

**Effect of Varieties and Nutrient Management on Productivity,  
Profitability and Nutrient Uptake of Clusterbean [*Cyamopsis*  
*tetragonoloba* (L.) Taub]**

**THESIS**



*Submitted to the*

**Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya**

In partial fulfilment of the requirements for the degree of

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**AGRONOMY**

*by*

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**2013**

## **CERTIFICATE - I**

This is to certify that the thesis entitled “**Effect of varieties and nutrient management on productivity, profitability and nutrient uptake of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]**” submitted in partial fulfilment of the requirements for the Degree of **DOCTOR OF PHILOSOPHY in Agriculture (Agronomy)** of **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** is a record of the bona-fide research work carried out by **Ms. UPAMA RAWAT** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of this investigations has been acknowledged by scholar.

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# CHAPTER – I

## INTRODUCTION

Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] commonly known as guar, is an annual Kharif arid legume grown for green fodder, vegetable, green manuring, gum and seed purpose from ancient time. Being drought tolerant and hardy, the crop is cultivated under rainfed condition in India since ancient time. Agro-ecological condition of India is ideal for guar cultivation.

Its deep penetrating root system enables the plant to utilize available moisture more efficiently and thus offers better scope for rainfed cropping. The crop survives best even at moderate salinity and alkalinity. There is no other legume crop so hardy and drought tolerant as clusterbean. It's a good source of carbohydrates, protein, fibre and minerals like calcium, phosphorus and iron as well as contains appreciable amount of vitamin C. It provides nutritive concentrate and fodder for cattle and adds to the fertility of soil, by fixing considerable amount of atmospheric nitrogen. Clusterbean seed is used as concentrate for animal and for extraction of gum, seeds contain 28 to 33 per cent gum. Guar gum is used in almost all types of industries viz., fertilizers, papers, petroleum, pharmaceuticals, food processing, cosmetics, mining explosive, oil drilling etc. India is earning crores of foreign exchange every year by exporting guar gum and a record Rs. 731 crores was obtained in year 1998-99 (Anonymous, 2000). Therefore, India occupies top position in world trade of guar gum. The byproduct from gum extraction process is of a high value protein feed for cattle as it contains about 40 per cent protein.

India is the largest grower and producer country of guar in the world, and the same is grown in the north-western states of India, namely, Rajasthan, Gujarat, Haryana, Punjab and some parts of Uttar Pradesh and Madhya Pradesh.

In India, it is grown on an area of 2.23 million hectare with the production of 1.69 million tonnes and the productivity is 491 kg/ha (C.L.R.S. 2010). The agro-ecological condition of M.P. is ideal for guar cultivation. In M.P. guar is cultivated as pure crop in 24340 ha and productivity is 316 kg/ha. Cultivated as a mixed crop in an area of 54782 ha (C.L.R.S. 2012). Several attempts have been made to increase the yield potential of clusterbean, primarily with the use of fertilizer, pesticides and better management practices coupled with genetic improvement. But, very little attention has been given to the physiological processes, nutrient uptake and use of organic manure etc. which limit the crop productivity.

The indiscriminate use of chemical fertilizers resulted in the deficiency of secondary and micronutrients and decline in organic carbon. Therefore, sustainability of crop production system is going to depend on integrated nutrient management and balanced supply of nutrients from inorganic, organic and biological sources. Organic manures and vermicompost are the important constituents of the integrated plant nutrient management system. Singh *et al.* (2006) found that when manure was applied in conjunction with chemical fertilizers for efficient growth of crop, the decline in organic carbon was arrested and the gap between potential yield and actual yield was bridged to a large extent. According to Roy and Singh (2006) the use of vermicompost is being advocated for sustaining soil fertility in various field crops. The use of organic

manures and vermicompost improves the physical, chemical and biological properties of soil, fertilizer use efficiency, mitigates short supply of micronutrients, stimulates the proliferation of diverse group of soil microorganisms and play an important role in the maintenance of soil fertility and improves the ecological balance of rhizosphere.

The long-term use of chemical fertilizers is known to degrade physico-chemical and biological properties of soil i.e. soil environment and soil health. The nutrient requirement of crops can not, however, be met through fertilizers alone. Besides the escalating prices of fertilizers and their inadequacy calls for integration of nutrient sources for meeting the nutrient demand of crops.

The organic sources of nutrients are gaining global importance in crop production and are required to be integrated with chemical fertilizers. Recycling of farm by-products (organic matter) has become inevitable in the present intensive cropping system in enhancing the crop productivity and sustaining the soil health. This is eco-friendly system where all living organisms are mutually benefited and food for better health is obtained.

