

Production Potential of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] as Influenced by Sowing Time, Plant Density and Fertilizer Levels.

**खोज [/ कबली / वसुधैकुर्वित् ¼ य-½ वसुधै] ध मरि कनु {कक
ij cqlbzI e;} ikni ?KRo ,oamo]d Lrjkd k iKko**

Thesis
Submitted to the
**Maharana Pratap University of Agriculture
and Technology, Udaipur**
In Partial Fulfilment of the Requirement for
the Degree of
Master of Science
In the
Faculty of Agriculture
(Agronomy)



By
BAHADUR
2003

**MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND
TECHNOLOGY, UDAIPUR**

RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR

CERTIFICATE – I

Dated: 05/07/2003

This is to certify that **Mr. Bahadur** has successfully completed the Comprehensive Examination held on 26 February, 2003 as required under the regulation for the degree of **Master of Science in Agriculture**.

(Dr. H.S. Dungarwal)
Professor & Head
Department of Agronomy
Rajasthan College of Agriculture
Udaipur (Raj.)

**MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND
TECHNOLOGY, UDAIPUR**

RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR

CERTIFICATE – II

Dated: 05/07/2003

This is to certify that, this thesis entitled “**Production Potential of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] as Influenced by Sowing Time, Plant Density and Fertilizer Levels**” submitted for the degree of **Master of Science in Agriculture** in the subject of **Agronomy**, embodies bonafide research work carried out by **Mr. Bahadur** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on 3rd July, 2003.

(Dr. H.S Dungarwal)
Head
Department of Agronomy

(Dr. P.C. Chaplot)
Major Advisor

(Dr. G.S. Sharma)
Dean
Rajasthan College of Agriculture,
Udaipur

**MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND
TECHNOLOGY, UDAIPUR**

RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR

CERTIFICATE – III

Dated: ___/___/2003

This is to certify that, the thesis entitled “**Production Potential of Clusterbean [Cyamopsis tetragonoloba (L.) Taub] as Influenced by Sowing Time, Plant Density and Fertilizer Levels**” submitted by *Mr. Bahadur* to the Maharana Pratap University of Agriculture and Technology, Udaipur in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** in the subject of **Agronomy** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination on his thesis has been found satisfactory, we, therefore, recommend that the thesis be approved.

(Dr. P.C. Chaplot)
Major Advisor

(Dr. V. Nepalia)
Advisor

(Dr. S.C. Bhandari)
Advisor

(Dr. H.S. Purohit)
DRI Nominee

(Dr. H.S. Dungarwal)
Head
Department of Agronomy

APPROVED

(Dr. L.L. Somani)

Director, Resident Instructions
Maharana Pratap University of Agriculture & Technology,
Udaipur (Raj.)

**MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND
TECHNOLOGY, UDAIPUR**

RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR

CERTIFICATE –IV

Dated: ___/___/2003

This is to certify that **Mr. Bahadur** of the Department of **Agronomy**, Rajasthan College of Agriculture, Udaipur has made all corrections/modifications in the thesis entitled “**Production Potential of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] as Influenced by Sowing Time, Plant Density and Fertilizer Levels**” which were suggested by the external examiner and the advisory committee in the oral examination held on_____. The final copies of the thesis duly bound and corrected were submitted on_____are enclosed herewith for approval.

(Dr. P.C. Chaplot)
Major Advisor

(Dr. G.S. Sharma)
Dean
Rajasthan College of Agriculture
Udaipur

(Dr. H.S. Dungarwal)
Head
Department of Agronomy
Rajasthan College of Agriculture
Udaipur

“Production Potential of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] as Influenced by Sowing Time, Plant Density and Fertilizer Levels”

Bahadur*

Dr. Prakash ChanDra

Chaplot**

Research Scholar

Major

Advisor

ABSTRACT

The field experiment entitled “**Production Potential of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] as Influenced by Sowing Time, Plant Density and Fertilizer Levels”** was conducted on clay loam soil at the Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Udaipur, during *Kharif* season of the year 2002. The objective were to find out the optimum time of sowing, to study the effect of plant density and balanced mineral nutrition on productivity of clusterbean crop.

The experiment consisted of 24 treatment combinations comprising of four sowing time viz., 25th June (standard week no. 26), 2nd July (standard week no. 27), 9th July (standard week no. 28) and 16th July (standard week no. 29), two plant density viz., 3.33 lacs ha⁻¹ (30 cm x 10 cm) and 4.44 lacs ha⁻¹ (22.5 cm x 10 cm) and three fertilizer levels (10 + 20, 20 + 40 and 30 + 60 kg N + P₂O₅ ha⁻¹). These treatment combinations were evaluated under split plot design with three replications, allocating sowing time and plant density in main plots while fertilizer levels were assigned in sub plots.

The results revealed that clusterbean sown with the onset of monsoon (25th June) recorded significantly higher values of plant height, branches plant⁻¹ and dry matter accumulation. The crop sown on 25th June took significantly longer duration for flowering and maturity and recorded significantly higher values of yield attributes namely pods plant⁻¹ (28.11), test weight (29.08) and seed yield plant⁻¹ (5.97 g). These improvement manifested in realization of higher productivity in term of seed (16.99 q ha⁻¹), haulms (41.66 q ha⁻¹) and biological (58.65 q ha⁻¹) yield representing increases of 14.64, 15.53, 15.27 and 18.98, 21.99, 21.10 per cent compared to delayed sowings i.e. 9th and 16th July sowing, respectively but was found at par with 2nd July sown crop. Crop sown on 25th June, accumulates significantly higher quantum of N, P and K in seed, haulms and thus total. Likewise, aforesaid sowing time fetched highest net returns of Rs. 14262 ha⁻¹ and B: C ratio 3.36 thereby increased net profit by Rs. 690, 2628 and 3327 ha⁻¹ over crop sown on 2nd, 9th and 16th July sowings, respectively.

Crop under plant density of 3.33 lacs ha⁻¹ significantly improved growth parameters and yield attributes (pods plant⁻¹ and seed yield plant⁻¹) over plant density of 4.44 lacs ha⁻¹. While plant density failed to record significant gain in seed, haulms and biological yield. The total N uptake was higher under lowest plant density of 3.33 lacs ha⁻¹. The aforesaid plant density gave highest net returns of Rs. 12806 ha⁻¹ with B: C ratio of 3.14 indicating gains of Rs. 411 ha⁻¹ over plant density of 4.44 lacs ha⁻¹.

Addition of fertilizer upto 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved plant height, branches plant⁻¹ days to flowering and dry matter accumulation plant⁻¹. However, fertilizer application of 20 + 40 kg N + P₂O₅ ha⁻¹ significantly improve all yield attributes except seeds pod⁻¹ which showed response upto application of 30 + 60 kg + P₂O₅ ha⁻¹. Consequently the crop fertilized with 30 + 60 kg N + P₂O₅ ha⁻¹ produced highest seed, haulms and biological (16.61, 40.46 and 57.07 q ha⁻¹) yield which was significantly higher over 20 + 40 and 10 + 20 kg N + P₂O₅ ha⁻¹. However, N and P content in seed and haulms significantly improved upto application of 30 + 60 kg N + P₂O₅ ha⁻¹. While protein and gum content of seed significantly improved upto application of 20 + 40 kg N + P₂O₅ ha⁻¹. Further increase in fertilizer level failed to exhibit significant superiority. The uptake of N, P and K by seed, haulms and total uptake showed significant response upto application of highest level 30 + 60 kg N + P₂O₅ ha⁻¹. The aforesaid fertilizer level fetched significantly higher net returns (Rs. 13337 ha⁻¹) representing gains of Rs. 565 and 1644 ha⁻¹ over preceding levels (20 + 40 and 10 + 20 kg N+P₂O₅ ha⁻¹).

The combined effect showed that crop sown on 25th June with plant density of 3.33 lacs ha⁻¹ fertilized with 30 + 60 kg N + P₂O₅ ha⁻¹ recorded highest seed (18.20 q ha⁻¹) and haulms (45.21 q ha⁻¹) yield with net returns of Rs. 15379 ha⁻¹ and B: C ratio of 3.39.

Xokj [/ kbEhE/ / Vb/ks/ky/ksk ¼ y-½ VmE] dh mRiknu {kerk ij cøkbZ l e;} ikni ?kURo ,oamo]d Lrjka dk iHko

cglnj*
"kkskdrkZ

MWidk" k plhz piyk**
e[; l ykgdkj

vuqki .k

, d i{ks= l ájh{k.k ^Xokj [/ kbEhE/ / Vb/ks/ky/ksk ¼ y-½ VmE] dh mRiknu {kerk ij cøkbZ l e;} ikni ?kURo ,oamo]d Lrjka dk iHko** "khr'kd ds vUr'kr jktLFkku df'k egfok | ky; ds l L; foKku foHkx ds ijh{k.k kRRed i{ks= dh Dys nkeV enk ij o'kZ 2002 dh [kjhQ __rq ea vk; kstr fd; k x; kA l ájh{k.k ds mIs'; ka e] cøkbZ dk mfpr l e; Kkr djuk] ikni ?kURo ,oa l rfyfyr [kfut iksk.k dk Xokj dh mRikndrk ij iHko dk v/; ; u djuk Fkka

l ájh{k.k ds 24 mi pkj l a kstuka ea pkj cøkbZ l e; ftl e] 25 tuu vekud l lrg l [; k 26½ 2 tgykbZ vekud l lrg l [; k 27½ 9 tgykbZ vekud l lrg l [; k 28½ ,oa 16 tgykbZ vekud l lrg l [; k 29½ nks idkj dk ikni ?kuRo ftl ea 3-33 yk[k gs^{&1} 180 l eh- X 10 l eh-½ o 4-44 yk[k gs^{&1} 122-5 l eh- X 10 l eh-½ v[; rhu mo]d Lrj ¼10 +20] 20 +40],oa 30 +60 fdxt-u=tu + OkLQkj l gs^{&1}½ FkA bu mi pkj l a kstuks dk eV; kdau foi kfVr [k.M vfHkdYi uk ea rhu i pjkofr; ka ds l kfk fd; k x; kA cøkbZ ds l e; ,oa ikni ?kuRo dks e[; [k.Mks ea tcf d mo]d Lrjka dks mi [k.Mka ea j [kk x; kA

ifj.kke n"klz-a gð fd ekul uu ds "kq vkr ds l kfk ¼25 tuu½ cks h xbZ Xokj dh Ql y ea i k[ka dh mpk[] "kk[kk; a ifr i k[ka v[; "kq d inkfZ dk l p; u l kfkZd : i l s vf/kd ntZ fd; k x; kA 25 tuu dks cks h xbZ Xokj dh Ql y }kjk Qny vkus o idus ds fy, l kfkZd : i l s vf/kd l e; fy; k x; k rFk l kfkZd : i l s vf/kd mit dkj dka dk eku] ftl ea Qfy; k; i k[ka^{&1} ¼28-11½ , d gtkj chtka dk otu ¼29-08 xte½ v[; cht mit ifr i k[ka ¼5-97 xte i k[ka^{&1}½ ntZ fd; k x; kA ; s l qkkj Ql y dh vf/kd mRikndrk dh ol nyh ftl ea cht ¼16-99 fDo- gs^{&1}½ Hkk k ¼41-66 fDo- gs^{&1}½ v[; t[od ¼58-65 fDo- gs^{&1}½ mit ds : i ea 0; Dr gqA tks nj l s cks h xbZ Ql y t[s 9 ,oa 16 tgykbZ l s Øe" k% 14-64] 15-53] 15-27 v[; 18-98] 21-99] 21-10 ifr"kr vf/kd ik; h xbZ ; g mit 2 tgykbZ dks cks h xbZ Ql y ds l kfk vl kfkZd fl) g[25 tuu dks c"; h xbZ Ql y }kjk u=tu] OkLQkj l ,oa i k[ka" ds cht e] Hkk s ea ,oa l Ei wkZ i k[ka ea l kfkZd : i l s vf/kd l p; u fd; k x; kA bl h idkj mi jkDr cøkbZ l e; }kjk l okZ/kd "kq ykHk 14262 : - gs^{&1} ,oa ykHk % ykxr vuq kr 3-36 i ktr fd; k x; kA bl fy, 2] 9 ,oa 16 tgykbZ cøkbZ l s "kq ykHk Øe" k% 690] 2628 v[; 3227 : - gs^{&1} c<kA

* Lukrdlkj Nk=] l L; foKku foHkx] jktLFkku df'k egfok | ky;] mn; ij
** l gk; d v[ok;] l L; foKku foHkx] jktLFkku df'k egfok | ky;] mn; ij

3-33 yk[k ikni g^{s1} ikni ?kukRo okyh Ql y us of) ,oa mit dkjdka ¼Qfy; k ikk^{s1}
 ,oa cht mit ikk^{s1}½ d 4-44 yk[k ikni ?kuRo dh ctk, l kfkZd : i lsl dkkjka tcf d ikni
 ?kuRo cht] Hkk k ,oa tšod dh mit ij l kfkZd iHkko Mkyus ea vl Qy jghA l cl s de ikni
 ?kukRo 3-33 yk[k ikni g^{s1} ea dty u=tu dk mnxg.k vf/kd ik; k x; kA mijkš ikni ?kuRo us
 3-14 ds ykHk %ykxr vujkr ds l kfk mPpre 12806 : - g^{s1} "kq ykHk fn; k tks fd 4-44 yk[k
 ifr ikni ?kuRo ij 411 : - g^{s1} ikflr dks l dšrd dj jgk gA

30 +60 fdxt- u=tu +QkLQkj l g^{s1} mojd ds l ekosk us ikkka dh Åpkb] "kk[kk; a
 i kškk^{s1}] i kškk ea Qy vkus ds fnuka ,oa "kqd inkfkZ l p; u ikk^{s1} dks l kfkZd : i lsl dkkjka
 gkykfd 20 +40 fdxt- u=tu +QkLQkj l g^{s1} Mkyus l s cht Qyh^{s1} ds vykok l Hkh mit
 dkjdka ea l kfkZd : lk lsl dkkj gq/kA ftuea 30 +60 fdxt- u=tu + QkLQkj l g^{s1} mojd nh xbZ
 Ql y us l okZ/kd cht] Hkk k o tšod ¼16-61] 40-46 rFkk 57-07 fDo- g^{s1}½ mit išk dh tks fd
 20 +40 ,oa 10 +20 fdxt- u=tu +QkLQkj l g^{s1} lsl kfkZd : i lsvf/kd FkA gkykfd cht o
 Hkk k ea u=tu rFkk QkLQkj l fd ek=k e] 30 +60 fdxt- u=tu +QkLQkj l g^{s1} Mkyus rd
 l kfkZd : i lsl dkkj gq/k tcf d išk/hu o xe dh ek=k ea 20 +40 fdxt- u=tu +QkLQkj l g^{s1}
 Mkyus rd l kfkZd : i lsl dkkj gq/kA mojd Lrjka eafQj l sof) l kfkZd : i lsl dkkj fn[kkus ea
 vl Qy jghA cht] Hkk k o l Eiwk ikni }kjk dty u=tu] QkLQkj l o išk/k" k ds mnxg.k dk
 l kfkZd vuttko mojdka ds vf/kdre Lrj] 30 +60 fdxt- u=tu +QkLQkj l g^{s1} rd fd; k x; kA
 mijkš mojd Lrj }kjk l kfkZd : i lsvf/kd "kq ykHk ¼13337 : - g^{s1}½ vft r fd; k x; k tks
 fd 20 +40 rFkk 10 +20 fdxt- u=tu +QkLQkj l g^{s1} Lrjka l s Øe" k% 565 rFkk 1644 : - g^{s1}
 vf/kd FkA

mi pkjka dk l feefyr iHkko n"kkz k gS fd 25 tuu dks cks h xbZ Ql y 3-33 yk[k g^{s1}
 ikni ?kuRo ds l kfk ftl ea 30 +60 fdxt- u=tu +QkLQkj l g^{s1} mojd Lrjka dks iz; šx fd; k
 x; k Fk ftl ea 18-20 fDo- g^{s1} cht ,oa 45-21 fDo- g^{s1} Hkk k dh mit ds l kfk ykHk 15379 : -
 g^{s1} vkš ykHk %ykxr vujkr 3-39 iklr fd; k x; kA

1 INTRODUCTION

Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] popularly known by its vernacular name “Guar” is an ancient multipurpose legume grown for seed, green fodder, vegetables and green manuring. Besides conventional uses, clusterbean has emerged as an industrial crop because of the presence of galactomannan (guar gum) in its endosperm, which constitutes about 30-35 per cent of seed weight. Guar gum has diversified uses in textile, paper, petroleum, mining, cosmetic oil, pharmaceutical, explosives, purification of potash, photography, tobacco and food industries. Guar seed meal, a by product of guar gum industry, forms concentrated animal feed of immense value as it contains more than 42 per cent protein against 31 per cent in guar seed.

Clusterbean is an important foreign exchange earning crop. The export of guar gum was 90530 MT earning Rs. 725 crores during 1998-1999 (Fertilizer Statistics, 2001-02). Out of the total global production of guar gum, India is in a leading position with 50 per cent share followed by 45 per cent by Pakistan.

Being a deep rooted and drought hardy, clusterbean has occupied large areas in arid and semiarid tracts. India has the largest area (19.22 Lac ha.) and production (4.8 Lac tonnes) with average productivity of 249.74 kg ha⁻¹. The crop is mainly grown in Rajasthan, Gujarat, Haryana, Punjab and Uttar Pradesh. Rajasthan ranks first in respect of both area and production, where it is grown is 2.64 hectare area with production of 2.31 lac tonnes (AICGIP, 2001). However, average productivity is only 157 kg ha⁻¹ (Govt. of Rajasthan, 2001). The higher genetic potential upto 19 q ha⁻¹ (Singh and Singh, 1989) and realizable yield upto 10.5 q ha⁻¹ suggests ample scope for increasing productivity in India as a whole and Rajasthan in particular. The low yield of crop considered mainly due to cultivation of traditional low yielding varieties, without or with little fertilization and lack of other improved agronomic practices. Thus, it offers a great scope for increasing its productivity through sound crop husbandry.

