G.P. (1957). Pulse Crop of Indiar Gram pp.59. I.C.A.R. publication 1970.

Ahlawat, I.P.S., Saraf, C.S. and Singh, A. (1973). Response of Bengal gram (Cicer arietinum) to growth regulators. Paper presented at All India Co-ordinated Rabi Pulses Workshop held at Bose Research Institute, Calcutta. Sept. 10-14, 1973.

Arnon, D.I. (1949). Copper enzymes in isolated chloroplasts. Polyphenol-oxidase in Beta vulgaris. Plant Physiol. 24 : 1-15.

Ayyar, V.R. (1935). Anthesis and pollination of Bengal gram (Cicer arietinum L.). Madras Agric. J. 23 : 170-175.

Ayyar, V.R. and Balasubramanian, R. (1935). Anthesis and pollination in Bengal gram. Madras Agric. J. 23 : 170.

Aziz, M.A., Khan, M.A. and Shaw, S. (1960). Causes of low seed setting in gram (Cicer arietinum). Agriculture, Pakist. 11 : 37-48.

Bahl, P.N. and Jain, H.K. (1977). Association among agronomic characters and ideotypes in chickpea. Z. Planzenzuecht. 79 : 154-159.

Bahl, P.N., Mehra, R.B. and Raju, D.B. (1976). Path analysis and its implication in chickpea breeding. Z. Planzenzuechet. 77 : 67-71.

*Balls, W.L. (1912). The cotton plant in Egypt. London-1912.

Baluch, M.A.A. and Soomro, M.P.M. (1968). Correlation studies in gram. W. Pak. J. Agric. Res. 6 : 26-32.

Bhardwaj, R.P. and Singh, I.B. (1972). Correlation studies in gram. Indian Agric. 16 : 205-207.

Boardman, N.K. (1966). Photochlorophyll, in L.P. Vernon and G.R. Seely, eds., ' The Chlorophylls', New York, Adademic Press.

Boswel, V.R. (1962). The influence of temperature upon growth and yield of garden peas. Proc. Amer. Soc. Hort. Sci. 23 : 162-168.

Chandra, S. and Arora, S.K. (1968). An estimation of protein, ascorbic acid and mineral matter contents of some indigenous and exotic varieties of gram (Cicer arietinum L.). Curr. Sci. 37-8 : 237-238.

Choudhry, M.A. and Khan, M.A. (1974). Correlation studies in gram. Pak. J. Agric. Sci. 11 : 184-186.

Cardner, H.B. (1933). External and internal factors affecting blossum drop and set of pods in lima beans. Proc. Amer. Soc. Hort. Sci. 30 : 571-576.

Dahiya, B.S., Singh, K.B., Brar, H.S. and Brar, J.S. (1976). Identification of physiologically efficient genotypes in chickpea. Trop. Gran Legume Bull. 4 : 19-20.

Damodaran, N., Ramaswamy, R., Venketeswaram, T.R., Mahadevan, S. and Ramadas, K. (1946). Amide synthesis in plant. II. Amino acid changes in germinating seedlings. Proc. Indian Acad. Sci. 33-B : 159-164.

Davis, J.P. (1945). The effect of some environmental factors on the set of pods and yield of white pea beans. Jour. Agr. Res. 70 : 237-247.

Dure, L.S. (1975). Seed formation. Annual Review of Plant Physiology. 26 : 259-278.

Esh, G.C. and De, T.S. (1960). Studies on pulse proteins; association with thiamine and nicotianic acid content of pulse. J. Proc. Instn. Chem. India. 32 : 14-16.

Eshel, Y. (1967). Effect of sowing date on growth and seed yield components of chickpea. Israel J. Agri. Res. 17 : 193-197.

Eshel, Y. (1968). Flower development and pollen viability in chickpea. Israel J. Agri. Res. 18 : 31-32.

Ewing, E.C.A. (1918). Study of certain environmental factors and varietal differences influencing the fruiting of cotton. Mississippi Agrl. Exp. Sta. Tech. Bull. 8 : 1-95.

F.A.O. Production Year Book (1979). Statistics series. No.28. pp 124. Food and Agricultural Organization, Rome.

Friend, D.J.C., Helson, V.A. and Fischer, J.E. (1962). Leaf growth in Marquis wheat as regulated by temperature, light intensity and day length. Can. J. Bot. 40 : 299-311.