The estimated nutrient potential of organic wastes in the country is more than 20 million tonnes. This can be transformed into unstable manures with high nutritive value (Sharanappa, 2002). Organic manures being economical and eco-friendly and gaining importance for sustainable crop production. Residual effect of organic manures in enhancing microbial activity in soil and increasing soil biomass and physical properties is very well known.

In fact, the balanced fertilization from different sources is referred as the integrated nutrient management. Organic manures such as vermicompost, poultry manure, FYM (cattle manure), composts, etc. as well as biofertilizers are important components of integrated nutrient management. Organic manures also supply the traces amounts of micronutrients which are generally not applied by the farmers to their crops. The conjoint use of vermicompost with inorganic fertilizers enhances utilization of nutrients by the soil microbial process (Lenin and Rangaswamy, 2002).

The vermicompost is an aerobically degraded organic matter which has undergone chemicals disintegration by enzymatic activity in the gut of earthworms and also enzymes of the associated microbial population (Kale *et al.* 1992). Vermicompost is rich in both macro and micronutrients, besides having the plant growth promoting substances, humus forming microbes and nitrogen fixers (Bano *et al.* 1987).

Worms convert 160,000 tonnes of waste material into fertilizer each year (Lotzof, 1999). Vermicompost, being a rich source of macro and micro-nutrients, vitamins, plant growth regulators and beneficial microflora, appeared to be the best organic source in maintaining soil fertility on sustainable basis towards an eco-friendly environment (Edwards and Arancon, 2004). Worm casts contain 5 times more N, 7 times more P and 11 times more K than ordinary soil, the main minerals needed for plant growth (Sharma and Agrawal, 2004). Vermicompost application to different field crops has been known to reduce the requirement of chemical fertilizer without any reduction in crop yield (Giraddi, 2000). Although good amount of research work has been done to study the effect of vermicompost on different vegetable crops (Patil *et al.*, 2004).

The intensive use of chemical fertilizers especially nitrogenous fertilizers without organics has created a number of problems which have significantly affected soil fertility and crop productivity. Hence, complementary or supplementary use of chemical fertilizers, organic manures and bio-fertilizers has assumed greater importance now-a-days to maintain as well as sustain a higher level of soil fertility, crop productivity and reduced cost of cultivation (Shalini *et al.*, 2002).

The development of high yielding genotypes of clusterbean has opened new area in its cultivation during rainy season. However, the yield potential of these genotypes is governed by different production factors involving organic sources of nutrients with reduced chemical fertilizer application. The varieties with higher dry matter production and its proper distribution towards reproductive organs result in higher productivity. The dry matter production can be increased by selecting varieties with high photosynthetic rate. The rate of photosynthesis can be increased by proper fertilizer nutrition which in turn increases the chlorophyll content of leaves and leaf area or photosynthetic area (Singh *et al.*, 1983).

Use of improved varieties in addition to adequate nutrient management has been reported effective in improving the productivity of clusterbean in arid zone (Singh *et al.*, 2004). Though the cultivars have their own ability for growth development and yield, yet some promising genotypes of guar have shown considerable variation particularly in yield potentials under varying level of fertility. The yield potential of different clusterbean varieties may differ under different agro-climatic conditions because of their inherent capacity.

Hence, there is a need to study the effect of newly released varieties and nutrients on physiological and morphological parameters and yield components in clusterbean to boost up the productivity. With this background, the present investigation was carried out with the following objectives :

- To find out the suitable variety of clusterbean in respect of growth parameters, yield attributes and productivity.
- To find out the suitable fertility level for clusterbean.
- To assess the nutrient uptake by clusterbean varieties.
- To study the interaction effects between varieties and fertility levels of clusterbean.
- To calculate the economics of different varieties and fertility levels.

## **CHAPTER – II**

### **REVIEW OF LITERATURE**

The suitable variety and optimum dose of fertilizers play an important role in increasing the productivity of clusterbean. A diminutive research work has been carried out in the country and abroad on these aspects like effect of fertility levels and varieties on growth, yield and quality of clusterbean. Available literature related to the present field of study has been reviewed in this chapter.

#### **2.1 Effect of varieties**

The technique of growth analysis has been extensively used in recent years for better understanding of the physiological basis of yield variation in crop in chronological sequence to elucidate and account the causes for differences in yield through the events that have occurred at different stages of growth (Krishnamurthy *et al.*, 1973).

Leaf area duration is an important factor for growth and development of a crop (Evans, 1975). Sinclair and Dewit (1976) reported that the leaf area plays an important role in determining productivity in soybean.

Khande (1978) found that LAI increased population density. Greater LAI of JS-2 in the early stages of growth is an attribute to larger seed, greater seedling vigour and lesser life span. Reduction in LAI at later stage was due to high population per unit area which resulted in severe competition, particularly for light causing retardation in development and accelerated leaf fall.