The most important non-monetary and preliminary agronomic aspect of crop production technology is the optimum sowing time. Optimum length of crop growing season is needed to exploit the environmental factor for proper vegetative and

reproductive growth, which is a prime necessary to realize express maximum production potential of a crop.

The optimum time of sowing varies from area to area depending upon climatic conditions and onset of monsoon. Sowing early as well as late reduce the crop yield (Sharma *et al.*, 1984). Late sowing of clusterbean reduces the yield significantly due to moisture stress at later stage of crop. Therefore, assessment of appropriate sowing date will not only help in balanced development during vegetative and reproductive phases of clusterbean but also help to improve productivity of crop. It has been stated that plants can realize its genetically programmed phasic development under certain ranges of environmental factors. Thus, weather conditions to which the crop is exposed during its life cycle is considered to be principal input parameter affecting its productivity despite availability of other input parameters and improved crop husbandry practices (Mavi, 1986). Therefore, evolving appropriate sowing time under prevailing conditions seems to be of paramount importance for achieving higher yields with least cost.

Amongst cultural manipulations, maintenance of optimum plant population through appropriate geometry is the most important factor for achieving higher yield. The maintenance of optimum plant population, which exerts near maximum pressure to exploit environmental resources to the fullest extent thereby leading to higher yield of clusterbean. The investigations on this aspect have clearly indicated that the population density in clusterbean needs to be adjusted as per growth habit of variety, sowing time, prevailing agroclimatic conditions etc. Thus there is a need to work out optimum population density by adjusting inter and intra-row spacing in relation to sowing time and other agronomic factors.

The clusterbean crop is generally grown on marginal and sub-marginal lands without or with nominal application of fertilizers. Hence, adequate fertilization is considered to be important factor for achieving higher yield. Amongst nutrients, nitrogen plays an important role in synthesis of chlorophyll, amino acids and other organic compounds of physiological significance in plant system. It also helps in early establishment of leaf area capable of photosynthesis and increased root development to enable more efficient use of water. Clusterbean being a leguminous crop can meet its nitrogen requirement through symbiotic nitrogen fixation. However, starter dose of nitrogen is needed to meet its initial requirement. Next to nitrogen, phosphorus is of paramount importance for increasing yield. Phosphorus apart from its role in root

development and nodule formation, plays important role in energy transfer in the living cells by means of high energy phosphate bond of ATP. Thus, it plays important role in formation and translocation of carbohydrates, fatty acids, glyceroids and other essential intermediate compounds. Therefore, there is need to work out optimum combination of nitrogen and phosphorus fertilization for clusterbean under prevailing agro-climatic conditions.

Since, a very little published information is available on all these aspects of clusterbean crop particularly under clay loam soils of subtropical climatic conditions of Udaipur region. The present investigation entitle “Production Potential of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] as Influenced by Sowing Time, Plant Density and Fertilizer Levels” was, undertaken with the following objectives.

- To assess the effect of various sowing time, plant density and fertilizer levels on growth and yield of clusterbean
- To work out optimum spacing and fertilizer dose for higher productivity
- To study the interaction effect, if any

2 REVIEW OF LITERATURE

A brief review related to the research work done on "Production Potential of Clusterbean [*Cyamopsis tetragonoloba* (L.) Tab] influenced by Sowing Time, Plant Density and Fertilizer Levels" is presented in this chapter. Since the work done on effect of sowing time, plant density and combined use of N and P fertilization particularly on clusterbean is meagre, hence to elucidate importance of these agronomic factors on other pulse crops have been incorporated whenever deemed necessary.

2.1 EFFECT OF SOWING TIME

2.1.1 Growth parameters:

At PAU Ludhiana, late sown crop (3rd August) matured eight to ten days earlier than earlier sowing on 6th July (Bains and Dhillon, 1977). Under irrigated conditions, plant height of clusterbean var. G-80 was significantly higher by 7 cm and 30 cm, when crop was sown on 15th June compared to 30th June and 15th July sowings, respectively. But under unirrigated conditions, sowing dates failed to significantly effect growth characters (AICGIP, 1988). Meena (1988) while working at Jobner, recorded significantly higher plant height, branches plant⁻¹ and dry matter accumulation by clusterbean under earlier sowing i.e. 15th June over that of later sowing (30th June and 15th July). At Banaskantha (Gujrat), plant height and branches plant⁻¹ were higher by 34.2 cm and 36.63 per cent, respectively when crop was planted with the onset of monsoon compared to crop planted 20 days later (AICGIP, 1990). Similarly at Gwalior (MP), early sown (6th July) crop recorded significantly higher plant height by 13.6 and 25.5 cm over late i.e. 17th and 27th July sowings, respectively (AICGIP, 1990). At Udaipur, clusterbean sown early (26th June) attained significantly higher plant height by 10.8 cm, 31 cm, primary and secondary branches plant⁻¹ by 14.08, 24.62 and 17.02, 27.91 per cent weight of effective nodules plant⁻¹ by 12.25, 22.51 per cent over normal (10th July) and late (24th July) sowings, respectively (Palsaniya, 2002).

2.1.2. Yield attributes:

Bains and Dhillon (1977) reported that early sown (6th July) crop produced significantly higher clusters plant⁻¹ by 34 and 63 per cent over the crop planted timely (17th July) and late (3rd August), respectively. Similarly, number of pods plant⁻¹ and seeds pod⁻¹

were also significantly higher in early planted crop. At Bhatinda under irrigated conditions, clusterbean var. G-80 produced significantly higher seed yield plant⁻¹ by 11.39 per cent when sown timely (30th June) over early (15th June) sown crop. While seeds pod⁻¹, seed index, and pods plant⁻¹ were not significantly influence by variation in sowing time. However, under unirrigated conditions, aforesaid variety produced significantly higher seed yield plant⁻¹, seeds pod⁻¹, and 100 grain weight by 32.79, 11.11, 16.22 and 15.71, 16.67, 10.26 per cent when sown timely (30th June) over early (15th June) and late (15th July) sowings, respectively. But pods plant⁻¹ were not influence due to sowing dates (AICGIP, 1988). Likewise at Jobner, clusterbean sown on 15th and 30th June produced significantly higher pods plant⁻¹ and seeds pod⁻¹ over 15th July sowings by 23.10, 17.62 and 5.80, 6.00 per cent, respectively (Meena, 1988). At Banaskantha (Gujrat), clusterbean sown with the onset of monsoon produced significantly higher pods plant⁻¹, seeds pod⁻¹, clusters plant⁻¹ and weight of 100 grain to the tune of 52.23, 11.11, 15.95 and 6.13 per cent, respectively over crop planted 20 days later (AICGIP, 1990). Contrary at Gwalior (MP), late sown crop (17th July) recorded significantly higher number of pods plant⁻¹ and pod length by 10.04, 2.57 and 37.80, 1.36 per cent over timely (6th July) and very late (27th July) sowings, respectively (AICGIP, 1990). Bhadoria and Chauhan (1994) reported that sowing of clusterbean on 10th July produced 40.22, 38.16, 10.97 and 24.43, 20.20, 8.92 per cent higher number of clusters plant⁻¹, pods plant⁻¹ and test weight over that produced under 25th July and 8th August sowings, respectively. Likewise at Udaipur, crop sown early (26th June) attained significantly highest number of pods plant⁻¹, test weight and seed yield plant⁻¹ by 12.98, 2.01, 17.45 and 40.98, 6.10, 43.20 per cent compared to crop sown on 10th and 24th July, respectively (Palsaniya, 2002).

2.1.3 Yield:

At Ludhiana, Bains and Dhillon (1977) recorded highest seed yield (11.9 q ha⁻¹) of clusterbean when crop sown on 6th July compared to sowing on 20th July and 8th August. Likewise at Jodhpur, clusterbean crop sown on 21st July produced significantly higher seed yield by 96 per cent over crop sown on 13th August (AICRPDA, 1979). At the same location, sowing of clusterbean in the second fortnight of July (12th July) recorded 47.8 per cent higher seed yield over crop sown one month later (2.3 q ha⁻¹). Similarly at Agra (UP), crop planted in second fortnight of July gave significantly highest seed yield (13.8 q ha⁻¹) representing increase of 6.91 and 51.60 per cent over later sowings by 10 and 20 days, respectively (AICRPDA, 1980). Under rainfed conditions, clusterbean varieties gave higher seed yield when sown upto 15th July (Singh *et al.*, 1980). Significantly higher seed yield of clusterbean sown in first fortnight of July in comparison to late sowing have also been noted by Ali (1982). At Hissar, clusterbean sown on 5th July produced significantly higher seed yield by

38.02, 20.99 and 48.48 per cent than sown on 20th June, 20th July and 5th August, respectively (Sharma *et al.*, 1984). At Jobner, sowing of clusterbean on 15th June produced the significantly highest yield of 8.5 q ha⁻¹ as compared 7.9 and 7.5 q ha⁻¹ obtained under 30th June and 15th July sowings, respectively (Meena, 1988). Under irrigated conditions, 30th June sown crop produced the highest seed yield (16.5 q ha⁻¹) which was significantly higher by 11.40 per cent over 15th June sown crop. However, under unirrigated conditions, 30th June sowing improved seed yield by 15.32 and 14.60 per cent over 15th June and 15th July sowings, respectively but to the non-significant extent (AICGIP, 1988). Conversely at Banaskantha (Gujrat), variation in sowing time did not significantly affect seed yield of clusterbean (AICGIP, 1990). While at Gwalior (MP), sowing of clusterbean on 6th July was found optimum time as it produced 18.78 and 8.44 per cent higher seed yield over 17th and 27th July planted crop, respectively (AICGIP, 1990). Normal sown crop produced 16.51 per cent higher seed yield than late sown crop at Hissar have also been reported under the auspices of AICGIP (1993). Bhadoria and Chauhan (1994) reported that sowing of clusterbean on 10th July produced maximum seed yield (16.85 q ha⁻¹) while sowing beyond this period i.e. 25th July and 8th August reduced the seed yield by 13.41 and 24.63 per cent, respectively. Palsaniya (2002), reported that early sowing (26th June) significantly increased the seed yield by 10.58 and 28.04 per cent over normal (10th July) and late sowing (24th July), respectively.

2.1.4 Quality:

Bains and Dhillon (1977) reported that percentage of crude protein and gum content were not affected significantly by sowing dates. However, the late sowing (15th and 25th July) slightly increased the percentage of crude protein as compared to earlier sowing (6th July). While at Hissar, Sharma *et al.* (1984) estimated highest crude proteins content (33.81 per cent) in clusterbean seed under 5th July sowing compared to 20th June, 20th July and 5th August sowings. Similarly at Jobner, protein content in clusterbean seed was significantly higher under 15th June sowing than crop sown beyond this period i.e. 30th June and 15th July (Meena, 1988). Protein content in clusterbean seed was not influenced significantly by sowing time have also been reported by Palsaniya (2002).

2.1.5 Nutrient content and uptake:

Clusterbean sown on 30th June accumulated higher N content in seed compared to 15th June and 15th July sowings. While seed produced under 30th June and 15th July sowings had higher N content in straw over 15th June sowing (Meena *et al.*, 1988). Crop sown on 26th June accumulated higher quantum of nutrients in seed and straw thereby significantly

increased total uptake of N, P, and K to the extent of 11.31, 12.79, 11.68 and 29.21, 30.96, 30.59 per cent, respectively over 10th and 24th July sowing (Palsaniya, 2002).

2.2 EFFECT OF PLANT DENSITY/SPACING

2.2.1 Growth parameters:

At Jobner, clusterbean sown at 60 cm row spacing accumulated significantly higher dry matter plant⁻¹ by 15.04 and 21.53 per cent over 30 and 45 cm row spacings, respectively (Yadav, 1979). While Malik *et al.* (1981) failed to record significant influence on plant height and dry matter plant⁻¹ due to row spacings. Clusterbean sown under population density of 1.6 lac plants ha⁻¹ recorded significantly higher branches plant⁻¹ by 27.27 and 21.12 per cent over 2.2 and 3.3 lac plants ha⁻¹, respectively (Ali, 1982). But at Bhatinda (Punjab), branches plant⁻¹ and plant height were not influenced significantly due to sowing of clusterbean in rows at 30 and 45 cm apart (AICGIP, 1988). Similar trend was also recorded at Gwalior (AICGIP, 1990). On the other hand at Hissar, plants under closer row spacing of 30 cm attained 13 cm higher height compared to 45 cm row spacing (AICGIP, 1990). Row spacing did not significantly influence plant height and branches plant⁻¹ (Singh and Tiwana, 1995). At Hissar, crop sown 45 cm apart produced higher number of branches plant⁻¹ and plant height compared to 30 cm row spacing (AICGIP, 1995). On the other hand row spacing of 30 cm recorded more plant height over 45 cm row spacing (AICRPAL, 1999). Likewise at Udaipur, Palsaniya (2002) found that population density of 3.33 lacs ha⁻¹ maintained through spacing of 30 cm x 10 cm produced significantly higher primary and secondary branches plant⁻¹ by 8.70 and 5.72 per cent, respectively over that recorded under 4.44 lacs ha⁻¹ (22.5 cm x 10 cm).

2.2.2 Yield attributes and yield:

While working at Ludhiana, Bains and Dhillon (1977) noted significant improvement in number of clusters and pods plant⁻¹ when clusterbean was sown at wider row spacing (45 cm and 60 cm) compared to closer row spacing (30 cm). However the seed yield was reduced by increasing row spacing and it was higher at 30 cm. At Jobner, crop sown in rows 60 cm apart significantly increased pods and seed yield plant⁻¹ over 30 cm but seed and straw yield were significantly higher under 30 cm row spacing over 60 cm (Yadav, 1979). On red loam soil of Jhansi, population

density of 2.2 lacs ha⁻¹ significantly increased pods plant⁻¹ and seed yield by 12.52 and 5.31 per cent, respectively compared to 3.3 lac plants ha⁻¹ (Ali, 1982). At Hissar, Sharma *et al.* (1984) found that crop sown at narrow row spacing of 30 cm produced significantly higher seed yield by 16.49 and 39.43 per cent over wider row spacing of 45 and 60 cm, respectively. On deep loamy soils of Bikaner, inter row spacing of 30 cm enhanced seed yield of clusterbean by 22 per cent compared to 45 cm row spacing (Kacker *et al.*, 1984). While at Hissar, Singh and Singh (1986) noted 14.72 q ha⁻¹ seed yield of clusterbean at plant population of 1 lacs ha⁻¹, which was significantly higher by 3.84 and 11.90 per cent over plant population of 1.25 and 1.5 lacs ha⁻¹, respectively. Further, they found that the row spacing of 45 and 60 cm gave 34.31 and 11.50 per cent more seed yield over 75 cm rows spacing. While at Bhatinda (Punjab), variation in row spacing failed to record significant influence on yield attributes and yield of clusterbean (AICGIP, 1988). But at Durgapura (Jaipur), 30 cm rows spacing gave significantly higher seed yield of 10.04 q ha⁻¹ compared to 9.10 q ha⁻¹ obtained under wider row spacing of 45 cm (AICGIP, 1989). Contrary to these findings, row spacing failed to brought about significant influence on yield and yield attributes of clusterbean crop at Bhatinda (AICGIP, 1990). While at Hissar, crop sown in rows of 45 cm apart produced significantly higher number of clusters, pods and seed yield plant⁻¹ by 34.69, 24.57 and 21.98 per cent, respectively over crop sown in rows 30 cm apart. However, both row spacings were at par with regards to seed yield (AICGIP, 1990). Bhadoria and Chauhan (1994) reported that inter-row spacing of 45 cm significantly improved number of clusters plant⁻¹, pods plant⁻¹ and test weight over spacing of 30 cm and increased the seed yield by 20.08 per cent. However, at Bhatinda, row spacing (30 and 45 cm) failed to alter yield attributes and yield of clusterbean (Singh and Tiwana, 1995). But at Hissar, crop sown at wider row spacing (45 cm) produced significantly higher number of pods plant⁻¹ and seed yield compared to 30 cm row spacing (AICGIP, 1995). At the same location, wider row spacing of 45 cm produced more number of pods and branches plant⁻¹, thus significantly increased seed yield by 7.82 per cent compared to narrow row spacing of 30 cm (AICRPAL, 1999). Similarly at Durgapura, closer spaced crop (30 cm) produced 5.53 per cent higher seed yield compared to 7.65 q ha⁻¹ obtained from wider spaced sown crop i.e. 45 cm apart (AICRPAL, 2000). In a multilocation trial conducted under AICRP on Arid Legume revealed that closer row spacing of 30 cm was found better than wider spacing at 45 cm in term of yield (AICRPAL, 2001).

Palsaniya (2002) reported that population density of 3.33 lacs ha⁻¹ maintained through spacing of 30 cm x 10 cm produced significantly higher number of pods and seed yield plant⁻¹ by 7.22 and 9.82 per cent, respectively over 4.44 lac plants ha⁻¹ (22.5 cm x 10 cm). Further, he failed to record significant variation on seed yield due to varying plant population.

2.2.3 Seed quality:

Singh *et al.* (1978) and Yadav (1979) failed to record significant variation on protein content of clusterbean seed due to varying plant population/row spacings. While, Sharma *et al.* (1984) recorded significantly higher protein content in guar seed by 13.90 per cent with medium spacing (45 cm) than wider spacing (60 cm). At Udaipur, Palsaniya noted 0.03 g 100g⁻¹ more protein content when crop was sown at 30 cm x 10 cm as compared to 45 cm x 10 cm spacing.