Goodwin, T. (1960). Chemistry, biogenesis and physiology of the carotenoids. In W. Rubland, ed., Encyclopedia of Plant Physiology 5 : Part. 1, 394. Berlin : Springer.

Gupta, V.P. and Sohan Lal (1981). Developmental allometry and plant type in chickpea. International chickpea News Letter(ICRISAT) 4 : 8-9.

Gurbaksh Singh (1975). Effect of Asocrbic Acid on the yield of gram. J. Res. Punjab Agric. Univ. 12 : 339.

Hadi, S.M. (1966). Quantitative changes in nucleic acid and nucleases during germination of Cicer arietinum. Indian J. Biochem. 3 : 203.

*Hardman, L.L. (1970). The effect of some environmental conditions on flower production and pod set in soybean (Glycene max. L.) var. Hork - Ph.D. Thesis, Univ. of Minnesota. Diss. Abstr. 31(5) 240(B).

*Harland, S.C. (1917). Mamurial experiments with Seedsøland Cotton in St. Vincent with some notes on factors affecting yield. West Indian Bull. 16 : 169-202.

*Hugon, E. (1960). Stimulative influences capable to oppose apical dominance in Cicer arietinum. C.r. hebd. Seanc. Acad. Sci. Paris. 250 : 1334-1336.

*Hugon, E. (1961). Some aspects of correlations between buds of Cicer arietinum. C.r. Soc. Fr. Physio-Veg. B 7-2 : 94.

*Hugon, E. (1962). Comparative mode of action of gibberillic acid and kinetin in the apical dominance in Cicer arietinum. Cr. hebd. Seanc. Acad. Sci. Paris. 255-2 : 350-352.

*Hugon, E. (1969). Effect of 5, fluorodeoxy uridine on the development of etiolated parts of Cicer arietinum and on branching induced by application of cytokinin. Cr r. hebd. Se_nac. Acad. Sci, Paris. (France) 269 : 1969-1972.

*Hugon, E. (1970). Effect of local application of cold and cytokinins on transport of ^{32}P and associated increases of inhibition in Cicer arietinum L. Physiol. Veg. 8 : 235-245.

Jackson, M.L. (1967). Soil chemical analysis. Prentice - Hall of India Private Limited, New Delhi. pp. 183.

Jadhav, K.A. and Airan, J.W. (1961). Amino acids in cereals. (Bengal gram) Food Sci. 10 : 218.

Jolouzot, R. (1971). Studies of nucleic acids and protein metabolism during initiation of adventitious roots. Planta : 97 : 16-27.

Joshi, S.N. (1972). Variability and association of some yield components in gram. Indian J. Agric. Sci. 42 : 397-399.

Kadam, B.S., Kulkarni, R.K. and Patel, S.M. (1938). Flowering and pod setting in gram. (Cicer arietinum L.). J. Amer. Soc. Agro. 30 : 547-557.

Kadwe, R.S., Thakare, K.K. and Badhe, N.N. (1974). A note on the protein content and mineral composition of 25 varieties of pulses. Indian J. Nutr. Diet. 11-2 : 83-85.

Katiyar, R.P. (1979). Correlation path analysis of yield components in chickpea. Indian J. Agric. Sci. 49 : 35-38.

Katiyar, R.P., Prasad, J., Singh, A.B. and Ram, K. (1977). Association analysis of gram yield and its components in aggregating population. Indian J. Agric. Sci. 47 : 305-327.

Kaul, J.N. and Sekhon, H.S. (1974). Response of G-130 gram and field pea T-163 to growth regulators - Paper presented at All India Coordinated Rabi Pulses Workshop held at UPIAS, Kanpur, 1974. (c.f. M.C. Saxena and Yadav. International Workshop on grain legumes 1975. Jan. 13-16 at ICRISAT, Hyderabad).

Kaul, J.N. and Sekhon, H.S. (1976). Performances of chickpea genotypes as affected by the dates ofsowing and row spacing. Crop Improvement 3 : 22-26.

Kaul, J.N., Singh, K.B. and Sekhon, H.S. (1976). The amount of flower shedding in some Kharif Pulses. J. Agr. Sci. (U.K.) 86 : 219.