Khande (1978) recorded that the NAR of JS-2 and Kalitur under varying population densities did not vary significantly during 15 to 30 days interval after sowing. At 30 to 45 days, the NAR increased for both the varieties; after 45 days NAR of both the varieties decreased at all densities.

Khande (1978) reported that between 15 to 30 days RGR decreased with increasing population. It was significant to note that maximum RGR was attained at 30 to 45 days and there after it decreased as the season progressed probably

because the leaf area ratio (LAR) was maximum at that time and dry matter accumulation was less. As the season progressed the dry matter accumulation was more which resulted in decreased RGR. It is a complex physiological character related to the net photosynthetic efficiency of the variety and is dependent on the LAR and NAR.

Pandey *et al.* (1978) observed a significant genotypic variability in CGR among blackgram genotypes at 49 and 56 days after sowing. On the otherhand, genotypic differences in NAR was not observed at any stage of crop. They further reported that NAR and RGR decreased with the advancement of crop growth in all the genotypes. Genotypic differences in NAR were also significant at all the stages of study.

Kalubarme and Pandey (1979) reported that leaf area ratio attained its peak between 21 and 28 days after sowing and declined thereafter steadily up to harvest in greengram.

Scott and Batchelor (1979) studied the dry matter accumulation and leaf area in diverse soybean cultivars and observed significant difference for various growth analysis parameters like crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), leaf area ratio (LAR), leaf weight ratio (LWR) and specific leaf area (SLA). The CGR was maximum at late vegetative and early reproductive stages ( $18.6 \text{ m}^{-2}\text{day}^{-1}$ ), whereas, the RGR, NAR and LAR were highest during early vegetative growth and decreased as season progressed.

Kenneth and Hell (1980) reported that seed yield was positively and significantly correlated with NAR and CGR in soybean. In mungbean, higher LAR during bud initiation stage was obligatory for better yield (Nijhawan and Chandra, 1980)

Gopal Singh *et al.* (1985) observed that LAI was higher in all the greengram genotypes. They further reported that SLW continued to increase from 33 to 44 days after sowing in all the varieties of greengram during both *Kharif* and summer seasons and decreased thereafter until maturity. On the otherhand, LAR and LWR decreased gradually in all the varieties with advancement in crop age. The values of CGR, RGR

and NAR were more in all the greengram varieties when grown during summer as compared to *Kharif*.

Thandapani (1985) reported a high genotypic variability with respect to both LAI and LAD among greengram genotypes. He also reported a positive relationship between leaf area and seed yield in greengram.

Nijhawan (1986) found that leaf area differed significantly among 25 promising varieties of greengram. He observed an increasing trend of LA up to 15 days after the initiation of buds and thereafter there was a steady decline in all the cultivars. The high yielding cultivars also possessed higher leaf area. Further, they found significant differences among 25 diverse greengram genotypes with respect to both SLW and LAR. They also observed that high yielding varieties possessed higher SLW at 15 days after bud initiation, while SLA was highest at maturity.

Panwar *et al.* (1986) and Nijhawan (1986) reported that in greengram, both leaf area and LAI attained the maximum values at 45 days and started declining thereafter till harvest.

Similarly, Basuchaudhari (1987) found that the seed yield is associated with high LAI and number of seeds/m<sup>2</sup> and moderate seed weight and dry matter production in soybean. Panwar *et al.* (1986) noticed both LA and LAI attained maximum values around 49<sup>th</sup> day from sowing, remained stable upto 70 days after sowing and started declining thereafter in all the greengram genotypes studied. They also showed that the cultivars which possessed larger LA and as well as LAI were high yielders.

Egli and Yu (1991) reported that the number of seeds per unit area is an important yield component in soybean and linear relationship between CGR and seeds per m<sup>2</sup> were established. They computed that seeds per m<sup>2</sup> is a direct function of canopy photosynthesis and partitioning co-efficient. Similar results were reported by Reganayaki and Sreerangasamy (1992) in blackgram.

Rana *et al.* (1991) reported that performance of clusterbean varieties differed significantly under each 30 and 45 cm row spacing.

Yadav *et al.* (1992) reported that amongst the 10 guar genotypes, HGS-365 gave significantly higher seed yield (18.09 q/ha) over the standard check, Naveen (13.38 q/ha) and HG-75 (12.10 q/ha). The increase in seed yield by HGS-365 was to the tune of 35.2 and 49.6 per cent, over Naveen and HG-75, respectively. The higher seed yield with HGS-365 may be because of combined effect of higher number of pods/plant, 1000 seed weight and seed yield/ plant.

Yadav *et al.* (1992) suggested that guar genotypes HG-365 may be sown at 45 cm row spacing in the first fortnight of July for higher seed yields.