2.3 EFFECT OF FERTILIZER LEVELS

2.3.1 Growth parameters :

On sandy loam soils of Bichpuri (UP), application of 20 kg N ha⁻¹ significantly improved nodules plant⁻¹ by 5.12 per cent over control (Singh and Singh, 1989). Chauhan and Bajpai (1979) recorded maximum dry matter (22.49 g plant⁻¹) with 90 kg P₂O₅ ha⁻¹ which was significantly higher over 60 kg P₂O₅ ha⁻¹ by 17.73 per cent. Beneficial effect upto application of 60 kg P₂O₅ ha⁻¹ on root nodules and root weight were also noticed by Taneja *et al.* (1981). At New Delhi, Kumar (1987) reported that application of 40 kg P₂O₅ ha⁻¹ increased plant height, branches plant⁻¹ and dry matter over control. At Agra, application of 60 kg P₂O₅ ha⁻¹ significantly improved nodules plant⁻¹ and root dry weight by 18.18 and 20.00 per cent, respectively over control (Singh and Singh, 1989). At Jobner, application of 40 kg P₂O₅ ha⁻¹ significantly increased plant height and dry matter of clusterbean over control (Meena, *et al.*, 1991). Similarly, plants under influence of 40 kg P₂O₅ ha⁻¹ attained maximum plant height and dry matter accumulation over control (Shivran, 1994). While at Bhatinda, application of 60 kg P₂O₅ ha⁻¹ significantly increased the plant height by 19.4 cm over control (Singh and Tiwana, 1995). However, at Udaipur, Pareek (1995) confirmed positive influence of phosphorus fertilization upto 40 kg P₂O₅ ha⁻¹ and increased the plant dry matter by 7.60 and 4.86 per cent, respectively

over control. On sandy loam soils having low P status, clusterbean crop showed positive response upto 40 kg P₂O₅ ha⁻¹ as it increased plant height and dry matter by 5.7 cm and 14.86 per cent, respectively over 20 kg P₂O₅ ha⁻¹ (Shivran *et al.*, 1996). At Gwalior, increasing level of P₂O₅ upto 60 kg ha⁻¹ significantly increased the plant height, branches plant⁻¹ and clusters plant⁻¹ of clusterbean by 8.40, 15.66, 20.87 and 11.82, 17.88, 25.71 per cent, respectively over 40 and 20 kg P₂O₅ ha⁻¹ (Bhadoria *et al.*, 1997). At Bikaner, increasing level of P₂O₅ upto 40 kg ha⁻¹ significantly increased plant height by 4.8 cm and 12.1 cm over 20 kg P₂O₅ ha⁻¹ and control, respectively (Solanki *et al.*, 1998). While at Jobner, crop under the influence of 30 kg P₂O₅ ha⁻¹ significantly improved plant height, dry matter accumulation and branches plant⁻¹ over control, 10 and 20 kg P₂O₅ ha⁻¹ (Dadhich *et al.*, 2001). Significant improvement in plant height, branches plant⁻¹ and dry matter accumulation due to application of 40 kg P₂O₅ ha⁻¹ was also noted by Reager (2001).

Consistent improvement in different growth parameters of clusterbean were estimated under the influence of 40 + 80 kg N + P₂O₅ ha⁻¹ compared to control and 20 + 40 kg N + P₂O₅ ha⁻¹ (Dahiya *et al.*, 1996). On sandy loam soils having medium N and P status, application of 30 + 60 kg N + P₂O₅ ha⁻¹ significantly increased nodules plant⁻¹ and their weight and dry matter accumulation plant⁻¹ by 41.81, 21.40 and 27.39 per cent, respectively over 30 + 30 kg N + P₂O₅ ha⁻¹ (Sarawagi *et al.*, 1998). Likewise, application of 20 + 40 kg N + P₂O₅ ha⁻¹ significantly improved plant height, primary and secondary branches plant⁻¹, total and effective nodules plant⁻¹ by 7.80, 16.86, 9.87, 2.03, 11.38 per cent over 10 + 20 kg N + P₂O₅ ha⁻¹ and 15.71, 29.09, 26.74, 4.50 and 28.90 per cent, over control (Dhakar, 2001). At Udaipur, clusterbean crop under the influence of 30 + 60 kg N + P₂O₅ ha⁻¹ recorded significantly higher plant height by 4.1 and 5.3 cm, number of primary and secondary branches plant⁻¹ by 5.60, 17.50 and 7.00, 22.12 per cent over 20 + 40 and 10 + 20 kg N + P₂O₅ ha⁻¹, respectively (Palsaniya, 2002).

2.3.2 Yield attributes:

At Agra, increasing level of N upto 20 kg ha⁻¹ significantly increased pods plant⁻¹ of clusterbean by 24.91 per cent over control (Singh and Singh, 1989). Whereas at Jobner, significant improvement in yield attributes was estimated upto

application of 40 kg N ha⁻¹ over 20 kg N ha⁻¹ and control (Mundra and Maliwal, 1990).

Clusterbean crop under the influence of 60 kg P₂O₅ ha⁻¹ recorded significantly higher pods plant⁻¹ and test weight by 26.26 and 17.60 per cent, respectively over control (Singh and Singh, 1989). In another field studies, on loamy sand soils, seeds pod⁻¹ and test weight of clusterbean were increased with the application of 40 kg P₂O₅ ha⁻¹ over 20 kg P₂O₅ ha⁻¹ by 5.72 and 4.73 per cent, respectively but pods plant⁻¹ remained unaffected (Meena *et al.*, 1991). Whereas on sandy loam soils of Bhatinda, 30 kg P₂O₅ ha⁻¹ proved optimum dose which produced 12.16, 10.72 and 31.03 per cent higher seeds pod⁻¹, pods plant⁻¹ and test weight, respectively over control (Singh and Tiwana, 1995). At Jobner, Shivran *et al.* (1996) recorded significant improvement in pods plant⁻¹, seeds pod⁻¹ and test weight by 11.94, 9.63 and 6.73 per cent with 40 kg P₂O₅ ha⁻¹ respectively over control. But Bhadoria *et al.* (1997), recorded significant increase in yield components i.e. pods plant⁻¹, pod length, seeds pod⁻¹, test weight, and seed yield plant⁻¹ of clusterbean under 60 kg P₂O₅ ha⁻¹ by 20.27, 5.55, 2.79, 5.38, 14.03 and 34.84, 7.54, 5.88, 6.28, 22.64 per cent over 40 and 20 kg P₂O₅ ha⁻¹, respectively. The positive influence of 60 kg P₂O₅ ha⁻¹ on yield attributes of clusterbean was also noted by Baboo and Rana (1995) and Khan and Gurjar (1997). At Jobner, successive increase in P levels upto 30 kg P₂O₅ ha⁻¹ significantly improved yield attributes of clusterbean (Dadhich *et al.*, 2001).

At Jind (Haryana), application of 40 + 80 kg N + P₂O₅ ha⁻¹ significantly improved yield attributes of clusterbean over control (Dahiya *et al.*, 1996). While at Udaipur, application of 20 + 40 kg N + P₂O₅ ha⁻¹ significantly improved pods plant⁻¹, test weight and seed yield plant⁻¹ by 19.43, 10.17, 9.58 and 42.78, 26.27, 30.76 per cent, respectively over 10 + 20 kg N + P₂O₅ ha⁻¹ and control (Dhakar, 2001). At the same location, Palsaniya (2002) found that the application of 20 + 40 kg N + P₂O₅ ha⁻¹ significantly improved pods plant⁻¹, test weight, seeds pod⁻¹ and seed yield plant⁻¹ by 6.33, 5.10, 13.32 and 20.83 per cent, respectively over 10 + 20 kg N + P₂O₅ ha⁻¹. Further increase in fertilizer level to 30 + 60 kg N + P₂O₅ ha⁻¹ though positively influenced aforesaid yield components except seeds pod⁻¹ but failed to record significant gains.

2.3.3 Yield:

Singh and Singh (1989) reported that crop fertilized with 20 kg N ha⁻¹ produced significantly higher seed and straw yield by 10.94 and 30.88 per cent, respectively over control. Significant increase in seed and straw yield by 14.49 and 21.74 per cent with the application of 40 kg N ha⁻¹ over control was noted by Mundra and Maliwal (1990). While Baboo and Rana (1995) recorded significant increase in seed and stover yield by 13.5 and 6.1 per cent with the application of 20 kg N ha⁻¹ over control, respectively.

Chauhan and Bajpai (1979) noted highest seed yield of 8.32 q ha⁻¹ with the application of 90 kg P₂O₅ ha⁻¹, which was significantly higher by 16.60, 21.81 and 51.82 per cent over 60, 30 kg P₂O₅ ha⁻¹ and control, respectively. But at Haryana, the application of 30 kg P₂O₅ ha⁻¹ significantly enhanced seed yield of clusterbean over control (Gill and Singh, 1981). Whereas Taneja, *et al.* (1981) recorded significant increase in seed yield upto application of 60 kg P₂O₅ ha⁻¹. While at Durgapura, application of 40 kg P₂O₅ ha⁻¹ produced significantly higher seed yield over 20 kg P₂O₅ ha⁻¹ and control (AICGIP, 1989). Singh and Singh (1989) indicated significant increase in seed yield with the application of 60 kg P₂O₅ ha⁻¹ by 13.6 and 38.12 per cent over 30 kg P₂O₅ ha⁻¹ and control, respectively. But at Bhatinda, application of 30 and 60 kg P₂O₅ ha⁻¹ improved seed yield by 27.78 and 31.11 per cent, respectively over control (AICGIP, 1990). Similarly Singh and Tiwana (1995) observed that application of 30 kg P₂O₅ ha⁻¹ raised the seed yield by 50.78 per cent over yield of 12.8 q ha⁻¹ obtained under control. Likewise, Shivran *et al.* (1996) recorded seed and straw yield of 12.5 and 31.8 q ha⁻¹ under 20 kg P₂O₅ ha⁻¹, which was significantly improved by 21.60 and 14.47 per cent with the application of 40 kg P₂O₅ ha⁻¹, respectively. However, phosphorus application failed to influence harvest index of the crop. Whereas Bhadoria *et al.* (1997) reported that application of 60 kg P₂O₅ ha⁻¹ increased the seed yield by 20.90, 29.50 and 44.85 per cent, over 40, 20 kg P₂O₅ ha⁻¹ and control, respectively. While Dadhich and Gupta (2001) noted 50.0 per cent higher seed yield with the application of 30 kg P₂O₅ ha⁻¹ over control.

At Bhatinda, application of 20 + 60 kg N + P₂O₅ ha⁻¹ significantly enhanced green pod yield of clusterbean by 10.21 and 26.34 per cent over 20+40 kg N P₂O₅ ha⁻¹ and control, respectively (AICGIP, 1990). Whereas, at Jind (Haryana), Dahiya *et al.* (1996) noticed significant response of seed yield upto application of 40+80 kg N +

P_2O_5 ha^{-1} . Crop under the influence of 20+40 kg N + P_2O_5 ha^{-1} significantly enhanced seed and straw yield by 11.23, 11.23 and 27.42, 25.97 per cent over 10 + 20 kg N + P_2O_5 ha^{-1} and control, respectively (Dhakar, 2001). Crop fertilized with 30 + 60 kg N + P_2O_5 ha^{-1} significantly improved seed, straw and biological yield by 7.39, 7.61, 7.56 and 24.94, 23.23, 23.73 per cent, respectively over 20 + 40 and 10+ 20 kg N P_2O_5 ha^{-1} (Palsaniya, 2002).

2.3.4 Seed quality:

Singh and Singh (1989) estimated significantly higher protein content by 15.75 per cent with application of 20 kg N ha^{-1} over control. Similarly at Lakhaoti, application of 20 kg N ha^{-1} significantly improved crude protein content of seed by 13.05 per cent over control (Baboo and Rana, 1995).

Beneficial effect of phosphorus application on protein content of clusterbean was reported by Taneja *et al.* (1981) and Malik *et al.* (1981). Increasing rate of phosphorus application from 20, 40 and 60 kg P_2O_5 ha^{-1} significantly improved protein content of seed by 1.17, 2.50 and 2.81 per cent, respectively over control (Jain *et al.*, 1988). At Agra, application of 60 kg P_2O_5 ha^{-1} significantly improved protein content by 5.95 and 11.71 per cent respectively over 30 kg P_2O_5 ha^{-1} and control (Singh and Singh, 1989). Likewise Shivran (1994) reported that protein content in seed was significantly improved by 7.20 per cent with the application of 40 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1} . Baboo and Rana (1995) reported that application of 30 and 60 kg P_2O_5 ha^{-1} significantly increased protein content by 6.30, 8.09 and 12.61, 13.62 per cent respectively, over control. Application of 40 kg P_2O_5 ha^{-1} enhanced protein content by 2.15 and 3.46 per cent over 20 kg P_2O_5 ha^{-1} and control, respectively (Bhadoria *et al.*, 1997). Jat *et al.* (2001) reported that application of 60 kg P_2O_5 ha^{-1} increased protein and gum content by 9.59, 29.94, 53.25 and 3.20, 6.00, 11.31 per cent over 45, 30, 15 kg P_2O_5 ha^{-1} , respectively.

Singh and Rajpoot (1985) reported that application of 20 + 60 kg N + P_2O_5 ha^{-1} significantly enhanced protein content of vegetable clusterbean seed over control. Dhakar (2001) indicated that increasing levels of fertilizer upto 20 + 40 kg N + P_2O_5 ha^{-1} significantly increased protein content by 2.47 and 5.68 per cent over 10 + 20 kg N + P_2O_5 ha^{-1} and control, respectively. Further increase in fertilizer level upto 30 +

60 kg N + P₂O₅ ha⁻¹, though had positive impact on protein content but failed to attained statistical significance.

At Udaipur, increasing level of fertilizer upto 20 + 40 kg N + P₂O₅ ha⁻¹ significantly increased protein content by 4.75 per cent over 10 + 20 kg N + P₂O₅ ha⁻¹. However, further increase in fertilizer level 30 + 60 kg N + P₂O₅ ha⁻¹ though increased protein content by 0.31 per cent over 20 + 40 kg N + P₂O₅ ha⁻¹ but failed to attained statistical significance (Palsaniya, 2002).

2.3.5 Nutrient content and uptake:

Application of 20 kg N ha⁻¹ significantly improved total N accumulation by clusterbean crop to the extent of 21.19 per cent over 80.7 kg N estimated under control (Baboo and Rana, 1995).

Boolchandani (1980) reported that application of 20 and 40 kg P₂O₅ ha⁻¹ significantly increased N and P accumulation in forage guar over control. Whereas, Singh and Singh (1989) observed that increasing rates of P upto 60 kg P₂O₅ ha⁻¹ significantly increased P content and uptake over control. At Udaipur, application of 40 kg P₂O₅ ha⁻¹ significantly enhanced N and P content in seed by 3.50, 6.78 and 7.93, 5.96 per cent, respectively over 20 kg P₂O₅ ha⁻¹ and control (Pareek, 1995). Baboo and Rana (1995) reported that application of 60 kg P₂O₅ ha⁻¹ to the clusterbean significantly increased total N and P uptake by 15.46, 44.65 and 18.22, 42.85 per cent, respectively over 30 kg P₂O₅ ha⁻¹ and control. Similarly, Bhadoria *et al.* (1997) indicated that application of 60 kg P₂O₅ ha⁻¹ significantly enhanced P content of seed by 8.10 and 11.66 per cent respectively over 20 kg P₂O₅ ha⁻¹ and control. Dhakar (2001) revealed that clusterbean seed produced under the influence of 20 + 40 kg N + P₂O₅ ha⁻¹ had significantly higher N and P content by 2.73, 5.70 and 2.57, 5.94 per cent, respectively over 10 + 20 kg N + P₂O₅ ha⁻¹ and control. Application of 20 + 40 kg N + P₂O₅ ha⁻¹ significantly increased N and P content in seed and straw over 10 + 20 kg N + P₂O₅ ha⁻¹ (Palsaniya, 2002). He further noted that crop accumulated highest quantum of N, P and K when it was fertilized with 30 + 60 kg N + P₂O₅ ha⁻¹, which was 30.52, 34.21, 25.51 and 7.82, 9.69, 8.18 per cent higher over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, respectively.

3 MATERIAL AND METHODS

The field experiment entitled, “Production Potential of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] as Influenced by Sowing Time, Plant Density and Fertilizer Levels” was conducted during the *Kharif* season of the year 2002. The details of the material used, experimental techniques followed, criteria adopted for evaluation of treatments during course of investigation are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was laid out at the instructional Farm, Rajasthan College of Agriculture, Udaipur, which is situated at 24° 35' N latitude and 73° 42' E longitude at an altitude 582.17 metre above mean sea level. It falls under the agro-climatic zone IV a (sub-humid southern plain and Aravali hill) of Rajasthan and agro-climatic zone VIII (central plateau & hills) of India.

3.1.1 Climatic and Weather Conditions:

This zone has typical subtropical climatic conditions characterized by mild winter and moderate summer, associated with high humidity specially during the month of July to September. The mean annual rainfall is 637 mm, mostly contributed by South-West monsoon during the last week of June to September. The mean weekly meteorological observations recorded during the crop period are presented in table 3.1 and depicted as fig. 3.1. A perusal of data (Table 3.1) show that maximum and minimum temperature during the crop season fluctuated between 28.1 to 36.6 and 17.3 to 27.3 °C, respectively. The maximum and minimum relative humidity ranged between 62 to 91 and 23 to 83 per cent, respectively. The total rainfall received during the crop season was 353.3 mm, out of which 71 per cent occurred in the month of August and September.

3.1.2 Physico-chemical Properties of Soil:

Primary soil samples from the experimental sites were drawn upto 30 cm depth before experimentation and a composite sample was prepared. This was subjected to mechanical, physical and chemical analysis to ascertain the physico-chemical properties of experimental soils. The data (Table 3.2) shows that soils of

experimental field was clay loam in texture, slightly alkaline in reaction and calcareous in nature, medium in available nitrogen, phosphorus and potassium status.