Khan, M.A. and Choudhry, M.A. (1976). Effect of growth regulators and flowering and yield of gram. Pak. J. Agr. Sci. 13 : 105-112.

*Kovac, S. (1963). The gradient of anthesis and seed setting in soybean. Acta. Agron. Hung. 12 : 233-250.

Kumari, P.S. and Sinha, S.K. (1972). Variation in chlorophyll and Photosynthetic rate in cultivars of Bengal gram. Phytosynthetica. 6 : 189-194.

Lad, B.L. (1976). Hormonal regulation of fibre elongation in lintless and linted genotypes of desi cotton (Gossypium arboreum L.). M.Sc. Thesis in Plant Physiology, Indian Agricultural Research Institute, New Delhi. pp. 45.

Lal, B.M., Rohewal, S.S., Verma, S.C. and Ved Prakash (1963). Chemical composition of some pure strains of Bengal gram. Ann. Biochem. exp. Med. 23-12 : 543-548.

Lal, B.M. and Verma, S.C. (1968). Physiology of Bengal gram seed III. Changes in the phosphorus compounds of the seed parts during ripening of the seed. J. Sci. Food Agr. 19-2 : 113-116.

Lal, S. (1976). Relationship between grain and biological yields in chickpea. Trop. Grain Legume Bull. 6 : 29-31.

*Lambeth, V.N. (1950). Some factors influencing pod set and yield of lima beans. Univ. Missouri, Agrl. Exp. Sta. Res. Bull. No. 466.

Lindoo, S.J. and Nooden, L.D. (1977). Studies on the behaviour of senescence signal in Anoka soybeans. Plant Physiol. 59 : 1136-1140.

Lloyd, F.E. (1920). Environmental changes and their effect upon boll shedding in cotton. New York, Acad. Sci. 29 : 1-131.

Lowry, O.H., Rosenberg, N.J., Farr, A.L. and Randall, R.J. (1951). Protein measurement with follin phenol reagent. J. Biol. Chem. 23 : 1675-1680.

Lund, H.A. (1956). The biosynthesis of IAA in the style and ovaries of tobacco, preliminary to the setting of fruits. Plant Physiol. 31 : 334-339.

Luthra, R.C. and Gill, A.S. (1974). Effect of sowing dates, seed rates and P_2O_5 on the yield of gram. J. Res. Punjab Agric. Univ. 11 : 355-358.

*Mange, M. (1962). On some modifications caused by gibberillic treatment of Cicer arietinum. Annls. Scient. Univ. Basancon Ser. 2 (Bot.) 18 : 137-140.

*Mange, M. (1965). Study of organic acids and sugars in Cicer arietinum, comparison between stems and leaves. Ann. Sci. Univ. Basancon Bot. (France) 2 : 33-34.

*Mange, M. (1968). Effect of treatment with GA on the content of carbohydrates, amino acids and free organic acids in Cicer arietinum. Ann. Sci. Univ. Basancon. Bot. (France) 3 : 28-31.

*Mange, M. (1969 a). Relationship between the elongation of rate of stem of Cicer arietinum and certain aspects of carbohydrate metabolism. C. r. Hebd. Seanc. Acad. Sci. Paris. 288 : 512-515.

*Mange, M. (1969 b). Comparison between the effect of GA in light and in dark on growth and carbohydrate metabolism of Cicer arietinum L. Ann. Sci. Univ. Basancon. Bot. (France) 6 : 46-55.

*Mange, M. (1972). Metabolism of Aspartic acid $U^{14}C$ and glutamic acid $U^{14}C$ in leaves of Cicer arietinum treated with GA. Ann. Sci. Univ. Basancon. Bot. (France) 12 : 69-76.

Mathur, O.P. and Tomer, P.S. (1966). Effect of time of sowing on yield of different varieties of gram under water scarcity conditions of Rajasthan. Indian J. Agron. 11 : 207-209.

Mc Blain, B.A. and Hume, D.J. (1981). Reproductive abortion and yield components and nitrogen content in three early soybean cultivars. Cand. Jour. Plant Sci. 61 : 444-505.

Mehtha, P.M., Patel, R.J. and Rao, B.V.N. (1974). Effect of Gibberyillic acid, ascorbic acid and morphactin and their combinatinns on seedling growth and enzymes of Cicer arietinum. Geobios (Jodhpur) 1 : 130-133.