Sharma and Sharma (1993) reported that the CGR, RGR and NAR differed significantly among the soybean genotypes. the CGR and NAR values ranged from 11.6 to 21.6  $\text{gm}^{-2}\text{day}^{-1}$  and 0.17 to 2.21  $\text{mg cm}^{-2}\text{day}^{-1}$ , respectively. However, significant differences for dry matter accumulation were not observed.

Singh and Singh (1996) reported that the decrease net assimilation rate with an advancement of crop growth in the present investigation could be attributed not only to a decline in leaf area but also due to natural shading of leaves within the canopy.

Dodwad (1997) stated that the important morpho-physiological traits associated with higher productivity in greengram are higher number of leaves, higher TDM, LAI, CGR, LAD, BMD, photosynthetic rate, nitrate reductase activity, higher correlation between SLW at the beginning of seed fill stage and grain yield ( $r=0.63$ ).

Budhiraja *et al.* (1998) reported that amongst the four cluster bean varieties (HG-75, HG 258, HGS 365 and RGC 936), HGS 365 proved superior which matured early (90 days). It was dwarf in height and produced higher seed yield and harvest index. Seed yield in HGS-365 was more due to more number of clusters and pods/ plant and highest test weight as compared to other varieties.

The important morpho-physiological traits associated with higher productivity in greengram are higher number of leaves, higher TDM, LAI, CGR, LAD, BMD, photosynthetic rate, nitrate reductase activity, higher number of fruiting clusters, higher seeds per plant and higher harvest index. These traits may be considered important for developing an ideotype concept in greengram (Goswami, 2000)

A trial on agronomic management of promising clusterbean genotypes at Bikaner and S.K. Nagar to evaluate suitable genotypes of guar for obtaining maximum grain yield under different agronomic management showed that HG-365 out yielded others, while, at S.K. Nagar both RGC-1025 and HG-365 proved superior to RGC-936 genotype (Anonymous, 2001-02). It was further reported on the basis of results (average over 13 centres) of initial varietal trial (early maturing group) that guar variety HG-365 recorded maximum plant height, higher number of branches and pods/ plant (Anonymous, 2001-02).

Garg *et al.* (2002) reported that the seed yield of early clusterbean genotypes was significantly higher (59.3 %) than that of late genotypes during the year of low rainfall while, late genotypes out yielded early types during the high rainfall year.

Vyas (2002) reported in his study on response of early and late clusterbean genotypes under field drought at Bhuj that the late genotypes had better vegetative growth in terms of plant height, number of leaves, number of branches and number of pods/ plant. The test weight of 100 seeds and the seed yield of both the varieties did not show significant difference.

Rajput (2002) observed that guar varieties RGC-1025, RGM-112, HG-365 and local responses better in terms of plant population, plant height, number of branches per plant, number of clusters/plant, number of seed per pod, yield, harvest index, protein content in seed and biomass yield.

Garg *et al.* (2003) reported that the results indicated that RGC-936 had a significant superiority over Maru guar under low rainfall conditions due to better utilization of available soil moisture, conservative leaf area development and better partitioning of assimilates and N to seeds leading to higher harvest index and nutrient use efficiency. On the other hand, under more favourable rainfall conditions, Maru guar performed better in terms of seed yield, water use efficiency and N use efficiency.

D'almeida and Tikka (2003) stated that genotypes HGS-843, RGC-1022, RGC-1017, GAUG-8832 and GG-1 gave stable performance for seed yield, whereas

genotype GAUG-9003 was found to be highly responsive to unfavourable environments. RGM-111 was identified as stable genotype, having high protein and gum contents, and bold seeds. The utilization of these genotypes in breeding programme is suggested to improve the productivity and quality of guar.

Forty one genotypes of cluster bean and 47 genotypes of mothbean were evaluated for crop physiological and yield traits during *Kharif* by Talwar *et al.* (2004). They concluded that there exists a significant relationship between SLA and seed yield, further suggested that low SLA could be an important character for selecting for higher yield.

Bhadoria and Kushwah (2005) concluded that clusterbean variety GAUG-9703 gave the highest yield closely followed by GAUG-003 and the lower yield was recorded under RGC-1055.

Choudhary *et al.* (2005) found that short duration varieties RGC-936, RGC-1002, RGC-1003 and RGC-1017 of clusterbean made significant contributions towards increased production and productivity in Rajasthan state.

Singh *et al.* (2005) registered that clusterbean varieties RGC-936, RGC-1002, RGC-1003, RGC-1017, RGC-1029, RGC-1033 and RGC-1038 were found superior in terms of seed yield, most of the yield attributing characters, fodder yield and early maturing.

Sheoran and Rana (2007) revealed that variety IGFRI-95 gave significantly higher seed yield followed by Bundel Lobia. The lowest seed yield was recorded in variety UPC-9202. The highest straw yield was obtained from UPC-9202.