Table 3.1 Mean weekly meteorological data during crop season

Std week No.	Dates	Temperature (°C)		Relative humidity (%)		Evaporation (mm)	Sunshine (hrs.)	Rainfall (mm)
		Max.	Min.	Max.	Min.			
25	18-24 June	36.6	27.3	73	42	10.5	11.6	000.0
26	25 June-01 July	32.8	24.5	82	63	5.0	4.1	100.1
27	02-08 July	31.9	25.3	72	55	7.4	6.6	000.0
28	9-15 July	32.9	25.0	72	47	8.0	9.7	000.0
29	16-22 July	32.0	24.9	72	56	6.3	5.7	000.0
30	23-29 July	30.7	24.5	73	56	6.8	5.3	000.0
31	30 July-05 Aug.	32.6	23.7	83	61	6.5	5.1	62.4
32	06-12 Aug.	28.3	23.3	91	83	3.1	1.5	62.2
33	13-19 Aug.	28.1	23.1	83	71	3.7	1.6	2.6
34	20-26 Aug.	30.5	23.0	88	70	4.5	7.4	51.7
35	27 Aug.-02 Sept.	28.8	22.3	86	69	3.3	5.3	27.2
36	3-09 Sept	31.3	21.8	88	61	4.6	7.9	28.4
37	10-16 Sept.	31.8	20.1	74	44	5.0	10.6	000.0
38	17-23 Sept.	30.8	20.1	79	55	4.7	8.8	2.9
39	24-30 Sept.	33.5	20.5	72	44	5.4	9.1	12.8
40	01-07 Oct.	36.3	17.3	62	23	5.9	10.5	000.0
41	08-14 Oct.	36.4	19.0	71	32	5.5	9.8	3.0

Source: Meteorological Observatory, Rajasthan College of Agriculture, Udaipur

3.2. CROPPING HISTORY

Wheat crop was grown on the experimental field during preceding *rabi* season of 2001-2002. The crop was raised as per recommendations of the region.

3.3 EXPERIMENTAL DETAILS

The experiment comprised combinations of following factors:

3.3.1 Treatments:

(A) Sowing dates

- (i) June, 25 (Standard week no. 26)
- (ii) July, 02 (Standard week no. 27)
- (iii) July, 09 (Standard week no. 28)
- (iv) July, 16 (Standard week no. 29)

(B) Plant density

- (i) 3.33 lacs ha⁻¹ (30 cm x 10 cm)
- (ii) 4.44 lacs ha⁻¹ (22.5 cm x 10 cm)

(C) Fertilizer levels

- (i) 10kg N + 20 kg P₂O₅ ha⁻¹
- (ii) 20 kg N + 40 kg P₂O₅ ha⁻¹
- (iii) 30 kg N + 60 kg P₂O₅ ha⁻¹

3.3.2 Total number of treatments : 4 X 2 X 3 = 24

3.3.3 Design : Split plot
Main plot : Sowing dates X plant density
Sub plot : Fertilizer levels

3.3.4 Replication : Three

3.3.5 Plot size:

Gross plot size : 4 m X 3.6 m = 14.4 m²
Net plot size : 3 m X 2.4 m = 7.2 m²
(for 30 cm x 10 cm spacing)
3 m X 2.7 m = 8.1 m²
(for 22.5 cm x 10 cm spacing)

3.4 DETAILS OF CROP RAISING

3.4.1 Field Preparation:

After the harvest of *rabi* wheat crop, the field was ploughed with tractor drawn disc plough and left fallow during summer with the onset of monsoon. Field was prepared by cross harrowing followed by planking to obtain well leveled and pulverized soil tilth. The field was then demarketed into different plots even of 14.4 m² with sufficient provision of irrigation channels.

3.4.2 Seed Inoculation:

The seeds were inoculated with efficient *Rhizobium* strain procured from Department of Soil Science (Microbiology unit) as per recommended procedure.

3.4.3 Fertilizer Application:

Nitrogen and phosphorus were applied as per treatments. The quantity of phosphorus through DAP was calculated and after subtracting the quantity of N supplied through DAP, the balance amount of N was added by urea. The whole quantity of fertilizer (Nitrogen + Phosphorus) was drilled in furrow at 5 cm below seeding depth before each sowing.

3.4.4 Seed and Sowing:

Clusterbean variety RGC-936* was used as test crop. Furrows were opened at a spacing of 30 cm and 22.5 cm as per treatment and seeds were placed at a depth of 3-4 cm.

3.4.5 Sowing Time:

As per treatment, the crop was sown on 25th June, 2nd, 9th and 16th July 2002.

*This variety was developed at ARS, Durgapura (Jaipur). The plant matures in about 95-100 days and height of plants ranges between 105-115 cm. The plants are branched. The seeds are grey colour and bold. The average yield of variety is range between 8-11 q ha⁻¹ and suitable for sole cropping.

3.4.6 Thinning:

In order to maintain desired plant population of 3.33 and 4.44 lacs ha⁻¹ as per treatment, thinning was done at 15 DAS keeping plant to plant distance of 10 cm.

3.4.7 Irrigation:

There was moisture stress at seed development stage, a life saving irrigation was given at 75, 68, 61 and 54 DAS under 25th June, 2nd, 9th and 16th July sowing, respectively. To ensure germination, pre-sowing irrigation was given under 9th and 16th July sowings.

3.4.8 Harvesting and Threshing:

The crop was harvested at physiological maturity when plants turned golden yellow. The plants from border areas were harvested first, collected and removed from each plot. After this, crop in net plot was harvested, bundled and tagged separately. These bundles were brought to the threshing floor and left for sun drying for a period of 15 days. The dried bundles were weighed to record biological yield. After threshing, winnowing and cleaning, seeds were weighed separately to record seed yield ha⁻¹. The composite seed and straw samples from each experimental unit were collected for laboratory studies. The details of cultural operations carried out during crop growing period are given in table 3.3.

3.5 TREATMENT EVALUATION

In order to evaluate effect of treatments on growth, yield components, yield, nutrient content, their uptake and other aspects of clusterbean crop, observation were recorded for each parameters as per below mentioned methodology.

3.5.1 Plant Population:

The number of plants were counted in five randomly selected one metre length in each experimented unit after thinning (15 DAS) and at harvest. These were averaged and number of plant ha⁻¹ were worked out.

3.5.2 Growth Parameters:

3.5.2.1 Day to 50 % flowering and maturity:

From five central rows in each plot, observation was recorded when 50 per cent plants attained flowering. Similarly, date on which 75 per cent plants in each plot turned yellow and attained maturity was recorded and then duration required to attained 50 % flowering and maturity were worked out.

3.5.2.2 Primary branches per plant:

The number of primary branches from the five randomly selected plants from each plot were recorded and averaged to work out primary branches plant⁻¹.

3.5.2.3 Secondary branches per plant:

The number of secondary branches from the five randomly selected plants from each plot was recorded and averaged to work out secondary branches plant⁻¹.

3.5.2.4 Plant height (at harvest):

Height of five randomly selected plants from each plot was measured from base of the plant to fully open leaf tip and average was worked out.

3.5.2.5 Dry matter accumulation:

The periodic changes in dry matter accumulation plant⁻¹ were recorded at 30, 60 DAS and at harvest by uprooting five randomly selected plants from each plot. These samples were chopped and placed in separate perforated paper bags, sun dried for two days and finally kept in oven at 70⁰ C for 72 hours till a constant weight was noted. Dry matter accumulation plant⁻¹ was computed for each treatment at each stage was computed for each treatment at all the stages.

3.5.2.6 CGR and RGR:

For computation of CGR and RGR, dry matter recorded at 30, 60 DAS and at harvest were used.

(i) **Crop Growth Rate (CGR):**

CGR was computed by using following formula as suggested by Watson (1958).

$$\text{CGR (g m}^{-2}\text{ day}^{-1}) = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{1}{P}$$

Where,

W_1 and W_2 are dry weight plant⁻¹ at time T_1 and T_2 , respectively

P = Ground area occupied plant⁻¹

(ii) **Relative growth rate (RGR):**

RGR was computed by using following formula as suggested by Dhopte and Manuel (1989).

$$\text{RGR (g g}^{-1}\text{ day}^{-1}) = \frac{\text{Log}_e W_2 - \text{log}_e W_1}{T_2 - T_1}$$

Where,

W_1 and W_2 are dry weight plant⁻¹ at time T_1 and T_2 , respectively

3.5.3 Yield Attributes:

3.5.3.1 Pods per plant:

Fully matured and developed pods from randomly selected five plants from each plot were plucked and counted. The average pods plant⁻¹ was worked out.

3.5.3.2 Seeds per pod:

Pods collected from randomly selected plants were threshed, cleaned and total number of seeds were counted, the average number of seed pod⁻¹ was estimated.

3.5.3.3 Seed yield per plant:

At harvest, five randomly selected plants from each net plot were threshed and produce was cleaned and weighed to work out seed yield plant⁻¹.

3.5.3.4 Test weight:

Seed sample was drawn after weighing of produce from each net plot yield. From these, 1000 seeds were counted and weighed.

3.5.3.5 Harvest index:

It is ratio of economic yield (seed yield) to the biological yield, which was worked out by following formula (Donald and Hamblin, 1976) and expressed in percentage.

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (q ha}^{-1}\text{)}}{\text{Biological yield (q ha}^{-1}\text{)}} \times 100$$

3.5.4 Yield:

3.5.4.1 Seed yield:

After threshing and winnowing seed yield net plot⁻¹ was recorded which was used to compute seed yield q ha⁻¹.

3.5.4.2 Haulms yield:

The haulms yield was computed by subtracting the corresponding seed yield from biological yield and expressed in terms of q ha⁻¹.

3.5.4.3 Biological yield:

The produce (seed + haulms) from each net plot area after thorough sun drying was weighed for recording biological yield and expressed as q ha⁻¹.

3.5.5 Chemical Studies:

3.5.5.1 Nutrient content:

Seed and haulms samples collected at harvest from produce of each experimental unit were oven dried at 70⁰ C to a constant weight and grounded in laboratory mill. These samples were subjected to chemical analysis for determining N, P and K contents. The following standard methods for analysis were adopted.

- (i) Nitrogen : Nessler's reagent colorimetric method (Lindner, 1944)
- (ii) Phosphorus : Ammonium vanadomolybdate yellow colour method (Richards, 1968)
- (iii) Potassium : Flame photometric method (Richards, 1968)

3.5.5.2 Nutrient Uptake:

Uptake of N, P and K by seed as well as haulms was estimated by using following formulae:

Nutrient uptake by seed (kg ha^{-1}) = Nutrient content in seed (%) x seed yield (q ha^{-1})

Nutrient uptake by haulms (kg ha^{-1}) = Nutrient content in haulms (%) x haulms yield (q ha^{-1})

Total uptake of nutrients by crop was computed by summing up the uptake by seed and haulms.

3.5.5.3 Protein Content:

The protein content of seed was estimated by multiplying nitrogen content of seed with conversion factor of 6.25 (A.O.A.C., 1960)

3.5.5.4 Gum Content:

The seed samples were analysed for per cent gum content by phenol sulphuric acid method (Das *et. al.*, 1977).

3.6 STATISTICAL ANALYSIS

3.6.1 Analysis of Variance, Test of Significance and Presentation of Data:

The data recorded for evaluation of treatment were subjected to statistical analysis by applying techniques of analysis of variance as advocated by Fisher (1949). The critical difference for the comparison of treatment was worked out, wherever, the 'F' test was significant at 5 per cent level of significance. In order to elucidate the nature and the magnitude of effects, summary tables along with S.Em. \pm and C.D. at 5 per cent level are embodied in the next chapter "Experimental Results" and their analysis of variance are given in the appendices at the end. The results have also been illustrated and depicted through suitable diagrams, wherever necessary.

3.6.2 Correlation and Regression Studies:

Correlation studies were carried out with a view to determine interrelationship between various characters as per method described by Panse and Sukhatme (1985). Regression equations for the characters indicating significant correlations were also worked out and presented at appropriate places.

3.7 ECONOMICS

To find out economic viability of treatment, net monetary return ha^{-1} was worked out. The cost of cultivation including the treatment cost was subtracted from the gross income obtained under each treatment using prevailing input-output prices.

Further, to ascertain profitability on per rupee investment, Benefit: Cost ratio was also worked out.

4 Experimental Results

The results of the experiment entitled “**Production Potential of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] as Influenced by Sowing Time, Plant Density and Fertilizer Levels**” conducted during *Kharif*, 2002 are being presented in this chapter. Data pertaining to various criteria used for treatment evaluation were statistically analyzed and analysis of variance for these data have been given in Appendices (I to XIV). The results for main effects have been described invariably in succeeding paragraphs.

4.1 EFFECT OF SOWING TIME, PLANT DENSITY AND FERTILIZER LEVELS ON PLANT DENSITY

Data on number of plants ha^{-1} under the influence of treatments are presented in Table 4.1 and pertaining analysis of variance is given in Appendix I. A perusal of data reveals that sowing time as well as fertilizer levels did not significantly influence number of plants ha^{-1} recorded after thinning (15 DAS) as well as at harvest of the crop. The adoption of crop geometry of 30 x 10 cm and 22.5 x 10 cm recorded plant density ha^{-1} per treatment. After final thinning (15 DAS) and at harvest the exact plant population under treatment of 4.44 lacs ha^{-1} was 4.35 and 4.30 lacs ha^{-1} which were significantly higher by 24.13 and 32.30 per cent respectively, over plant density of 3.33 lacs ha^{-1} .

4.2 EFFECT OF SOWING TIME, PLANT DENSITY AND FERTILIZER LEVELS ON GROWTH PARAMETERS

The data pertaining to effect of treatments on various growth parameters are presented in Table 4.2 to 4.5 and analysis of variance for these observations are reported in Appendices II to V.

4.2.1 Days to flowering:

Sowing time: It is explicit from data (Table 4.2) that clusterbean crop sown on 25th June took significantly longer duration to attain this phenological stage. Further delay in sowing of the crop beyond 25th June, there was significant reduction in number of days required for flowering upto last date of sowing i.e. 16th July. The 25th June sown crop attained flowering late by 2, 4 and 6 days over 2nd, 9th and 16th July sowings, respectively.

Plant density: The crop under population density of 3.33 and 4.44 lacs ha^{-1} did not show significant variation in days required for flowering.

Fertilizer levels: Increasing rates of fertilizer application from 10 + 20 to 30 + 60 kg N + P₂O₅ ha⁻¹ significantly enhanced days taken for flowering. The crop fertilized with 30 + 60 kg N + P₂O₅ ha⁻¹ took maximum days for flowering (32.42) as compared to 30.94 and 31.69 days taken under the influence to 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹.

4.2.2 Days to maturity:

Sowing time: The data presented in Table 4.2 reveals that the sowing date brought about significant difference in days required for maturity. The crop sown on 25th June matured significantly late by 2, 5 and 11 days as compared to crop sown on 2nd, 9th and 16th July, respectively. Moreover, successive delay in sowing beyond 25th June, the crop matured significantly earlier over the previous sowing date.

Plant density: The crop under population density of 3.33 and 4.44 lac plants ha⁻¹ did not show perceptible variation in days required for maturity.

Fertilizer levels: The crop fertilized with 20 + 40 kg N + P₂O₅ ha⁻¹ took significantly longer duration for maturity by 2 days compared to 10 + 20 kg N + P₂O₅ ha⁻¹ (88.75 days). Further, increase in fertilizer levels to 30 + 60 kg N + P₂O₅ ha⁻¹ delayed maturity to the non-significant extent.

4.2.3. Plant height (at harvest):

Sowing time: It is evident from data (Table 4.2) that clusterbean crop sown on 25th June attained highest plant height of 106.9 cm which was significantly reduced with every delay in sowing by 7 days beyond 25th June. The magnitude of reduction was of the order of 4.93, 9.70 and 14.37 cm under 2nd, 9th, and 16th July sowing, respectively.

Plant density: The plant height attained by the crop under the influence of plant density 4.44 and 3.33 lacs ha⁻¹ did not vary significantly.

Fertilizer levels: The plant height increased with increasing level of fertilizer applications from 10 + 20 to 30 + 60 kg P₂O₅ ha⁻¹. The highest plant height of 104.21 cm was recorded under the influence of 30 + 60 kg N + P₂O₅ ha⁻¹ which was significantly higher by 9.80 and 3.88 cm over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, respectively.

4.2.4. Primary branches per plant:

Sowing time: It is explicit from data (Table 4.3) that clusterbean sown on 25th June proved most efficient as it produced significantly higher number of primary branches plant⁻¹ and each delay in sowing recorded significant reduction. The magnitude of increase in primary branches plant⁻¹ under earliest sowing (25th June) was by 6.49, 18.78 and 44.94 per cent, over 2nd, 9th and 16th July sowings, respectively.

Plant density: Data further reveals that alteration of row spacing thereby plant density significantly influenced number of primary branches plant⁻¹. The crop under lower plant density (3.33 lacs ha⁻¹) produced significantly higher number of primary branches plant⁻¹ by 11.06 per cent over higher population of 4.44 lac plants ha⁻¹.

Fertilizer levels: Successive increase in fertilizer level from 10 + 20 to 30 + 60 N + P₂O₅ ha⁻¹ significantly increased primary branches plant⁻¹. The crop fertilized with 30 + 60 N + P₂O₅ ha⁻¹ recorded highest number of primary branches plant⁻¹ which were significantly higher by 22.94 and 7.18 per cent over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, respectively.

4.2.5. Secondary branches per plant:

Sowing time: It is apparent from data (Table 4.3) that sowing time had significant effect on number of secondary branches plant⁻¹. The crop sown on 25th June recorded significantly higher number of secondary branches plant⁻¹ by 10.53, 19.68 and 29.85 per cent over that under delayed sown crop, i.e. 2nd, 9th and 16th July, respectively.