Mehtha, P.M., Patel, R.J. and Rao, B.V.N. (1975). Effect of Gibberillic acid, ascorbic acid, morphactin and their combinations on amylose activity in Cicer arietinum. Geobios (Jodhpur) 2 : 28-29.

Morris, D.L. (1948). Quantitative determination of carbohydrate with Drew Wood's Anthrone reagent. Scince 107 : 254-255.

*Moursi, M.A., Abd, E.L. and Gawad, A.A. (1963). Legume photoperiodism. 2. Formative and photoperiodic reaction to light duration. Ann. Agric. Sci. Univ. Ain Shams. 8 : 297-304.

Mukherjee, D.K., Datta, P.C. and Adhikari, B.K.D. (1969). Studies on pulses. 6 Physiological and anatomical studies on the effects of spraying sugars and auxins on gram. Bull. Bot. Soc. Bengal 23 : 177-183.

Murfet, I.C. (1977). Environmental interactions and the genetics of flowering. Annual Review of Plant Physiology. 28 : 253-278.

Nanda, K.K. and Chinoy, J.J. (1960 a) Effect of vernalisation and photoperiodic treatments on Cicer arietinum. 1. Phasic development in relation to its photo and thermic quanta. Indian J. Plant Physiol. 3 : 32-44.

Nanda, K.K. and Chinoy, J.J. (1960 b). Effect of photoperiodic treatments on growth and development of Cicer arietinum. 2. Stem elongation and branching of Cicer arietinum and their correlation with flowering under varying photo periodic and vernalisation treatments. Indian J. Plant Physiol. 3 : 45-55.

Ogur, M. and Rosen, G. (1950). The nucleic acid of plant tissues. 1. The extraction and estimation of deoxypentose nucleic acid and pentose nucleic acid. Arch. Biochem. Biophysics. 25 : 262-276.

Oraon, P., Prakash, R. and Haque, H.F. (1977). Correlation studies in chickpea. Trop. Grain Legume Bull. 7 : 18-19.

Oraon, P., Prakash, R. and Haque, Md.F. (1977). Floral biology of chickpea. Trop. Grain. Legume Bull. 7 : 19-20.

Pal, B.P. and Murthy, G.A. (1941). Vernalisation of Indian crops. J. Genetic Pl. Breed. 1 : 61-85.

Pal, B.P. and Rao, T.N. (1940). Ovule mortality in gram. Proc. Ind. Acad. Sci. B_3 : 527-534.

Pandey, R.K., Saxena, M.C. and Singh, V.B. (1977). Genotypic differences in photoperiodic response in chickpea. Pantnagar J. Res. 2 : 123-126.

Pandey, R.K., Saxena, M.C., Singh, V.B. and Singh, B.K. (1978). Assimilation and utilization of ^{14}C assimilation to chickpea. J. Nucl. Agric. Biol. 7 : 56-70.

Panse, V.G. and Sukhatme, P.V. (1978). Statistical methods for Agricultural workers. Indian Council of Agricultural Research, New Delhi.

Patil, V.N. and Pokle, Y.S. (1974). Correlation and selection indices in improvement of seed yield in gram. Nagpur Agrl. Coll. Mag. 47 : 36-42.

Paul, G., Mahlberg and Venketeswaran, S. (1966). Pigment analysis of normal and proliferated genetical strains of Nicotiana under cultural conditions. Bot. Gaz. 127 : 114-115.

Phadnis, B.A., Ekbote, A.P. and Ainchwar, A.S. (1970). Path coefficient analysis in gram. Indian J. Agric. Sci. 40 : 1013-1016.

Pokhriyal, T.C. and Abrol, Y.P. (1980). Nitrate assimilation in relation to total reduced-N in Bengal Gram (Cicer arietinum). Exptl. Agric. 16 : 127-135.

Redford, P.J. (1967). Growth analysis formula - their use and abuse. Crop Sci. 7 : 171-175.

Roberts, E.H., Summerfield, R.J., Minchin, F.R. and Hardley, P. (1981). Phenology of chickpeas (Cicer arietimum L.) in contrasting aerial environemnts (c.f. R.J. Summerfield, Minchin, F.R., E.H. Roberts and P. Hardley (1981). "Adaptation to contrasting aerial environemnts in chickpea. Trop. Agric. 58 : 97-113.