Mohan Kumar (2008) reported that leaf area (LA) and leaf area index (LAI) increased progressive from 30 to 60 DAS and declined thereafter up to harvest. Significantly higher leaf area and leaf area index was recorded in high yielding genotypes.

Mohan Kumar (2008) observed significant differences among the genotypes with respect to leaf area ratio only during the initial stage in *Kharif*. Leaf

area ratio (LAR) decreased steadily with an advancement of crop growth from 30 DAS up to harvest.

Mohan Kumar (2008) reported that progressive increase of leaf area duration (LAD) and biomass duration with an advancement of crop growth and the genotypes differed significantly with respect to pod growth rate, leaf area duration and biomass duration at all the stages. The genotypes which performed better during both seasons recorded significantly higher pod growth rate, leaf area duration and biomass duration over all other genotypes and local check.

Mohan Kumar (2008) observed that significant differences were found among the genotypes for absolute growth rate and crop growth rate at all the stages. In general, absolute growth rate and crop growth rate increased with an advancement of crop growth. The genotypes which yielded high, possessed significantly higher absolute growth rate and crop growth rate over other genotypes.

Kalyani *et al.* (2011) reported that the variety Durgapur Safed significantly out-yielded the other varieties in respect of seed, protein and gum production.

## **2.2 Effect of fertility levels**

Nogucira *et al.* (1980) concluded that no significant differences were found in leaf area and LAI between phosphorus source but seed yield was significantly higher with superphosphate than theromphosphate. Irrespective of phosphorus sources, leaf area per plant, leaf area index and seed yield were higher with 400 kg phosphorus per hectare than 200 kg and 100 kg phosphorus per hectare.

Hogue *et al.* (1984) showed that application of phosphorus increased seed phosphorus content and phosphorus uptake with increase in rates of applied phosphorus fertilizer. Plant phosphorus uptake was increased while soil phosphorus uptake was decreased.

The data recorded on physiological aspects of growth and development characters revealed that with every increase in  $P_2O_5$  rate, growth measured in terms of height, number of branches, leaves and dry matter per plant, CRG, RGR, AGR,

NAR, LAI and LAR were significantly superior at all the stages of observation starting from 20<sup>th</sup> to 40<sup>th</sup> day during both the seasons (Rajput, 1985).

Rajput (1989) reported that the CGR, RGR, AGR, LAI, LAR and NAR significantly increased with the increasing levels of phosphorus except LAI, LAR and CGR.

Rafey and Srivastava (1989) reported that the application of 20 kg N + 30 kg P<sub>2</sub>O<sub>5</sub>/ha significantly enhanced the yield of horsegram as compared to the rest of the treatment combinations but identical with 20 kg N + 10 kg P<sub>2</sub>O<sub>5</sub>, 20 kg N + 20 kg P<sub>2</sub>O<sub>5</sub> and 0 kg N + 30 kg P<sub>2</sub>O<sub>5</sub>/ha.

Singh and Singh (1989) observed that the application of 20 kg N/ha along with seed inoculation and 60 kg P<sub>2</sub>O<sub>5</sub>/ha singly gave higher grain yield and net profit.

Patra (1991) found that grain yield was significantly increased with 20 kg N + 40 kg P<sub>2</sub>O<sub>5</sub> over the other doses. There was, however, decrease in grain yield when levels of N and P<sub>2</sub>O<sub>5</sub> were increased further. He reported that N and P in combination also had a significant favorable effect on growth and yield parameters viz., plant height, pods/plant, grains per pod and 1000 grain weight.

Yadav *et al.* (1991) in a trial on clusterbean reported that recommended fertilizer dose (20 kg N + 40 kg P<sub>2</sub>O<sub>5</sub>) and weed control practice was found to be the best with regard to seed yield (17.5 and 21.4 q/ha) and net profit (Rs. 2870 and 3852/ha) during 1989 and 1990, respectively.

Yadav *et al.* (1991) reported that application of 20 kg N + 40 kg P<sub>2</sub>O<sub>5</sub> / ha increased dry matter production and nutrient uptake significantly.

Rao and Tarafdar (1993) revealed that nodulation, N<sub>2</sub>-ase activity, per cent root infection by VAM fungi, and the number of VAM spores in the rhizosphere increased significantly upon inoculation. There was no change in the activity of acid phosphatase in the mycorrhizosphere, while alkaline phosphatase activity was enhanced, indicating that the enzyme increased the availability of P by the breakdown of organic phosphates. An improvement in dry matter production and grain yield of clusterbean upon inoculation with VAM fungi was evident. Inoculation

did not influence the uptake of K and Fe but the concentration of P, Zn, Cu, and Mn in the mycorrhizal plants was increased.