Plant density: The number of secondary branches plant⁻¹ were significantly reduced with increase in plant density from 3.33 lacs to 4.44 lacs ha⁻¹. The extent of reduction was of the order of 6.59 per cent.

Fertilizer levels: Alike primary branches, increasing rates of fertilizer application upto 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved secondary branches plant⁻¹ by 18.26 and 6.09 per cent over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, respectively.

4.2.6 Dry matter accumulation per plant:

Sowing time: An examination of data (Table 4.4) reveals that there was significant effect of sowing dates on dry matter accumulation at each growth stage. The crop sown on 25th June accumulated significantly higher amount of dry matter plant⁻¹ at 30, 60 DAS and at harvest over rest of the sowing dates. The increase in DMA was 19.16, 44.51, 72.96, per cent at 30 DAS, 8.64, 19.79, 36.60 per cent at 60 DAS and 8.04, 17.83, 34.09 per cent at harvest over 2nd, 9th and 16th July sowing, respectively. Further each delay in sowing beyond 25th June there was significant reduction in DMA plant⁻¹ over previous date. At harvest the least DMA

plant⁻¹ was recorded under 16th July sowing, which was significantly lower by 1.23, 2.50 and 4.20 g plant⁻¹ over 9th, 2nd July and 25th June, respectively.

Plant density: Significant variation in biomass plant⁻¹ was recorded due to alteration of row spacing at all the stages of crop growth. The crop under plant density of 3.33 lacs ha⁻¹ accumulated significantly higher biomass over 4.44 lacs ha⁻¹ by 11.57, 8.02 and 5.58 per cent at 30, 60 DAS and at harvest, respectively.

Fertilizer levels: Increasing level of fertilizer from 10 + 20 to 20 + 40 and 20 + 40 to 30 + 60 kg N + P₂O₅ ha⁻¹ significantly increased dry matter accumulation plant⁻¹ right from 30 DAS till harvest of the crop. The crop fertilized with 30 + 60 kg N + P₂O₅ ha⁻¹ accumulated significantly highest amount of dry matter at 30, 60 DAS and at harvest. The magnitude of increase was to the tune of 51.21, 27.43, 23.48 and 22.52, 9.35, 7.85 per cent over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, respectively.

4.2.7 Crop growth rate (CGR):

Sowing time: A perusal of data (Table 4.5) shows that sowing time failed to bring about significant variation on CGR estimated between 30-60 DAS and 60 DAS-harvest.

Plant density: The accumulation of biomass per unit area per unit time was significantly reduced with increase in plant density. The crop under plant density of 3.33 lacs ha⁻¹ enhanced CGR between 30-60 DAS and 60 DAS-harvest by 79.31 and 73.68 per cent, respectively over 4.44 lac plants ha⁻¹.

Fertilizer levels: The application of fertilizer upto 20 + 40 kg N + P₂O₅ ha⁻¹ significantly improved CGR estimated between 30-60 DAS and 60 DAS-harvest by 12.00 and 9.72 per cent, respectively over 10 + 20 kg N + P₂O₅ ha⁻¹. At the same time, aforesaid level was found at par with 30 + 60 kg N + P₂O₅ ha⁻¹ in this respect.

4.2.8 Relative growth rate (RGR):

Sowing time: The data presented in Table 4.5 indicates that sowing date failed to bring about significant variation on RGR estimated during later duration of crop growth (i.e. between 60 DAS-harvest). While during early stage i.e. between 30-60 DAS, the successive delay in sowing beyond 25th June, the RGR was increased significantly over previous sowing date. Thus when compared to RGR of 0.0185 g gm⁻¹ day⁻¹ under 25th June sowing, the crop sown on 2nd, 9th, and 16th July increased it by 21.62, 34.59 and 43.24 per cent, respectively.

Plant density: Data further reveals that alteration of row spacing failed to bring about significant influence on RGR between 30-60 DAS. But between 60 DAS-harvest, the crop

under plant density of 4.44 lacs ha⁻¹ recorded significant increase in RGR by 5.73 per cent over 3.33 lac plants ha⁻¹.

Fertilizer levels: Each increment in fertilizer dose upto 30 + 60 kg N + P₂O₅ ha⁻¹ significantly reduced RGR estimated between 30-60 DAS. But during 60 DAS-harvest the difference between 10 + 20 and 20 + 40, 20 + 40 and 30 + 60 kg N + P₂O₅ ha⁻¹ was not significant. Thus when compared to least RGR under 30 + 60 kg N + P₂O₅ ha⁻¹, the application of 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹ increased it by 35.93, 25.0 and 8.26, 33.05 per cent between 30-60 DAS and 60 DAS-harvest, respectively.

4.3 EFFECTS OF SOWING TIME, PLANT DENSITY AND FERTILIZER

LEVELS ON YIELD ATTRIBUTES

Data on yield attributes under the influence of various treatments are presented in Table 4.6 and pertinent analysis of variance are appended at the end (Appendix VI).

4.3.1 Pods per plant:

Sowing times: Data presented in Table 4.6 show that successive delay in sowing time by 7 days beyond 25th June significantly reduced number of pods plant⁻¹. Thus when compared to highest pods (28.11 plant⁻¹) under 25th June sowing, crop sown on 2nd, 9th and 16th July recorded reduction by 5.44, 15.58 and 23.23 per cent, respectively.

Plant density: Plant density of 3.33 lac plants ha⁻¹ recorded highest number of pods plant⁻¹ (25.79), which were significantly higher by 6.70 per cent over 4.44 lac plants ha⁻¹.

Fertilizer levels: Increasing rates of fertilizer application from 10 + 20 to 20 + 40 kg N + P₂O₅ ha⁻¹ significantly increased pods plant⁻¹ but further elevation in fertilizer level to 30 + 60 kg N + P₂O₅ ha⁻¹ failed to show any significant impact. The magnitude of increase in pods plant⁻¹ was 3.83 per cent under application of 20 + 40 kg N + P₂O₅ ha⁻¹ over 10 + 20 kg N + P₂O₅ ha⁻¹.

4.3.2 Seeds per pod:

Sowing time: Data (Table 4.6) reveals that sowing time failed to bring about significant variation on seeds pod⁻¹.

Plant density: The number of seeds pod⁻¹ recorded under the influence of plant density did not vary significantly.

Fertilizer levels: Graded increase in fertilizer levels from 10 + 20 to 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved number of seeds pod⁻¹. Thus when compared to 10 + 20 and

20 + 40 kg N + P₂O₅ ha⁻¹ application of 30 + 60 kg N + P₂O₅ ha⁻¹ significantly increased seeds pod⁻¹ by 13.51 and 6.62 per cent, respectively.

4.3.3 Test weight:

Sowing time: Data (Table 4.6) reflects that the highest test weight of 29.08 g was recorded under crop sown on 25th June, which was significantly higher by 11.28 and 13.29 per cent over crop sown on 9th and 16th July, respectively but was at par with 2nd July sowing. Further the difference in test weight of seed produced under crop sown on 9th and 16th July was non-significant.

Plant density: Plant density did not significantly influenced the test weight.

Fertilizer levels: The application of fertilizer upto 20 + 40 kg N + P₂O₅ ha⁻¹ significantly improved weight of individual seed estimated in terms of test weight by 4.84 per cent over 10 + 20 kg N + P₂O₅ ha⁻¹. At the same time, aforesaid level was found at par with 30 + 60 kg N + P₂O₅ ha⁻¹ in this respect.

4.3.4 Seed yield per plant:

Sowing time: A perusal of data (Table 4.6) reveals that sowing time significantly influenced the seed yield plant⁻¹. The crop sown on 25th June recorded highest seed yield plant⁻¹(5.97 g) which was significantly higher over 9th and 16th July sowings by 10.76 and 13.71 per cent, respectively. Further this treatment was at par with 2nd July (5.93 g plant⁻¹) sowing in this respect but recorded increase of 10.01 and 12.95 per cent over 9th and 16th July sowings, respectively. The difference in seed yield plant⁻¹ produced under 9th and 16th July sowings was non-significant.

Plant density: The crop under lower plant density of 3.33 lac plants ha⁻¹ recorded significantly higher seed yield plant⁻¹ by 22.28 per cent over 4.44 lac plants ha⁻¹.

Fertilizer levels: Increasing rate of fertilizer application upto 20 + 40 kg N + P₂O₅ ha⁻¹ significantly improved seed yield plant⁻¹ by 6.56 per cent over lowest level of 10 + 20 kg N + P₂O₅ ha⁻¹. Further, increase in level from 20 + 40 to 30 + 60 kg N + P₂O₅ ha⁻¹ though improved yield by 0.21 g plant⁻¹ but failed to record statistical significance.

4.4 EFFECT OF SOWING TIME, PLANT DENSITY AND FERTILIZER

LEVELS ON YIELD AND HARVEST INDEX

Data on crop productivity recorded in terms of seed, haulms biological yield and crop efficiency i.e. harvest index, under the influence of treatments are presented in Table 4.7 and corresponding analysis of variance for each observation is given in Appendix VII.

4.4.1 Seed yield:

Sowing time: A perusal of data (Table 4.7) reveals that 25th June sown crop produced highest seed yield of 16.99 q ha⁻¹ which was at par with 2nd July sowing (16.55 q ha⁻¹) but recorded significant increase by 14.64 and 18.97 per cent over 9th and 16th July sown crop, respectively. While the extent of increase in yield under 2nd July sown crop was by 11.67 and 15.89 per cent. Further the difference in seed yield produced under 9th and 16th July was not significant.

Plant density: The plant densities of 3.33 and 4.44 lac plants ha⁻¹ failed to record significant variation in seed yield.

Fertilizer levels: Each increment in fertilizer dose upto 30 + 60 kg N + P₂O₅ ha⁻¹ significantly increased seed yield of clusterbean. Thus, when compared to seed yield of 14.57 q ha⁻¹ under the application of 10 + 20 kg N + P₂O₅ ha⁻¹, the application of 20 + 40 and 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved seed yield by 8.37 and 14.00 per cent, respectively. Further, the crop fertilized with 30 + 60 kg N + P₂O₅ ha⁻¹ produced significantly higher yield by 5.19 per cent over 20 + 40 kg N + P₂O₅ ha⁻¹.

4.4.2. Haulms yield:

Sowing time: It is explicit from data (Table 4.7) that sowing time significantly influenced haulms yield. The crop sown on 25th June produced the highest haulms yield (41.66 q ha⁻¹) which was significantly higher by 15.52 and 21.99 per cent over 9th and 16th July sown crop, respectively but was found at par with 2nd July sown crop (39.01 q ha⁻¹). Further the difference in haulms yield under 9th and 16th July was not significant.

Plant density: The plant densities of 3.33 and 4.44 lac plants ha⁻¹ failed to record significant variation in haulms yield.

Fertilizer levels: The crop fertilized with 30 + 60 kg N + P₂O₅ ha⁻¹ produced the highest haulms yield of 40.46 q ha⁻¹ which was significantly higher by 16.53 and 6.52 per cent over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹.

4.4.3 Biological yield:

Sowing time: An assessment of data (Table 4.7) reveals that biological yield was significantly influenced by sowing time. The crop sown on 25th June produced significantly highest biological yield of 58.65 q ha⁻¹. While each delay in sowing by 7 day, i.e. 2nd, 9th and 16th July sowing reduced it to the extent of 5.26, 13.24 and 17.42 per cent, respectively over 25th June sowing. Further difference in biological yield produced under 9th and 16th July sowing was non-significant.

Plant density: The population density did not significantly influence the biological yield.

Fertilizer levels: Increasing level of fertilizer from 10 + 20 to 20 + 40 and 20 + 40 to 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved biological yield. The corresponding increase was to the tune of 15.78 and 6.13 per cent, respectively.

4.4.4 Harvest index:

It is revealed from data (Table 4.7) that sowing time, plant density and fertilizer levels failed to record significant influence on crop efficiency estimated in terms of harvest index.

4.5 EFFECT OF SOWING TIME, PLANT DENSITY AND FERTILIZER LEVELS ON N, P AND K CONTENT

The estimate of N, P, and K content of plant parts (seed and haulms) under the influence of various treatments are presented in Table 4.8, the respective analysis of variances have been given in Appendix VIII.

4.5.1 Nitrogen:

4.5.1.1 Seed: Data (Table 4.8) reveals that sowing time as well as plant density failed to show significant variation in nitrogen content of seed.

Fertilizer levels: The seed produced under influence of 20 + 40 kg N + P₂O₅ ha⁻¹ significantly higher N content by 4.70 per cent over 10 + 20 kg N + P₂O₅ ha⁻¹. Further increase in fertilizer level to 30 + 60 kg N + P₂O₅ ha⁻¹ though improved N concentration in seed but failed to significantly alter it over preceding level.

4.5.1.2 Haulms:

Data (Table 4.8) show that haulms produced under varying sowing dates and population densities failed to record significant influence on N content of haulms.

Fertilizer levels: An examination of data further reveals that increasing rates of fertilizer application upto 20 + 40 kg N + P₂O₅ ha⁻¹ significantly improved N content of haulms. Further increase in fertilizer level upto 30 + 60 kg N + P₂O₅ ha⁻¹ though positively influenced N content of haulms but failed to record statistical significance.

4.5.2 Phosphorus:

4.5.2.1 Seed:

It is apparent from data (Table 4.8) that sowing time and population densities failed to significantly influence on P content of seed.

Fertilizer levels: Seed produced under application of 20 + 40 kg N + P₂O₅ ha⁻¹ had significantly higher P content over 10 + 20 kg N + P₂O₅ ha⁻¹. Further increase in fertilizer level to 30 + 60 kg N + P₂O₅ ha⁻¹ though improved P content over preceding dose but failed to record significance. The magnitude of increase at 20 + 40 kg N + P₂O₅ ha⁻¹ level over 10 + 20 kg N + P₂O₅ ha⁻¹ was 6.09 per cent.

4.5.2.2 Haulms:

A perusal of data (Table 4.8) shows that P content in haulms did not vary significantly between sowing time and population densities.

Fertilizer levels: P content in haulms was significantly increased with increase in levels of fertilizer from 10 + 20 to 30 + 60 kg N + P₂O₅ ha⁻¹. The fertilizer level of 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved P content in haulms over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹ to the extent of 9.72 and 1.71 per cent, respectively.

4.5.3 Potassium content:

It is apparent from data (Table 4.8) that the crop under the influence of varying sowing time, population densities and fertilizer level did not vary significantly in respect of K content in seed and haulms.

4.6 EFFECT OF SOWING TIME, PLANT DENSITY AND FERTILIZER LEVELS ON N, P AND K UPTAKE

The estimates of nutrient uptake by seed, haulms and total uptake by the crop under various treatment are presented in Table 4.9 to 4.11 and respective analysis of variance have been furnished in Appendix IX and X.

4.6.1.1 Nitrogen uptake:

Sowing time: The nitrogen uptake by seed was reduced significantly with the successive delay in sowing time from 25th June to 16th July. The crop sown on 25th June accumulated significantly higher quantum of N by seed to the extent of 7.63, 16.38 and 26.26 per cent over 2nd, 9th and 16th July, respectively.

Plant density: An examination of data (Table 4.9) reveals that plant density significantly influenced N uptake by seed. The higher plant density (4.44 lacs ha⁻¹) recorded significant reduction in N uptake by seed to the tune of 5.42 per cent over lower plant density (3.33 lacs ha⁻¹).

Fertilizer levels: Increasing level of fertilizer application significantly increased N uptake by seed. At highest level of fertilizer application i.e. 30 + 60 kg N + P₂O₅ ha⁻¹ the seeds accumulated highest N (67.08 kg ha⁻¹) which recorded significant increase of 15.73 and 4.22 per cent over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, respectively.

4.6.1.2 Haulms:

Sowing time: The N uptake by haulms decreased significantly with each delay in sowing by 7 days beyond 25th June. The crop sown on 25th June accumulated significantly higher quantum of N by haulms (36.05 kg ha⁻¹) which was significantly higher by 13.08, 27.70 and 48.04 per cent over 2nd, 9th and 16th July, respectively.

Plant density: Under plant density of 3.33 lacs ha⁻¹ haulms accumulated significantly higher quantum of N over plant density of 4.44 lacs ha⁻¹ by 9.45 per cent.

Fertilizer levels: A critical examination of data (Table 4.9) explicit that N uptake of haulms responded significantly upto application of 30 + 60 kg N + P₂O₅ ha⁻¹. At aforesaid level, N accumulation showed increase of 23.99 and 7.89 per cent over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, respectively.

4.6.1.3 Total N uptake:

Sowing time: Data presented in Table 4.9 show that 25th June sown crop accumulated significantly higher quantum of N over 2nd, 9th and 16th July sowings. The increase in total uptake of N under 25th June sowing was by 9.40, 19.98 and 32.87 per cent, respectively.

Plant density: Plant density significantly influenced total N uptake by clusterbean crop. Thus compared to plant density of 4.44 lacs ha⁻¹, lower plant density of 3.33 lacs ha⁻¹ significantly increased total N uptake by 6.89 per cent.

Fertilizer levels: Data explicit almost similar trend of fertilizer application on total N uptake as observed in N uptake of haulms and seed. Among fertilizer levels, application of highest fertilizer i.e. 30 + 60 kg N + P₂O₅ ha⁻¹ significantly enhanced total N accumulation over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹ by 18.35 and 5.40 per cent, respectively.

4.6.2 Phosphorus uptake:

4.6.2.1 Seed:

Sowing time: A reference of data (Table 4.10) reveals that significantly higher P uptake by seed was recorded when crop was sown on 25th June over 2nd, 9th and 16th July sowing. The corresponding increase was to extent of 19.77, 36.55 and 61.83 per cent, respectively.

Plant density: P uptake by seed was not influenced significantly by alteration in plant densities.