*Rodriguez, Lopez, M. (1953). Effects on seeds of Cicer arietinum L. caused by treatment with some growth substances. Ann. Inst. Bot. AJ. Cavanillo. 11 : 19-33.

Sahai, J.M. (1955). A note on the pod setting in gram. Agri. Ani. Husb. (U.P.) 6 : 27-31.

Salisbery, F.B. (1963). " The flowering process". pp.234. Pergamon Press, Oxford.

Sandhu, T.S. and Hodges, H.F. (1971). Effect of photoperiod, light intensity and temperature on vegetative growth and seed production in Cicer arietinum. Agron. J. 63 : 913-914.

Sandhu, T.S. and Singh, N.B. (1972). Correlation, path coefficient analysis and discriminant function selection in Cicer arietinum L.). J. Res. Punjab Agric. Univ. 9-3 : 417-421.

Saraf, C.S., Ahlawat, I.P.S. and Singh, A. (1974). Report on agronomic investigations on rabi pulses at I.A.R.I., New Delhi, 1973-74 - All India Co-ordinated Pulse Workshop, UPAIS, Kanpur.

Saxena, N.P. and Krishnamurthy, L. (1979). Analysis of growth and yield. Section I. ICRISAT - Pulse physiology progress report 1978-79 Part II. chickpea physiology, pp. 1-40.

Saxena, N.P. and Sheldrake, A.R. (1976). Pulse physiology annual progress report, Part II 1975-76 chickpea physiology, ICRISAT. pp.179.

Saxena, N.P. and Sheldrake, A.R. (1980). Physiology of growth and development and yield of chickpea in India. ICRISAT - Proceedings of the International Workshop on chickpea improvement. 28 Feb. - 2 March 1979 at Hyderabad. pp.106-111.

Saxena, M.C. and Yadev, D.S. (1975). Some agronomic considerations of pigeon peas and chickpeas. Internationsl Workshop of Grain Legumes. Jan. 1975. ICRISAT. pp.31.

Sen, S. and Mukherjee, D. (1961). Preliminary studies on defective seed setting in gram. Sci. Cult. 27 : 185-188.

Sen, S., Sen Gupta, K. and Mukherjee, D. (1964). Effect of deferred sowing in gram. Indian Agriculturist. 18 : 31-32.

Sharma, A.K., Tiwari, R.K. and Tiwari, A.S. (1969). Studies on genotypic, phenotypic and environmental correlations in gram. Indian J. Sci. Ind. (A) 3 : 43-46.

Sharma, H.D., Batra, B. and Vaidya, S.M. (1967). Effect of normal and late sowings on the behaviour of some improved types of gram. J. Postgrad. Sch. Ind. Agric. Res. Inst. 2 : 56-61.

Sheldrake, A.R. and Saxena, N.P. (1979). Comparison of earlier and late formed pods of chickpeas. Ann. Bot. 43 : 467-473.

Sheldrake, A.R. and Saxena, N.P. (1979). The growth and development of chickpea under progressive moisture stress. In : Stress Physiology in important crop plants by H. Mussel and Staples. R.C., J. Wieley, New York, 1979.

Shoji, K., Addicot, F.T. and Swets, W.A. (1951). Auxin in relation to leaf blade abscission. Plant Physiol. 26 : 189-191.

Singh, A. (1958). Influence of increase in day length on growth behaviour root nodulation and flower initiation in Cicer arietinum. Proc. Nat. Acad. Sci., India, B 28 : 231-241.

Singh, D. (1968). Correlation studies in gram. Lebdev J. Sci. Tech. (B) 6 : 155-158.

Singh, K.P., Singh, V.P. and Choudhry, B.D. (1977). Path coefficient analysis in chickpea. Z. Planzenzuecht. 79 : 219-233.

Singh, U. and Jambunathan, R. (1980). Studies on Desi and Kabuli chickpea (Cicer arietinum L.) cultivars. 1. Chemical composition. ICRISAT 1980 Proceedings of the International Workshop on Chickpea Improvement 28 Feb. to 2 March, 1979 at Hyderabad, pp.61.

Singh, U., Jambunathan, R. and Saxena, N.P. (1981). Changes in carbohydrates, amino acids and proteins in developing seed of chickpea. Phytochemistry. 20 : 373-378.