Kher *et al.* (1994) showed that the grain yield recorded with 20 and 40 kg N/ha not differ markedly but was appreciably high over the control. Yield obtained under 20 and 40 kg Nitrogen/ ha was higher owing to higher number of seeds/pod, more length of pod and test weight. They further reported that the application of phosphorus at 40 and 80 kg/ha did not differ practically in respect of growth parameters, yield attributes and yield, however, apparently higher over the control. In case of nitrogen application, similar findings were also reported by Prasad (1985).

Tarafdar *et al.* (1995) results indicated that the significant increase in phosphatase (acid and alkaline), dehydrogenase and nitrogenase activities was observed. Nodulation and nitrogenase activities were most affected by inoculation. Inoculation significantly improved the dry matter production, grain yield, number and dry weight of nodules and decreased shoot : root ratio. In general, there was a significant enhancement in the concentration of N, P, Ca, Mg, Fe and Zn while no effect on Mn with the inoculation of any PPF on clusterbean. A significant improvement in K concentration due to inoculation of *Aspergillus fumigatus* and Cu concentration with the inoculation of *Aspergillus rugulosus* and *Aspergillus terreus* was noted. *Aspergillus rugulosus* was found to be the best amongst PPF tested followed by *Aspergillus fumigatus*. The experiment confirmed that PPF have a significant effect on growth and nutrient uptake in the clusterbean and indicated the importance of these fungi on clusterbean production in an arid soil.

Baboo and Rana (1995) reported that application of 20 kg N/ha + *Rhizobium* inoculation resulted in higher yield over their individual application and control, except *Rhizobium* alone in 1988. Dose of 60 kg P<sub>2</sub>O<sub>5</sub>/ha gave markedly higher seed yield over lower rate of P in both the seasons.

Arya and Singh (1996) indicated that major plant nutrients mainly nitrogen and phosphorus had a positive effect on plant height, number of leaves, dry matter/plant, number of pods/plant and number of grains/pod. Number of branches/plant was unaffected while 1000 grain weight was found to be adversely

affected. The grain yield was increased with the application of nitrogenous fertilizers up to 20 kg N/ha and phosphatic fertilizers up to 60 kg  $P_2O_5$ /ha. Higher net income (Rs. 9899/ha and cost: benefit ratio (1: 3.54) were also recorded with the same level of fertility. They also reported that the levels of fertilizer did not affect the plant stand. Katiyar (1984) also recommended the application of nitrogen @ 15-20 kg N and phosphorus @ 40-50 kg  $P_2O_5$ /ha for taking higher yield of horsegram in Himachal Pradesh.

Bist and Chandel (1996) found non-significant response of 10 tonnes FYM /ha on number of pods/plant seed yield (q/ha) and protein content of soybean over control.

Dubey and Gupta (1996) reported that FYM @5 tonnes/ha enhanced the yield (12.6%) of black gram

Experiments conducted at Hisar and Durgapura revealed that the application of recommended dose of fertilizer gave significantly higher grain yield in comparison to 50% of recommended fertilizer dose at Bikaner and Durgapura (Anonymous, 1997-98).

Sarkar *et al.* (1997) reported that application of 10 tonnes FYM /ha gave significantly higher seed yield of pigeonpea (6.7 q/ha) over no FYM.

Varuna and Reddy (1999) concluded that application of 15 tonnes organic matter and 50 kg N as urea in Glycine mob resulted in significant highest seed yield of 1127 kg/ha which was 42, 20 and 25% more than 5 to 10 tonnes of organic matter with 50 kg of N and 100 kg N/ha as urea alone, respectively. The protein and oil content in seed also increased in the rate of organic matter and between any two rates the difference was significant.

Bheemaiah and Subramanyam (2001) showed that the net returns were significantly increased due to 40 kg  $P_2O_5$ /ha over 20 kg  $P_2O_5$ /ha during 1998-99 and up to 60 kg  $P_2O_5$ /ha over 20 kg  $P_2O_5$ /ha during 1999-2000, but not due to the application of N. The application of 40 kg N + 40 kg P produced more returns than other levels. Similarly the application of 60 kg P/ha resulted in higher gross returns but equally at par with 40 kg P/ha during both the years. It is evident that though both

the crops being legumes required more phosphorus, but the phosphorus dose can be reduced by 20 kg/ha on applying recommended dose of nitrogen, because of their synergistic effect. Similar results were also reported by Murty *et al.* (1990).

A coordinated agronomic experiment on clusterbean at Bikaner, Gwalior and S.K. Nagar centers during the year 2001-02 indicated that the application of recommended dose of fertilizer (20 kg N + 40 kg P<sub>2</sub>O<sub>5</sub>/ha) gave significantly higher yield than 50% of recommended fertilizer dose (10 kg N + 20 kg P<sub>2</sub>O<sub>5</sub>/ha) at Bikaner centre. On the basis of mean data it was further noted that recommended dose of fertilizer increased the seed yield by 18.21% over 50% of recommended dose (Anonymous, 2001-02).