Fertilizer levels: Increasing rates of fertilizer application upto 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved P accumulation by seed. At aforesaid level, the seed accumulated 7.42 kg P ha⁻¹, which was significantly higher by 1.47 and 0.52 kg ha⁻¹ over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, respectively.

4.6.2.2 Haulms:

Sowing time: Data (Table 4.10) explicit that the crop sown on 25th June significantly increased P uptake by haulms to the extent of 13.10, 28.96 and 50.68 per cent over 2nd, 9th and 16th July sowings, respectively.

Plant density: The plant densities of 3.33 and 4.44 lac plants ha⁻¹ failed to record significant variation in P uptake by haulms

Fertilizer levels: Successive increase in fertilizer application from 10 + 20 to 30 + 60 kg N + P₂O₅ ha⁻¹ significantly increased P accumulation by haulms. The magnitude of

increase was to the extent of 29.91 and 8.70 per cent over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, respectively.

4.6.2.3. Total P uptake:

Sowing time: Data (Table 4.10) indicate that the crop sown on 25th June accumulated significantly higher total P compared to successive delay in sowing by 7 days. Thus when compared to 2nd, 9th and 16th July sowings, the aforesaid sowing time increased total P uptake by 16.15, 32.34 and 55.73 per cent, respectively.

Plant density: The crop under the influence of varying plant densities did not vary significantly in respect to total P uptake.

Fertilizer levels: Application of highest level of fertilizer i.e. 30 + 60 kg N + P₂O₅ ha⁻¹ significantly increased the total uptake of P by 27.52 and 8.17 per cent over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, respectively.

4.6.3 Potassium uptake:

4.6.3.1 Seed:

Sowing time: A critical examination of data (Table 4.11) reveals that sowing time significantly influenced the K uptake by clusterbean seed. The delay in sowing beyond 25th June brought about significant reduction in K uptake by seed. The reduction was of the order of 10.80, 21.98 and 32.57 per cent under 2nd, 9th and 16th July sowings, respectively.

Plant density: Though maximum uptake of K by seed was recorded under plant density of 3.33 lacs ha⁻¹ but it failed to record significant increase over 4.44 lac plants ha⁻¹.

Fertilizer levels: Increasing rates of fertilizer upto 30 + 60 kg N + P₂O₅ ha⁻¹ significantly enhanced K uptake of seed. The extent of increase in K uptake by seed at aforesaid level over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹ was by 17.77 and 6.98 per cent, respectively.

4.6.3.2 Haulms:

Sowing time: A perusal of data (Table 4.11) reveals that crop sown on 25th June accumulated maximum K uptake by haulms. While it was decreased significantly with the successive delay in sowing time by 7 days. When compared to 25th June sowing, the crop sown on 2nd, 9th and 16th July decreased K uptake by 10.82, 22.00 and 32.35 per cent, respectively.

Plant density: Plant density failed to bring about significant variation in K uptake by haulms.

Fertilizer levels: Increasing rates of fertilizer application significantly influenced K uptake by haulms. Amongst fertilizer levels, application of 30 + 60 kg N + P₂O₅ ha⁻¹ significantly enhanced K accumulation over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹ by 20.99 and 8.88 per cent, respectively.

4.6.3.3 Total K uptake:

Sowing time: Data (Table 4.11) show that crop sown on 25th June recorded significantly higher quantum of total K uptake over that of delayed sowing at 7 days interval i.e. 2nd, 9th and 16th July. The corresponding increase in total K uptake was to the extent of 12.15, 28.20 and 47.94 per cent, respectively.

Plant density: Though maximum total uptake of K by crop was recorded under plant density of 3.33 lacs ha⁻¹ but it failed to record significant superiority over 4.44 lac plants ha⁻¹.

Fertilizer levels: The crop fertilized with 30 + 60 kg N + P₂O₅ ha⁻¹ showed significant increase in total K uptake by 20.20 and 8.41 per cent over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, respectively.

4.7 EFFECT OF SOWING TIME, PLANT DENSITY AND FERTILIZER

LEVELS ON PROTEIN, GUM CONTENT AND GUM YIELD

The estimates of protein and gum content in seed at maturity under the influence of various treatments are presented in Table 4.12. The respective analysis of variances have been given in Appendix XII.

4.7.1 Protein content:

It is explicit from data (Table 4.12) that protein content in clusterbean seed was not influenced significantly by sowing time and population densities whereas, application of 20 + 40 kg N + P₂O₅ ha⁻¹ significantly increased protein content by 4.69 per cent over 10 + 20 kg N + P₂O₅ ha⁻¹. Further increase in fertilizer level to 30 + 60 kg N + P₂O₅ ha⁻¹ failed to improve it significantly over 20 + 40 kg N + P₂O₅ ha⁻¹.

4.7.2 Gum content:

Sowing time: A perusal of data (Table 4.12) reveals that seed of early sown crop i.e. 25th June and 2nd July had least gum content which was increased significantly under late sowing i.e. 9th and 16th July. The magnitude of difference between 25th June-2nd July and 9th – 16th July was statistically not significant. The least gum content of 27.23 per cent was recorded in 25th June sowing which was significantly lower by 4.45 and 5.81 per cent over 9th and 16th July sowings, respectively.

Plant density: The gum content of seed recorded under the influence of population densities did not vary significantly.

Fertilizer levels: Each increment in fertilizer dose upto 30 + 60 kg N + P₂O₅ ha⁻¹ significantly increased gum content of clusterbean seeds. Thus when compared to 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹, the application of 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved gum content by 7.35 and 3.45 per cent, respectively.

4.7.3 Gum yield:

Sowing time: A perusal of data (Table 4.12) reveals that 25th June sown crop produced highest gum yield of 463.38 kg ha⁻¹ which was at par with 2nd July sowing (456.12 kg ha⁻¹) but recorded significant increase by 9.49 and 12.00 per cent over 9th and 16th July sown crop, respectively. While the extent of increase in gum yield under 2nd July sown crop was 7.77 and 10.25 per cent. Further the difference in gum yield produced under 9th and 16th July was not significant.

Plant density: The plant densities of 3.33 and 4.44 lac plants ha⁻¹ failed to record significant variation in gum yield.

Fertilizer levels: Each increment in fertilizer dose upto 30 + 60 Kg N + P₂O₅ ha⁻¹ significantly increased gum yield of clusterbean. Thus, when compared of gum yield of 393.48 kg ha⁻¹ under application of 10 + 20 kg N + P₂O₅ ha⁻¹, the application of 20 + 40 and 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved gum yield by 12.32 and 22.46 per cent, respectively. Further, the crop fertilized with 30 + 60 kg N + P₂O₅ ha⁻¹ produced significantly higher gum yield by 9.02 per cent over 20 + 40 kg N + P₂O₅ ha⁻¹.

4.8 EFFECT OF SOWING TIME, PLANT DENSITY AND FERTILIZER

LEVELS ON NET RETURNS AND B: C RATIO

Data on economic evaluation of various treatments are presented in Table 4.13. The analysis and details of calculation are furnished in Appendices XII and XIII.

Sowing time: Data (Table 4.13) reveals that the highest net returns of Rs. 14262 ha⁻¹ was realized when clusterbean crop was sown on 25th June which was significantly higher over 9th and 16th July sowings by Rs. 2628 and 3327 ha⁻¹, respectively but found at par with 2nd July sown crop (Rs. 13572 ha⁻¹). Similarly, the highest B: C ratio (Rs. 3.36 Rupee⁻¹) was recorded under earliest sown crop (25th June) which was at par with 2nd July sown crop (Rs 3.25 Rupee⁻¹) but recorded significant increase over delayed sown crop (9th and 16th July)

Plant density: Though maximum net returns and B: C ratio was recorded under plant density of 3.33 lacs ha⁻¹ but it failed to record significant net returns over 4.44 lac plants ha⁻¹.

Fertilizer levels: A critical examination of data (Table 4.13) explicit that increasing rates of fertilizer application upto 30 + 60 kg N + P₂O₅ ha⁻¹ significantly increased net returns over 10 + 20 and 20 + 40 kg N + P₂O₅ ha⁻¹. However, B: C ratio did not vary between levels of fertilization.

5 DISCUSSION

While presenting the results of the field experiment entitled “Production Potential of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] as Influenced by Sowing Time, Plant Density and Fertilizer Levels” significant variations in the criteria used for evaluation of treatments were observed. Such variations and also those having uniform trend are discussed in this chapter in the light of solvent evidences and positive explanations so as to establish the cause and effect relationship.

5.1 EFFECT OF SOWING TIME

5.1.1 Growth parameters:

The results showed that amongst sowing time, the crop sown early i.e. on 25th June produced the maximum plant height, primary and secondary branches plant⁻¹ and dry matter accumulation at successive growth stages and increased final biomass plant⁻¹ by 8.04, 17.83 and 34.09 per cent over 2nd, 9th and 16th July sowings, respectively. The phenological studies revealed that crop sown on 25th June took the longer duration for flowering and maturity compared to 2nd, 9th and 16th July sowings (Table 4.2 to 4.4). In general, overall improvement in growth and vigour of the crop sown with the onset of monsoon i.e. 25th June could be ascribed to favourable internal environment of the plants as well as external environment (atmospheric conditions) to which it was exposed during its life cycle. Under the present study, significant improvement in accumulation of biomass (Table 4.4) and nutrients (Table 4.8) amply suggest prevalence of congenial internal environment of plants for its growth and development under 25th June sown crop. Besides this, the crop sown during this period was also exposed to optimum environmental (climatic variables) and soil moisture conditions required for its proper growth, Mavi (1986) stated that plants can realize its genetic programmed phasic development under certain ranges of environmental factors. Significant increase in total crop duration by 2, 5 and 11 days under early sowing (25th June) over late sowings i.e. 2nd, 9th and 16th July, respectively (Table 4.2) also substantiate that under 25th June sowing, the availability of favourable conditions (external/internal) led to better growth of each components. Further, the estimates of nutrient uptake also revealed improvement in endogenous nutrient status of plants under 25th June sown crop (Table 4.9 to 4.11). Thus, increased availability of nutrients seems to have promoted vegetative growth by way of active cell elongation, thereby, improving morphological parameters (plant height, branches plant⁻¹ etc.). Improvement in these parameters under 25th June sowing might have helped in rapid initiation of leaves, while on the other hand higher nutrient uptake seems to have provided

adequate supply of nutrients thereby helped in vigorous growth of plants. The reduction in morphological parameters under 2nd, 9th and 16th July sowing was due to shorter days experienced under late sowing, which cause early flowering in clusterbean, as it is a short day plant. Thus, the duration of late sown clusterbean is reduced significantly. The results of the present investigation are in agreement with the findings of Meena (1988) who also recorded increase in morphological parameter of clusterbean under early sowing.

The significant increase in dry matter at successive growth stages seems to be on account of larger canopy development due to production of higher number of primary and secondary branches (Table 4.3) and plant height under early sown crop i.e. 25th June. These might have increased interception, absorption and utilization of radiant energy as well as longer duration available for the growth and development of the crop. The significant reduction in dry matter could be ascribed to significant reduction in days to flowering under delayed sowing i.e. 2nd, 9th and 16th July. Therefore, shorter period was available for the production of dry matter. The correlation analysis also validated dependence of final dry matter accumulation on primary branches (0.596), secondary branches (0.720) and plant height (0.698). The significantly higher dry matter with early sowing i.e. 25th June was in close conformity with findings of Bhadoria and Chouhan (1994) and Palsaniya (2002).

5.1.2 Yield attributes and yield:

Data on yield attributes of the crop under the influence of sowing time revealed that various yield attributes viz., pods plant⁻¹, test weight and seed yield plant⁻¹ were significantly improved under 25th June sowing compared to successive delay in sowing by 7 days i.e. on 2nd, 9th and 16th July. The crop sown on 25th June produced higher seed, haulms and biological yield by 14.64, 15.52 and 15.27 and 18.97, 21.99 and 21.10 per cent over 9th and 16th July sowing but was found at par with 2nd July sown crop.

The marked improvement in various yield attributes of the crops seems to be on account of increased capacity of the early sown crop to exploit environment resources (above and below ground) for yield synthesis. Besides, adequate supply of growth inputs (Metabolites and nutrients), the congenial climatic conditions seems to have helped the plant to exploit their potential for reproductive growth. The production of higher amount of photosynthates in early sown crop (25th June) might be due to longer duration (flowering and maturity), which helped the plant to develop the larger sink in order to accumulate synthesized photosynthates. Thus resulted in increased growth and development of each yield component. The significant positive correlations between dry matter accumulation at harvest and pods plant⁻¹ (0.493), seeds pod⁻¹ (0.802) and test weight (0.695) also suggest positive

interrelationship between these parameters and dry matter accumulation at harvest. Further, regression analysis indicated that unit increase in dry matter accumulation increased these parameters by 0.85, 0.19 and 0.17 g, respectively.

Thus, as a consequence of favourable climatic conditions, improvement in growth and yield attributing characters, the crop sown early produced significantly higher yield, while delayed sowing reduced the crop duration (Table 4.7) which ultimately produced lower yield. Further, regression analysis indicated that unit increase in pods plant^{-1} , test weight and seed yield plant^{-1} increased the yield by 0.42, 0.82 and 1.26 q ha^{-1} , respectively.

The significant increase in haulms yield under earlier sowing (25th June) seem to be due to their direct effect in improving biomass plant^{-1} . While indirect effect might be on account of increased morphological parameters i.e. branches plant^{-1} and plant height. Further, biological yield is a function of seed and haulms yield. While increased seed and haulms yield under 25th June sowing resulted in production of higher biological yield. The results and present investigation are in close conformity with the findings of Palsaniya (2002), who reported that clusterbean sown early gave significantly higher seed and haulms yield compared to crop sown late i.e. beyond 25th June. The author reported that the depressing effect of delay sowing i.e. 2nd, 9th and 16th July on seed yield may be due to significantly lower test weight, pods plant^{-1} and seed yield plant^{-1} . Similarly, in several parts of country, early sowing (with onset of monsoon) significantly improved productivity of clusterbean (Bains and Dhillon, 1977; Bhadoria and Chauhan, 1994).

5.1.3 Nutrient content and uptake:

The results showed that sowing time failed to show significant variation on N, P and K content. However, the uptake studies revealed that crop sown early i.e. 25th June accumulated significantly higher amount of nutrients in seed and haulms and also recorded the maximum total uptake by the crop. While least uptake by the crop was under delayed sowing i.e. on 2nd, 9th and 16th July sowings (Table 4.9 to 4.11).

It is established fact that nutrient uptake by the crop is largely depends on its growth and development. Primarily it is a function of dry matter production and secondarily the concentration of nutrients at the cellular level. Under present study, though crop sown on 25th June failed to show improvement in nutrient content over crop sown on 2nd, 9th and 16th July but former sowing led to significant improvement in biomass accumulation by virtue of increase in morphological parameters and finally photosynthetic rate. The correlation studies also substantiated positive interrelationship of total N, P and K uptake with biological yield

by 0.982, 0.984 and 0.977, respectively. Further regression analysis indicated that a unit increase in biological yield increased total N, P and K uptake by 2.32, 0.55 and 1.55 kg ha⁻¹, respectively. Thus, the observed crop behaviour under present study could be ascribed only due to increased biomass which ultimately increased nutrients accumulation in various plant parts and finally total uptake by the crop.

5.2 EFFECT OF PLANT DENSITY

5.2.1 Plant population:

The results showed that reduction in row spacing from 30 to 22.5 cm at a constant plant to plant spacing of 10 cm significantly increased number of plants ha⁻¹ (Table 4.1). Further, the population density were maintained by and large as per treatment and difference between actual population maintained and respective population density treatments was marginal. The stand geometry of 22.5 cm x 10 cm recorded significantly higher plant population by 32.30 per cent over stand geometry 30 cm x 10 cm (Table 4.1).

The said difference in plant population were expected as inter-row spacing govern the space available to the individual plant within the rows. Hence, reduction in area plant⁻¹ through reduction in inter-row spacing from 30 cm to 22.5 cm resulted in accommodating higher plants unit area⁻¹.

5.2.2 Growth parameters:

The plants under lower population density (3.33 lacs ha⁻¹) recorded significant improvement in branches plant⁻¹ and dry matter accumulation at successive stages. The plant height and crop duration were not significantly influenced by plant densities (Table 4.2 to 4.4).

In general, improvement in aforesaid growth parameters under lower population density maintained through wider inter-row spacing of 30 cm could be ascribed to availability of more area plant⁻¹, which implies higher growth inputs (sun light, nutrients, moisture etc.) to individual plants with least competition as compared to plant under higher plant density maintained through 22.5 cm x 10 cm row spacing.

The better availability of inputs under least plant density might have helped the plant to grow profusely as evident from increased branching, which helped in rapid initiation of leaves and their expansion giving higher LAI ultimately resulting in higher rate of photosynthesis. Besides this, reduction in number of plants unit area⁻¹ under wider row spacing (3.33 lac plants ha⁻¹) might have also provided favourable environment for root

development below ground. This might have led to adequate supply of nutrient/metabolites from root to shoot resulting in higher biomass accumulation plant⁻¹. Thus, favourable environment above and below ground under lower plant density seems to have resulted in better performance of individual plant in terms of plant growth.

The observed crop behaviour under the influence of reduced population through increasing inter-row spacing are in accordance with finding of several researchers (Yadav, 1979; Ali, 1982; Palsaniya, 2002).

5.2.3 Yield attributes and yield:

Significant improvement in yield attributes namely pods plant⁻¹ and seed yield plant⁻¹ was noted when plant population was reduced from 4.44 lacs ha⁻¹ to 3.33 lacs ha⁻¹ (Table 4.6). Whereas seed, haulms and biological yield were not significantly influenced by varying plant density.