Sinha, S.K. (1977). Food Legumes : Distribution, "Adaptability and Biology of Yield. FAO Plant Production and Protection Paper. 3. Food and Agriculture Organisation of the United Nations, Rome, pp. 124.

Sinha, S.K. and Coworkers (1980). Research report on the scheme of Professor of Eminence (Plant Physiology), 1.7.1980 - 30.6.19 , Water Technology Centre, I.A.R.I., New Delhi, pp. 12.

Sinha, S.K. and Ghildiyal, M.C. (1973). Increase of yield of Bengal gram (Cicer arietinum) by 2, 3, 5 - triiodobenzoic acid. Crop Sci. 13 : 283.

Smartt, J. (1976). "Tropical Pulses", Tropical Agriculture Series, Ed. D. Rhind, Longman Group Limited, London, pp.122.

Smith Ben, W. (1954). Arachis hypogea reproductive efficiency. Amer. Jour. Bot. 41 : 607-616.

Srivastava, A.K., Azhar, S. and Krishna Murthy, C.R. (1973). Action of IAA on in vitro synthesis of tryptophan oxygenase by Cicer arietinum seedlings. Indian J. Biochem. Biophys. 10 : 191-194.

Srivastava, H.N. and Lalcraya, M.M. (1976). Effect of pigment precursors on GA induced inhibition in betacyanin synthesis in Celocia argentia. The Plant Biochem Jour. 3 : 134-136.

Srivastava, S.K. and Tomer, G.S. (1973). Note on the primary trial on the effect of Indole - 3- acetic acid on bud drops in gram. J.N.K.V.V. Res. J. 7 : 192-193.

Summerfield, R.J. and Minchin, F.R. (1976). An integrated strategy for day length and temperature sensitive screening of potentially tropic-adapted soybeans. pp 186-191 In : Expanding the use of soybeans in Asia and Oceana. R.M. Goodman ed. INSTOY, Illinois, U.S.A.

Summerfield, R.J., Minchin, F.R., Roberts, E.H. and Hardley, P. (1979). Effect of day length, day and night temperature on growth, reproductive development and seed yield of chickpea (Cicer arietinum L.) Univ. of Reading - ICRISAT, Internal communication No.2, 29 pp.

Summerfield, R.J., Minchin, F.R., Roberts, E.H. and Hardley, P. (1980). The effects of photoperiod and air temperature on growth and yield of chickpea (Cicer arietinum L.). Proceedings of the International Workshop on chickpea Improvement, 28 Feb. - 2 March, 1979 at Hyderabad, pp. 121.

Summerfield, R.J., Minchin, F.R., Roberts, E.H. and Hardley, P. (1981). Adaptation to contrasting aerial environments in chickpea (Cicer arietinum L.). Tropical Agriculture. 2 : 97-113.

Summerfield, R.J. and Wein, H.C. (1979). Effect of photoperiod and air temperature in growth and yield of economic legumes. pp. 17-36. In Advances in Legume Science, R.J. Summerfield and A.H. Bunting Ed. Her Mejesty's Stationery Office, London.

Sur, S.C., Gupta, K.S. and Sen, S. (1966). Optimum time of sowing gram in West Bengal. Ind. J. Agri. Sci. 36 : 173-179.

Swaraj, K. and Garg, O.P. (1969). Effect of treatment of growing apices of Cicer arietinum with Ascorbic acid and GA on nodulation and N-fixation. Indian J. Plant Physiol. 12 : 38-47.

Swaraj, K. and Garg, O.P. (1970). The effect of GA when applied to the rooting medium on nodulation and N-fixation in gram. Physiol. Plant 23 : 747-754.

*Swen, M.A. (1933). Factors affecting flower shedding in soybean. Ph.D. Thesis. Univ. of Illinois.

Thomas, F. Judiath and Rafer, C. David. (1976). Photoperiodic control of seed filling for soybean. Crop Sci. 16 : 667-672.

Tickoo, J.C., Singh, S.P. and Mehra, R.B. (1974). Effect of TIBA in Bengal gram. Indian J. Genet. 34 : 805-808.

Ting, I.P. and Duggar, W.M. (1968). Non autotropic carbon-di-oxide metabolism in cacti. Bot. Gaz. 129 : 9-15.