The recommended dose of fertilizer significantly increased the seed yield (q/ha) of guar over 50% of the recommended dose of fertilizer at Bhattinda, Bikaner, Durgapura and Hisar (Anonymous, 2001-02).

The addition of 5 t FYM/ha or 2 t vermicompost/ha gave significantly higher yield of chickpea than control (Anonymous, 2002).

Singh and Khan (2002) showed that the response of clusterbean cultivars Local and RGC-936 to N : P fertilizers at 0 : 0 and 20 : 40 kg/ha, and different cropping systems (sole and in combination with *Prosopis cineraria*). Intercropping did not negatively affect crop growth and seed yield and the yield obtained in the intercrop was similar to that in the sole crop. RGC-936 had higher values for yield contributing parameters compared to the local cultivar, and had 29.5% higher yield. N : P at 20 : 40 kg/ha increased yield attributes and seed yield. The maximum water use efficiency was obtained in the treatment using the cultivar RGC-936, and with the N : P rate of 20 : 40 kg/ha.

Singh (2002) reported that the highest clusterbean seed yield (608 kg/ha) was obtained under FYM 2.5 tonnes/ha + N P (10kg N + 25 kg P<sub>2</sub>O<sub>5</sub>/ha). Application of FYM 5 tonne/ha to the preceding crop of clusterbean increased 20% yield over control. The highest benefit : cost ratio (3.63) and net returns over the control (Rs. 5040) also occurred with application of 5 tonnes FYM/ha.

Shekhawat *et al.* (2002) reported that highest total return (Rs. 26463/ ha) was recorded under recommended dose of fertilizer and highest seed yield of clusterbean (9.779 q/ha) was also recorded with this treatment.

Kumar and Puri (2002) Studied the response of phosphorus and FYM application under rainfed condition. They recorded the highest number of pods/plant, seed per pod, 1000 seed weight and harvest index which in term reflected the higher grain and straw yield. Application of 50 kg  $P_2O_5$  with 10 tonnes of FYM enhanced in the plant height, pods per plant, seeds per pod and 1000 seed weight and there by higher yields.

Shakhela *et al.* (2002) reported that the individual application of N and P as well as combined application of N, P and S did not show any significant effect on the yield of clusterbean.

Jain and Sodani (2002) found that application of 10 kg N and 30 kg  $P_2O_5$ /ha significantly increased seed yield by 7 per cent over 5 kg N and 15 kg  $P_2O_5$ /ha.

Singh and Khan (2002) registered that the fertilization of clusterbean crop with 20 kg N + 40 kg  $P_2O_5$ /ha resulted in significantly higher seed yield over control.

Palsaniya and Chaplot (2002) stated that clusterbean was sown with early showers of monsoon (26 June). The application of 20 kg N/ha + 40 kg  $P_2O_5$ /ha significantly improved number of pods/plant, pod length and total biomass yield. However, seeds/pod was recorded maximum at 30 kg N/ha + 60 kg  $P_2O_5$ /ha. Consequently, the crop fertilized 30 kg N/ha + 60 kg  $P_2O_5$ /ha produced the highest seed (16.43 q/ha) and straw yield (42.02 q/ha), which was significantly higher than that with other treatments.

Choudhary *et al.* (2003) stated that application of phosphorus significantly increased the number of pods per plant, number of seeds per pod, pod length, test weight, seed and straw yield and net return up to 40 kg  $P_2O_5$ /ha in clusterbean.

Patel *et al.* (2003) suggested that incorporation of *G. sepicum* leaves alone or in combination with N enhanced the yield of clusterbean and improved the status of organic carbon, available N and K in soil under rainfed conditions.

Rajkhowa *et al.* (2003) reported 25-50% saving of fertilizer with the addition of 2.5 t/ha vermicompost and significantly increased the yield, nutrient uptake and nodulation of green gram and overall improved the soil health.

Shubhra and Goswami (2003) found that the phosphorus proved effective in improving the chlorophyll content as also dry weight of plant parts at all the stages. On the contrary, proline content of the leaf decreased by phosphorus treatment.

Meena and Nagar (2004) indicated that application of 30 kg  $P_2O_5$ /ha significantly increased the number of pods/plant, seeds per pod, length of pod, test weight, seed yield, straw yield, biological yield, gum yield, protein content in seed and straw, total uptake of N, P and S.

Vasanthi and Subramanian (2004) studied that application of organic manures (vermicompost + FYM) and fertilizer (25 : 50 : 0 kg/ha N,  $P_2O_5$  and  $K_2O$ ) on the uptake of nutrient and crop protein content in black gram. Highest crude protein N, P and K concentration and uptake were recorded in the treatment that received 2 t vermicompost/ha along with 100% recommended NPK uptake.