The marked improvement in pods plant⁻¹ and seed yield plant⁻¹ under lower population density appears to be on account of vigorous growth of individual plant as reflected by increased number of branches (primary and secondary and total dry matter accumulation plant⁻¹). A faster growth rate in terms of dry matter production as evince from higher CGR under lower plant density might have played a significant role in reducing competition for photosynthates and nutrients within plant. On the other hand, adequate supply of photosynthates due to higher photosynthetic efficiency at flowering might have enhanced number of flowers and their fertilization resulting in higher number of pods plant⁻¹.

It is an established fact that in crops, availability of assimilates (source) and storage organ (sink) exert an important regulation function on the complex process of yield formation. Further, proper development of root and nutrient status of the plant subscribe to the view that these helped the plants to develop more number of pods and thereafter their development. The positive relationship between dry matter plant⁻¹ and various yield components further substantiate this assumption (Table 5.1). The increased productivity of individual plant under the population density of 3.33 lacs ha⁻¹ seems to be the resultant of improvement in each yield component of the crop. The improvement in yield attributes of clusterbean under 3.33 lacs plants ha⁻¹ as evince from the present investigation is in close agreement with the findings Palsaniya (2002).

In contrast to results on yield components, the seed yield ha⁻¹ did not significantly influence by plant density. The seed yield was almost similar in both population densities of 3.33 and 4.44 lacs ha⁻¹. Although the improvement in yield attributes was more in plant

density of 3.33 lacs ha⁻¹ but the plant density of 4.44 lacs ha⁻¹ accommodated more number of plants unit area⁻¹, which seems to have compensated the improvement in yield attributes recorded with reduction in plant density such type results were also recorded by several research workers *viz.*, Kacker *et al.* (1984) and Singh and Tiwana (1995).

5.2.4 Quality:

Quality parameters *viz.*, gum and protein content of seed were not affected significantly due to variation in plant densities (Table 4.12). Content of gum and protein are inherent characteristics of the variety which cannot be changed due to change in plant densities. Similar findings were also reported by Palsaniya (2002). Who observed non-significant change in protein content of guar seed.

5.2.5 Nutrient content and uptake:

The results indicated that the plant density did not influence the amounts of nutrients (Table 4.8). The increased uptake of N with decrease in plant density despite non-significant variation in content of nutrient seems to be due to more biological yield under lower plant density. While the increased uptake of P and K with decrease in plant density did not influence the significant effect on nutrient uptake. Singh and Singh (2000) also reported that nutrient uptake increased under lower plant density due to higher biomass production.

5.3 EFFECT OF FERTILIZER LEVELS

5.3.1 Growth parameters:

The results revealed that increasing rates of fertilizer application upto 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved plant height, days to flowering, primary and secondary branches plant⁻¹ (Table 4.2 and 4.3). The dry matter accumulation by plant also tended to increase significantly upto application of 30 + 60 kg N + P₂O₅ ha⁻¹ and at harvest, the plants under the influence of aforesaid level accumulated 7.85 and 23.48 per cent higher biomass compared to 20 + 40 and 10 + 20 kg N + P₂O₅ ha⁻¹, respectively.

It is an established fact that amongst nutrients, N and P considered to be most important for exploiting genetic potentials of the crop for its growth and development (Tisdale *et al.*, 2003). Nitrogen is considered to be an essential constituent required for synthesis of protein, Chlorophyll and other organic compounds of physiological significance in the plant system. While P is involved in better root growth for plants as well as it plays active role in formation of high energy phosphate compounds, which are unstable in water and act as carrier for many vital reactions like oxidation of sugars through enhancing

enzymatic activities. Phosphorus nutrition is also involved in initial reaction for photosynthesis. In fact it is also considered to be energy currency within the plant system Kanwar (1976) and Tisdale et al. (2003).

Under the present investigation, profound influence of increasing rate of N + P₂O₅ per fertilization on various growth parameters seems to be due to improvement in nutritional environment of the plants on account of greater availability of these nutrients from the soil media. This is well evince from the estimates of nutrient status at harvest which showed that increased rate of N + P₂O₅ application improved their concentration in seed and haulms (Table 4.8) which are mainly translocated from vegetative parts. Thus greater availability of nutrient during vegetative phase might have enhanced meristamatic activities, thereby, increased division, enlargement and elongation of cells resulting in higher plant height. The larger canopy development on account of higher number of primary and secondary branches and plant height (Table 4.2 and 4.3) under the application of 30 + 60 kg N + P₂O₅ ha⁻¹ might have increased interception, absorption and utilization of radiant energy resulting in higher photosynthesis and finally accumulation of dry matter plant⁻¹. The significant positive correlation between dry matter accumulation (at harvest) and plant height (0.698) and number of primary braches plant⁻¹ (0.596) and secondary branches plant⁻¹ (0.720) also suggest positive inter-relationship between these parameters and dry matter accumulation plant⁻¹ at harvest. Further, regression analysis indicated strong dependence of dry matter accumulation on plant height, number of primary and secondary branches, as a unit increase in these parameters increased dry matter by 0.16, 0.83 and 2.02 g plant⁻¹, respectively. The significant improvement in growth parameters and over all growth of crop under the influence of balanced fertilization (N + P₂O₅) is in close conformity with findings of Sarawagi *et al.* (1998) and Palsaniya (2002).

5.3.2 Yield attributes and yield:

It was observed that increasing rates of fertilizer application upto 20 + 40 kg N + P₂O₅ ha⁻¹ significantly improved pods plant⁻¹, seed yield plant⁻¹ and test weight but seeds pod⁻¹ were enhanced upto 30 + 60 kg N + P₂O₅ ha⁻¹ (Table 4.6). The productivity recorded in terms of seed, haulms and biological yield showed significant response with increasing level of fertilization upto 30 + 60 kg N + P₂O₅ ha⁻¹. The crop efficiency estimated in terms of harvest index did not alter significantly with the application of fertilizer (Table 4.7).

The positive response of yield components of clusterbean could be ascribed to overall improvement in growth of the crop as evident from increased plant height, branches plant⁻¹ and dry matter accumulation early stage upto harvest. Thus, better growth of plants,

particularly in terms of biomass accumulation subscribe to the view that there was better availability of photosynthates, synchronized with the demand for growth and development of each yield component. In clusterbean, due to indeterminate growth characteristics, it has been widely assumed that both vegetative and reproductive development of plant compete with each other for the want of nutrient and metabolites. Thus, higher availability of both these growth inputs ($N + P_2O_5$) as evince from higher dry matter accumulation right from early stage to maturity (Table 4.4) and greater nutrient content and their accumulation (Table 4.8 to 4.11) at harvest under $N + P_2O_5$ fertilization clearly demonstrate reduced competition of these growth inputs, between developing structures, consequently, increased magnitude of each component and their functional activity. The regression analysis also revealed dependence of pods $plant^{-1}$ and seeds pod^{-1} on dry matter accumulation at harvest. The unit increase in dry matter accumulation at harvest increased 0.85 pods $plant^{-1}$ and 0.19 seeds pod^{-1} (Table 5.1). At the same time adequate availability of nutrients/metabolites due to increased nutrients uptake and higher photosynthetic activity in plants seem to have helped proper growth of individual seeds, which ultimately led to higher test weight under the influence of fertilizer application. The positive interrelationship between the test weight and nutrient content of seed N (0.418), P (0.400) and K (0.156) further confirms the role of balanced fertilization in improving growth of individual seeds, by virtue of increasing nutritional conditions. Further, the regression analysis substantiated strong dependence of seed yield $plant^{-1}$ on test weight and a unit increase in test weight improved seed yield to the extent of 0.25 g $plant^{-1}$. Positive response of clusterbean yield components to $N + P_2O_5$ fertilization was also noticed by several researches (Singh and Singh, 1989; Dahiya *et al.*, 1996; Shivran *et al.*, 1996; Palsaniya, 2002).

Since seed yield of crop is a function of several yield components, which are dependent on complementary interaction between vegetative and reproductive growth of the crop. Thus, positive influence of fertilizer application on both these phases of the crop ultimately resulted in realization of higher crop productivity in terms of seed yield. Under the present study, estimated interrelationship also validated strong positive 'r' between seed yield and seeds pod^{-1} (0.786), test weight (0.876) and pods $plant^{-1}$ (0.772). Further, regression analysis showed that unit increase in these parameters increased seed yield by 3.10, 0.82 and 0.42 q ha^{-1} , respectively.

Significant increase in seed and haulms yield under the influence of fertilizer application upto 30 + 60 kg $N + P_2O_5 ha^{-1}$ appears to be on account of its direct influence on higher dry matter accumulation at successive growth stages and indirectly via increase in plant height, primary and secondary branches $plant^{-1}$. The higher biological yield under the

influence of 30 + 60 kg N + P₂O₅ ha⁻¹ could be ascribed to its positive influence on both vegetative and reproductive growth of crop, which led to increase in seed and haulms yield, thereby higher biomass production ha⁻¹. The results of present investigation indicating higher productivity of clusterbean crop under the influence of N and P fertilization is in close conformity with findings of several researchers (Singh and Singh, 1989; Baboo and Rana, 1995; Bhadoria *et al.*, 1997; Palsaniya, 2002). However, these authors reported that optimum level of fertilization is dependent on inherent soil fertility and crop growing situation.

5.3.3 Seed quality:

The results indicated that increasing rates of fertilizer upto 20 + 40 kg N + P₂O₅ ha⁻¹ significantly improved protein content over 10 + 20 kg N + P₂O₅ ha⁻¹ while gum content was significantly improved upto 30 + 60 kg N + P₂O₅ ha⁻¹ (Table 4.12). The significant improvement in protein content of seed with application of fertilizer over 10 + 20 kg N + P₂O₅ ha⁻¹ was expected as the nutrient especially N is considered to be an essential constituent and actively involved in synthesis of proteins (Tisdale *et al.*, 2003). Similarly, improvement in P content of seed elevated protein content due to higher protein synthesis and formation of some stable phospho-protein compound. The increase in gum content might be perhaps due to augmented carbohydrates and fat synthesis in seeds due to application of higher rate of N + P₂O₅ application. The results are close agreement with the those of Bhadoria *et al.* (1997). The positive 'r' between protein content and N content of seed further validates dependence of protein content on N content. The results are in close conformity with those of Baboo and Rana (1995), Bhadoria *et al.* (1997) and Dhaker (2001).

5.3.4 Nutrient content and uptake:

The analysis of plant parts i.e. seed and haulms at the harvest of the crop revealed that increasing rates of fertilizer application upto 20 + 40 kg N + P₂O₅ ha⁻¹ significantly increased N content of seed and haulms over 10 + 20 kg N + P₂O₅ ha⁻¹. While increasing rates of fertilizer application upto 30 + 60 kg N + P₂O₅ ha⁻¹ significantly increase P content in seeds and haulms over 20 + 40 and 10 + 20 kg N + P₂O₅ ha⁻¹. Balanced fertilization failed to bring about significant variation of K content of seed and haulms. Further, increase in fertilizer level upto 30 + 60 kg N + P₂O₅ ha⁻¹ failed to exhibit significant superiority over its preceding level (Table 4.8). Whereas, application of higher level of fertilizer level i.e. 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved N, P and K uptake (seed, haulms and total) over lower level of 20 + 40 and 10 + 20 kg N + P₂O₅ ha⁻¹.

The positive influence of 20 + 40 kg N + P₂O₅ ha⁻¹ application on N status (Table 4.8) of plant parts seems to be due to their increased availability from soils. Moreover, higher photosynthetic activity in plants as evident from increased biomass accumulation at successive stages reveals higher availability of metabolites from shoot to roots. This might have promoted growth of root as well as their functional activity, resulting in higher extraction of nutrients from soil environment to aerial plant parts. The results of present investigation strongly support findings of Singh and Singh (1990). Similarly, at Udaipur (Rajasthan) application of 20 + 40 kg N + P₂O₅ ha⁻¹ significantly improved N content of clusterbean seed and haulms by 2.73 and 2.57 per cent, respectively over control (Dhaker, 2001). Likewise, Bhadoria *et al.* (1997) reported that application of 40 kg P₂O₅ ha⁻¹ significantly enhanced P content of seeds by 8.27 and 11.60 per cent, respectively over 20 kg P₂O₅ ha⁻¹ and control. It is well established fact that uptake of nutrients is largely dependent upon dry matter accumulation and its content. Therefore, increased N, P and K uptake by the crop can be explained due to increased seed and haulms yield and their increased nutrient content under the effect of fertilization. Higher uptake of these nutrients under the influence of fertilization has been widely reported in literatures (Baboo and Rana, 1995; Dhakar, 2001; Palsaniya, 2002).

6 SUMMARY

The field experiment entitled “**Production Potential of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] as Influenced by Sowing Time, Plant Density and Fertilizer Levels**” was conducted during *Kharif* 2002, at the Instructional Farm, Rajasthan College of Agriculture, Udaipur. The results presented and discussed in the preceding chapters are summarized below:

6.1 SOWING TIME

- Sowing time had no adverse effect on plant stand at 15 DAS and harvest.
- The Clusterbean crop sown early (25th June) took significantly more days to attain flowering by 2, 4 and 6 days and maturity by 2, 5 and 11 days compared to every delay in sowing by 7 days beyond 25th June i.e. 2nd, 9th and 16th July, respectively.
- The crop sown on 25th June recorded highest plant height which was significantly higher by 4.93, 9.70 and 14.37 cm over 2nd, 9th and 16th July sowings, respectively.
- Successive delay in sowing time by 7 days beyond 25th June significantly reduced in number of primary and secondary branches plant⁻¹ compared to 25th June sown crop.
- The clusterbean crop sown on 25th June recorded significantly higher biomass production plant⁻¹ at each growth stage. At harvest crop under 25th June sowing accumulated 8.04, 17.83 and 34.09 per cent higher dry matter plant⁻¹ over 2nd, 9th and 16th July sowings, respectively.
- Sowing time failed to bring about significant variation on CGR and RGR estimated between 30-60 DAS and 60 DAS-harvest except RGR during early stage where successive delay in sowing time beyond 25th June, the RGR was reduced significantly over previous date.
- Significant improvement in various yield attributes *viz.*, pods plant⁻¹, test weight and seed yield plant⁻¹ were noticed under 25th June sown crop compared to delayed sowing time i.e. 2nd, 9th and 16th July. However, seeds pods⁻¹ failed to respond sowing date.
- The clusterbean crop sown on 25th June produced highest seed (16.99 q ha⁻¹), haulms (41.66 q ha⁻¹) and biological (58.65 q ha⁻¹) yield which was significantly higher by

14.64, 15.52, 13.24 and 18.97, 21.99, 17.42 per cent over 9th and 16th July sown crop, respectively. The difference in seed and haulms yield produced under 25th June–2nd July and 9th–16th July sowing was non-significant.

- Sowing time failed to record significant improvement in concentration of nutrients i.e. N, P, K contents in both seed and haulms as well as protein content of seed.
- The crop sown on 25th June accumulated significantly higher quantum of nutrients in seed, haulms and total compared to successive delay in sowing by 7 days. Thus, when compared to 2nd, 9th and 16th July sowing, 25th June sown crop enhanced total uptake of N by 9.40, 19.98, 32.88, of P by 16.15, 32.35, 55.73 and of K by 12.15, 28.21, 49.94 per cent, respectively.
- Delayed sown crop i.e. 9th and 16th July had highest gum content compared to early sowing (25th June). The magnitude of difference in gum content between 25th June – 2nd July and 9th–16th July sowing was not significant.
- The crop sown on 25th June fetched highest net returns of Rs. 14262 ha⁻¹, which represented gains of Rs. 2628 and 3327 ha⁻¹ compared to delayed sown crop i.e. 9th and 16th July, respectively but found at par with 2nd July sown crop. In comparison to B: C ratio of 2.92 and 2.81 under 9th and 16th July, the crop sown on 25th June fetched highest returns of Rs. 3.36 rupee⁻¹.

6.2 PLANT DENSITY

- The alteration in inter row spacing at constant plant spacing of 10 cm significantly influenced total number of plants recorded after final thinning and at harvest. The spacing of 22.5 cm x 10 cm recorded the highest plant density of 4.30 lacs ha⁻¹ at harvest which was significantly higher by 32.30 per cent over spacing of 30 cm x 10 cm.
- Plant density did not vary significantly with respect to days to flowering, maturity and plant height, but increased plant density from 3.33 to 4.44 lacs ha⁻¹ significantly reduced primary and secondary branches plant⁻¹ by 9.96 and 6.60 per cent, respectively.
- The crop sown at wider row spacing of 30 cm (3.33 lac plant ha⁻¹) tended to accumulate significantly higher biomass at successive growth stages over sowing at narrow row spacing of 22.5 cm (4.44 lac plants ha⁻¹). At harvest, crop under plant

density of 3.33 lacs ha⁻¹ accumulated 5.59 per cent higher dry matter over 4.44 lac plants ha⁻¹.

- The crop under lower plant density of 3.33 lacs ha⁻¹ enhanced CGR between 30-60 DAS and 60 DAS-harvest by 79.31 and 73.64 per cent, respectively over 4.44 lac plants ha⁻¹. While RGR differed significantly at later stages (60 DAS-harvest) and it was higher under population density of 4.44 lacs ha⁻¹ over 3.33 lacs ha⁻¹.
- Yield attributes namely pods plant⁻¹ and seed yield plant⁻¹ were significantly higher under plant density of 3.33 lacs ha⁻¹ over that of 4.44 lacs ha⁻¹.
- Plant density of 3.33 and 4.44 lacs ha⁻¹ did not differ significantly in yield attributes. Likewise, though lower density of 3.33 lacs ha⁻¹ recorded increase in seed, haulms and biological yield of by 1.28, 2.20 and 1.93 per cent over 4.44 lac plants ha⁻¹ but magnitude failed to attend significant.
- The nutrient concentration in seed and haulms as well as gum and protein content of seed did not vary significantly between plant density.
- Clusterbean sown at spacing of 30 cm x 10 cm significantly increased total uptake of N by 6.90 per cent over spacing of 22.5 cm x 10 cm (4.44 lacs ha⁻¹).
- Crop sown at 30 cm x 10 cm spacing (3.33 lac plants ha⁻¹) fetched highest net returns (Rs. 12806 ha⁻¹) and B: C ratio (Rs. 3.14 rupee⁻¹) compared to that recorded under plant density of 4.44 lacs ha⁻¹ (Rs. 12395 ha⁻¹ and B: C ratio 3.03).