Uprety, D.C. (1968). Effect of GA_3 and N-dimethyl amino succinic acid (B.995) on the growth and development of gram. Indian J. Agron. 13 : 17-19.

Usciati, M., Codaccioni, M. and Mazliak, P. (1974). Lipogenisis modification induced by application of 6, Benzyl amino purine to inhibited axillery buds of Cicer arietinum L. Pl. Sci. Let. 2 : 295-301.

*Usciati, M., Sansoneti, A. and Gueru, J. (1974). Response of the base of an axillery bud of Cicer arietinum L. to the application of 6, Benzyl amino purine. Compt. rend. Acad. Agr. (France) 275 : 165-167.

van der Maesen, L.J.G. (1972). Cicer L. A Monograph of genus with special reference to chickpea (Cicer arietinum L.), its ecology and cultivation. Mededelingen Landbowhogeschool, Wageningen, Netherlands. No.72-10. 342 pp.

van Dobben, W.H. (1963). The physiological background of the reaction of peas to sowing time. Jaarb. I.B.S. 41-49.

van Schaik and Probst, A.H. (1958). Effect of some environemntal factors on flower production and re-productive efficiency. Agron. J. 50 : 192-197.

Varma, S.K. and Promila Kumari (1980). Nature, extent, periodicity and intensity of flower and pod shedding in gram (Cicer arietinum L.) Legume Research 1 : 108-114.

Verma, S.C. and Lal, B.M. (1966). Physiology of Bengal gram. 2. Changes in phosphorus compounds during ripening of seed. J. Sci. Food Agric. 17 : 43-46.

Verma, S.C., Lal, B.M. and Ved Prakash. (1964). Physiology of Bengal gram. 1. Changes in the chemical composition of the seed parts during ripening of Bengal gram seed. J. Sci. Food. Agric. 15-1 : 25-31.

Watson, D.J. (1952). The physiological basis of variation in yield. Adv. Agron. 4 : 101-145.

Weier, T. and Stocking, C. (1952). The chloroplast structure, inheritance and enzymology. Botn. Rev. 18 : 14-16.

---

* Originals not seen.

Appendix XIII Percentage distribution of RNA and DNA in floral parts in chickpea

Cultivar	JG-62				L-550				BG-209			
	Normal		Abscised		Normal		Abscised		Normal		Abscised	
Floral part	RNA	DNA	RNA	DNA	RNA	DNA	RNA	DNA	RNA	DNA	RNA	DNA
Peduncle	8.7	1.1	7.8	1.8	2.2	2.5	2.3	2.3	2.1	4.2	1.8	5.0
Pedicel	6.9	4.4	4.6	3.6	0.9	2.8	1.9	1.5	1.8	6.4	2.7	3.8
Calyx	3.9	1.4	7.7	1.4	0.7	0.8	3.0	2.2	2.0	4.6	3.7	6.1
Corolla	7.3	6.2	11.7	4.7	2.2	1.9	3.0	1.9	2.7	6.9	3.5	7.6
Androecium and Gynoecium	73.4	86.9	66.3	88.4	93.9	92.0	89.8	92.0	91.4	77.9	88.3	77.4

Appendix.XIV Nucleic acid content in normal and abscised flowers, pod, pod wall and seed in chickpea cv. L-550.

Size	Part	mg/g Fresh weight			
		Normal		Abscised	
		RNA	DNA	RNA	DNA
-	Flower	2.848	0.641	2.323	0.642
1	Pod (0.4 mm x 0.9 mm)	4.583	0.656	18.560	0.256
2	Pod (1.0 mm x 1.9 mm)	11.643	0.671	18.00	0.250
3	Pod (2.4 mm x 1.4 mm)	17.850	0.903	2.503	0.248
	Pod wall (3)	11.322	0.446	19.000	0.180
	Seed (3)	6.528	0.457	6.030	0.068

Appendix. XV Dry weight of floral parts of chickpea

Cultivar / Floral parts	Dry weight in mg		
	JG-62	L-550	BG-209
Peduncle	1.4	1.6	1.4
Pedicel	1.0	1.4	1.0
Calyx	2.6	2.5	2.6
Corolla	7.3	9.4	7.3
Andrœcium and Gynoecium	3.0	3.9	2.0
Whole flower	15.3	18.8	14.3