6.3 EFFECT OF FERTILIZER LEVELS

- Increasing rates of fertilizer application upto 30 + 60 kg N + P₂O₅ ha⁻¹ did not significantly influence plant stand recorded at 15 DAS and harvest of the crop.
- The crop fertilized with 30 + 60 kg N + P₂O₅ ha⁻¹ took longer duration for flowering and maturity.
- Fertilizer application upto 30 + 60 kg N + P₂O₅ ha⁻¹ significantly improved plant height by 3.88, 9.88 cm, primary and secondary branches plant⁻¹ by 7.18, 6.09 and 22.94, 18.27 per cent, respectively over 20 + 40 and 10 + 20 kg N + P₂O₅ ha⁻¹.
- Dry matter accumulation by plant at successive stages and at harvest also tended to increase with each increment in fertilization. At harvest, the plants under influence of

30 + 60 kg N + P₂O₅ ha⁻¹ accumulated 7.85 and 23.49 per cent higher biomass over 20 + 40 and 10 + 20 kg N + P₂O₅ ha⁻¹, respectively.

- Growth efficiency measured in terms of CGR showed positive response upto application of 20 + 40 kg N + P₂O₅ ha⁻¹. At the same time least RGR was observed under 30 + 60 kg N + P₂O₅ ha⁻¹.
- The yield attributes, namely pods plant⁻¹, test weight and seed yield plant⁻¹ showed significant response upto application of 20 + 40 kg N + P₂O₅ ha⁻¹. Further increase in fertilizer dose to 30 + 60 kg N + P₂O₅ ha⁻¹ though positively influenced aforesaid yield attributes, but failed to record significant gains. While seeds pod⁻¹ responded significantly upto 30 + 60 kg N + P₂O₅ ha⁻¹.
- Significant improvement in seed, haulms and biological yield was recorded upto application of 30 + 60 kg N + P₂O₅ ha⁻¹. The magnitude of increase in aforesaid yield parameters was to the extent of 5.19, 6.52, 6.14 and 14.00, 16.53, 15.78 per cent, respectively over 20 + 40 and 10 + 20 kg N + P₂O₅ ha⁻¹.
- Application of 20 + 40 kg N + P₂O₅ ha⁻¹ significantly enhanced N content of seed, haulms, gum and protein content of seed over 10 + 20 kg N + P₂O₅ ha⁻¹. While P content of seed, haulms were significantly higher under application of 30 + 60 kg N + P₂O₅ ha⁻¹. Potassium content of seed and haulms did not differ significantly between levels of fertilizer application.
- Uptake of nitrogen, phosphorus and potassium by seed, haulms and total showed significant increase upto 30 + 60 kg N + P₂O₅ ha⁻¹ over its lower level of 20 + 40 and 10 + 20 kg N + P₂O₅ ha⁻¹.
- Application of fertilizer upto 30 + 60 kg N + P₂O₅ ha⁻¹ recorded significantly higher net returns over 20 + 40 and 10 + 20 kg N + P₂O₅ ha⁻¹ by Rs. 565 ha⁻¹ and Rs. 1644 ha⁻¹, respectively.
- Application of 20 + 40 kg N + P₂O₅ ha⁻¹ fetched higher B: C ratio (3.12) which was found at par with 10 + 20 (3.08) and 30 + 60 (3.05) kg N + P₂O₅ ha⁻¹.

ConCl usion

Based on results emanated from the present investigation it can be concluded that under prevailing agroclimatic conditions of south-west Rajasthan, sowing of clusterbean should be done from 25th June to 1st July without affecting its productivity as it resulted in highest yield and monetary returns. A plant density of 3.33 lacs ha⁻¹ should be maintained by planting the crop at row spacing of 30 cm and intra-row spacing of 10 cm as it resulted in higher yield. Balanced fertilization of clusterbean crop involving 30 + 60 kg N + P₂O₅ ha⁻¹ is advisable because it realized higher yield and monetary returns. However, these results are only indicative based on one year experimentation and requires further confirmation before making final recommendation.

LITERATURE CITED

- A.O.A.C. 1960. Official method of analysis. 18th Ed. *Association of Official Agricultural Chemistry*; Washington.
- AICGIP. 1988. Annual Progress Report of All India Co-ordinated Guar Improvement Project, RRS, Bhatinda, PAU, Ludhiana.
- AICGIP. 1989. Annual Progress Report of All India Co-ordinated Guar Improvement Project, ARS, Durgapura, RAU, Bikaner.
- AICGIP. 1990. Annual Progress Report of All India Co-ordinated Guar Improvement Project, S.K. Nagar, Gujarat.
- AICGIP. 1990. Annual Progress Report of All India Co-ordinated Guar Improvement Project, JNKVV, Gwalior.
- AICGIP. 1990. Annual Progress Report of All India Co-ordinated Guar Improvement Project, HAU, Hisar.
- AICGIP. 1990. Annual Progress Report of All India Co-ordinated Guar Improvement Project, Banaskantha, Gujarat.
- AICGIP. 1990. Annual Report of All India Co-ordinated Guar Improvement Project, RRS, Bhatinda, PAU, Ludhiana.
- AICGIP. 1993. Annual Progress Report of All India Co-ordinated Guar Improvement Project, Hissar, Haryana.
- AICGIP. 1995. Annual Progress Report of All India Co-ordinated Guar Improvement Project, Hisar, Haryana.
- AICGIP. 2001. Annual Progress Report of All India Co-ordinated Guar Improvement Project, ARS, Durgapura, RAU, Bikaner.
- AICRPAL. 1993. Annual Progress Report of All India Co-ordinated Research Project on Arid Legumes, CCSHAU, Hisar.
- AICRPAL. 1999. Annual Progress Report of All India Co-ordinated Research Project on Arid Legumes, CCSHAU, Hisar.

- AICRPAL. 1999. Annual Progress Report of All India Co-ordinated Research Project on Arid Legumes, RRS Bhatinda, PAU, Ludhiana.
- AICRPAL. 2000. Annual Progress Report of All India Co-ordinated Research Project on Arid Legumes, ARS, Durgapura, RAU, Bikaner.
- AICRPAL. 2001. Annual Progress Report of All India Co-ordinated Research Project on Arid Legumes, CAZRI, Jodhpur.
- AICRPDA. 1979. Annual Progress Report of All India Co-ordinated Research Project for Dryland Agriculture, CAZRI, Jodhpur.
- AICRPDA. 1980. Annual Progress Report of All India Co-ordinated Research Project for Dryland Agriculture, Agra (UP).
- Ali, M. 1982. Effect of plant types and row spacings on clusterbean production under dryland conditions. *Indian J. Agron.* 27(2): 144-148.
- Baboo, R. and N.S. Rana. 1995. Nutrient uptake and yield of clusterbean (*Cyamopsis tetragonoloba*) as influenced by nitrogen, phosphorus and seed rate. *Indian J. Agron.* 40(3): 482-85.
- Bains, D.S. and A.S. Dhillon. 1977. The influence of sowing dates and row spacing patterns on the performance of two varieties of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]. *J. Res. Punjab. Agril. Univ.* 14(2):157-161.
- Bhadoria, R.B.S. and D.V.S. Chauhan. 1994. Response of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] to date of sowing and spacing. *Indian J. Agron.* 39(1): 156-157.
- Bhadoria, R.B.S., R.A.S. Tomar, H. Khan and M.K. Sharma. 1997. Effect of phosphorus and sulphur on yield and quality of clusterbean (*Cyamopsis tetragonoloba*). *Indian J. Agron.* 42(1): 131-34.
- Black, C.A. 1965. Method of soil analysis. *American Soc. Agron., Madison, Wisconsin, USA.*
- Boolchandani, J.K. 1980. To study the effect of varying levels of phosphorus and phosphate solubilizing bacteria with FYM on guar forage production. M.Sc. (Ag.) Thesis, Deptt. of Agron., Sukhadia University, Udaipur.
- Bouyoucos, G.J. 1962. Hydrometer method for making particle size analysis of soil. *Agron. J.* 55:464-65.

- Brady, N.C. and R. R. Well. 2003. The nature and property of soil (13th Ed.) Published Pearson Education (Singapore) Pte. Ltd., New Delhi, India.
- Chauhan, A. and M.R. Bajpai. 1979. A note on the response of rainfed guar to phosphorus and nitrogen. *Ann. Arid Zone*. 18(4): 272-73.
- Dadhich, L.K. and A.K. Gupta. 2001. Effect of phosphate solubilizing bacteria and phosphorus on the growth pattern of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]. *Ann. Biology*. 17(1): 107-110.
- Dadhich, L.K., A.K. Gupta and H.S. Sharma. 2001. Yield and quality of clusterbean as influenced by molybdenum and phosphorus. *Adv. Plant Sci*. 14(1):205-208.
- Dahiya, S.S., I.S. Hooda, S.C. Gupta, A.S. Faroda and M.C. Mundra. 1996. Response and economics of fertilizer application in guar under rainfed conditions. *Indian. J. Pulse Res*. 9(1):31-33.
- Das, B., S. K. Arora and J. P. Luthra. 1977. Proc. 1st ICAR workshop on Guar Research and Production, Udaipur, Jan. 11-12:117.
- Dhakar, T.R. 2001. Effect of microbial inoculation and fertilizer levels on productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]. M.Sc. (Ag.) Thesis, Deptt. of Agron., MPUAT, Udaipur.
- Dhopte, A. M. and M. Manuel Livera. 1989. Useful techniques for plant scientist published by Forum from plant physiologist.
- Donald, C.M. and Hamblin. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Adv. Agron*. 28: 361-404.
- Fertilizer Statistics. 2001-2002. The fertilizer association of India, New Delhi.
- Fisher, R.A. 1949. Statistical tables for biological, agricultural and medical research. Oliver and Byd, Edinburgh, London.
- Gill, P.S. and K.Singh. 1981. Effect of fertilization on yield contributing characters and grain yield of clusterbean (*Cyamopsis tetragonoloba*) varieties. *J. Res. Haryana. Agri. Univ*. 11(3): 333-338.
- Govt. of Rajasthan. 2001. Vital Agriculture Statistics. Directorate of Agriculture, Jaipur.
- Jain, N.K., H.C. Jain and U.R. Khandker. 1988. Response of *Kharif* legumes to fertilizers and *Rhizobium* inoculation. *Indian J. Agron*. 33(4): 347-50.

- Jat, A.S., H.L. Meena and M.L. Jat. 2001. Nutrient content, uptake and quality parameters of clusterbean (*Cyamopsis tetragonoloba*) as influenced by phosphorus and sulphur fertilization. *Agron. digest*. 1: 64-66.
- Kacker, N.L., H.S. Daulay and R.P. Singh. 1984. Effect of inter and intra-row spacings on grain yield of rainfed clusterbean. *Ann. Arid Zone*. 23(1): 1-5.
- Kanwar, J. S. 1976. Soil Fertility, Theory and Practice. ICAR Pub., New Delhi.
- Khan, H. and B.S. Gurjar. 1997. Effect of phosphorus and sulphur levels on yield of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]. *Bhartiya-Krishi-Anusandhan-Patrika*. 12(2): 113-117.
- Kumar, D. 1987. Effect of plant population and phosphorus on growth and yield of two varieties of guar (*Cyamopsis tetragonoloba*). M.Sc. (Ag.) Thesis, Div. of Agron., IARI, New Delhi.
- Lindner, R.C. 1944. Rapid analytical methods for some or more common organic substance of plants and soils. *Plant Physiol*. 19(1): 76-84.
- Malik, A.C., D.R. Dahiya, D.P. Singh and D.S. Malik. 1981. Yield and quality of two guar cultivars as influenced by inter-row spacing and phosphorus application. *J. Res. Haryana Agril. Univ*. 11(2): 155-61.
- Mavi, H.S. 1986. Introduction to agrometeorology, Oxford and IBH Pub. Co., Bombay.
- Meena, G. 1988. Effect of sowing dates and supersorb on clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] production in semi-arid climate. M.Sc. (Ag.) Thesis, Deptt. of Agron., RAU, Bikaner.
- Meena, K.C., G.D. Singh and S.L.Mundra. 1991. Effect of phosphorus, micronutrients and irrigation on clusterbean. *Indian J. Agron*. 36(2): 272-74.
- Mundra, S.L. and P.L. Maliwal. 1990. Effect of nitrogen and copper fertilization on the growth and yield of clusterbean. *Intern. J. Trop. Agri*. 8(3): 226-228.
- Olsen, S.R., C.W. Cole, F.S. Wathade and L.A. Dean. 1954. Estimation of available phosphorus in soil by extraction with NaHCO₃. USDA Circular. 1969:931.
- Palsaniya, D.R. 2002. Effect of sowing time, plant population and fertilizer levels on productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]. M.Sc. (Ag.) Thesis, Deptt. of Agron., MPUAT, Udaipur.

- Panse, V.G. and P.V. Sukhatme. 1985. Statistical methods for agricultural workers. ICAR, New Delhi.
- Pareek, R.G. 1995. Response of clusterbean to sulphur levels, sources of phosphorus and plant growth regulators and their residual effect on taramira. Ph.D. Thesis, Deptt. of Agron., RAU, Bikaner.
- Piper, C.S. 1950. Soil and plant analysis. Inter Service Pub. Inc., New York.
- Reager, M.L. 2001. Effect of weed control and phosphorus on growth, yield and quality of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]. M.Sc. (Ag.) Thesis, Deptt. of Agron., RAU, Bikaner.
- Richards, L.A. 1968. Diagnosis and improvement of saline and alkali soils. USDA Handbook No.6, Oxford and IBH Pub. Co., New Delhi.
- Sarawagi, S.K., Tiwari, S.K. and Tripathi, R.S. 1998. Nitrogen fixation, balance sheet and yield of winter soybean as affected by divergent nutrients. *Ann. Agric. Res.* 19(4): 379-85.
- Sharma, B.D., K. D. Taneja, M. J. Kairon and V. Jain. 1984. Effect of date of sowing on yield of clusterbean. *Indian J. Agron.* 29(4): 557-558.
- Shivran, A.C. 1994. Response of clusterbean varieties to sulphur and phosphorus. M.Sc. (Ag.) Thesis, Deptt. of Agron., RAU, Bikaner.
- Shivran, A.C., S.S. Khangarot, P.L. Shivran and D.R. Gora. 1996. Response of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] varieties to sulphur and phosphorus. *Indian J. Agron.* 41(2): 340-342.
- Singh, B.P. and J.P. Singh. 1986. Effect of crop geometry on seed yield and water use of dryland clusterbean on aridisols. *Intern. Seminar on Water Management in Arid and Semi-arid Zones*, held at Hissar, Nov. 27-29, 1986, pp. 231-237.
- Singh, D.P., D.N. Rathore, H. Singh and V. Kumar. 1978. A note on crude protein and gum production of two varieties of Guar [*Cyamopsis tetragonoloba* (L.) Taub] as influenced by different seed rates and row spacings. *Ann. Arid zone* 17(3): 329-331.
- Singh, H. and U.S. Tiwana. 1995. Response of guar [*Cyamopsis tetragonoloba* (L.) Taub] varieties to varying levels of phosphorus and spacing. *Indian J. Agric. Res.* 29(1): 49-52.

- Singh, K., S. Kumar and K.D. Taneja. 1980. Effect of different sowing dates on yield of different varieties of guar. *J. Res. Haryana Agril. Univ.* 9(4): 312-316.
- Singh, R. V. and R.R. Singh. 1990. Uptake of nitrogen, phosphorus and potassium by guar [*Cyamopsis tetragonoloba* (L.) Taub] as influenced by nitrogen (with and without seed inoculation), phosphorus and seeding rates under rainfed conditions. *Ann. Agric. Res.* 11(3-4): 329-332.
- Singh, R.V. and R.R. Singh. 1989. Effect of nitrogen, phosphorus and seedling rates on growth, yield and quality of guar under rainfed conditions. *Indian. J. Agron.* 34(1): 53-56.
- Singh, S.J.P. and C.B.S. Rajpoot. 1985. Effect of nitrogen, phosphorus and cycocel on physiological characters of clusterbean vegetable [*Cyamopsis tetragonoloba* (L.) Taub]. *Pusa Navbahar Prog. Horti.* 17(3): 181-84.
- Solanki, N.S., R.P.S. Shaktawat and B.S. Shekhawat. 1998. Efficacy of phosphate culture with phosphorus levels on growth and yield of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]. *Ann. Arid zone.* 37(4): 417-418.
- Subbbiah, B.V. and G.L. Asija. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.* 27(7): 259-60.
- Taneja, K.D., B.P. Sharma and P.S. Gill. 1981. Response of clusterbean to varying levels of phosphorus and bacterial culture. *Guar Newsletter.* 3:20-23.
- Tisdale, S.L., W.L. Nelson, J.D. Beaton and J.L. Havlin. 2003. Soil fertility and fertilizers (6th ed.). Published by Pearson Education (Singapore) Pte. Ltd. New Delhi, India.
- Walkley, A. and I.A. Black. 1947. Rapid titration method for organic carbon of soils. *Soil Sci.* 37(1): 29-32.
- Watson, D.J. 1958. The dependence of net assimilation rate on leaf area index. *Ann. Bot.* 22: 37-54.
- Yadav, G.L. 1979. Studies on optimum plant population of guar in relation to plant type. M.Sc. (Ag.) Thesis, Deptt. of Agron., Sukhadia University, Udaipur.