Bhadoria and Kushwah (2005) concluded that application of 100% recommended NPK was better than 50% recommended NPK in respect of growth, yield and yield attributing characters of clusterbean.

Patel *et al.* (2005) reported on the basis of three years pooled data that guar crop fertilized with any of three fertilizer doses i.e. 15 N + 20  $P_2O_5$ , 20N + 20  $P_2O_5$  and 25 N + 50  $P_2O_5$  kg/ha produced significantly higher seed and straw yield than control (crop sown without fertilizer).

Gupta *et al.* (2006) observed significant response of crop up to 60 kg  $P_2O_5$ /ha for seed and straw yield, phosphorus application also resulted in significantly increase in seed protein content and N and P uptake in seed and straw.

Gomma and Magda (2007) reported that root nodules formation, the diverse tested bio-organic treatments induced increases ranged from 25 to 100% over the positive control being the highest with 30 ton FYM/fed. + *Rhizobium* + *Rhodotorula*. Comparable results to the positive control were obtained for the forage yield per fed without significant differences. Moreover, the highest forage yield was obtained due to the bio-organic treatment of 20 ton FYM/fed. + *Rhizobium* + *Rhodotorula*. The bio fertilization of guar with either *Rhizobium* as such or accompanied with *Rhodotorula* augmented seed yield/fed. where the percentage of increases ranged from 3% to 28% being the highest due to the dual inoculation with both bio- fertilizers. The highest increase in biological yield per fed (36% over the positive control) was obtained due to the application of 30 ton FYM + *Rhizobium* + *Rhodotorula*. The increases in pods number/plant ranged between 25% and 44% over the positive control owing to the applied bio-organic treatments produced results for seed nutrient content were similar to that obtained with the positive control without significant differences especially for P content.

Rathore *et al.* (2007a) results indicated that significant improvement in growth, yield and nutrient uptake was recorded with sole and integrated application of nutrients through chemical fertilizers and biofertilizers. Application of chemical fertilizers registered significant improvement in seed yield over control and magnitude of increase with application of 50, 75 and 100% of recommended dose of fertilizer (20 kg N, 40 kg P<sub>2</sub>O<sub>5</sub> ha) was 21.1, 45.6 and 50.9 % over the control, respectively. Association between *Rhizobium* and phosphate-solublising bacteria was synergistic and inoculation of both fertilizers significantly improved the seed yield. Inoculation of *Rhizobium*, phosphate-solublising bacteria and *Rhizobium* + phosphate-solublising bacteria recorded 21.0, 14.0 and 24.6% higher seed yield than the control, respectively. Integration of biofertilizer with chemical fertilizer @ 50% recommended dose of fertilizer brought significant improvement in yield and nutrient uptake over the respective sole application of chemical and biofertilizer and was comparable with application of 100% recommended dose of fertilizer.

Rathore *et al.* (2007b) stated that the nutrient application showed significant influence on productivity, quality and resource utilization (nutrient and water) of clusterbean. Application of chemical fertilizer @ 100% RDF (20 kg N + 17.5 kg P/ha) recorded 50.9, 59.3 and 36.2% higher seed yield, gum yield water-use

efficiency, respectively over the control. Among biofertilizers tested, dual inoculation (*Rhizobium* + phosphate-solubilizing bacteria) registered maximum improvement in yield, quality and nutrient uptake, followed by single inoculation of *Rhizobium* and PSB. Integration of chemical fertilizer @ 50% RDF with dual inoculation of biofertilizer registered 43.7 and 52.9% higher seed and gum yield, respectively over the control. Dual inoculation of biofertilizer (*Rhizobium* + PSB) integrated with chemical fertilizer @ 50% RDF fetched maximum net returns (Rs. 8,213 /ha) and B: C ratio (1.6:1).

Meena *et al.* (2008) stated that application of 20 kg N + 5t FYM/ha recorded significantly higher clusterbean-equivalent yield (1.036 t/ha), net monetary returns (Rs. 7,793/ha) and B:C ratio (1.7:9) than of 90 kg N/ha alone and the absolute control. Addition of 5t FYM/ha along with 20 kg N/ha gave 8.5 and 9.8% higher uptake of N than of 40 kg N/ha and the control, respectively.

Rawat and Rawat (2008) conducted a field experiment during *Kharif* season of 2006 and 2007 at RVSKVV, College of Agriculture Research Farm, Gwalior to study the performance of early maturing Guar variety and Bio-fertilizers under different fertility levels. On the basis of two years data, results revealed that the application of 10: 20 NP kg ha<sup>-1</sup>+ *Rhizobium* + PSB gave significantly higher grain yield of clusterbean (21.75 qha<sup>-1</sup>), maximum net return (Rs. 30585/- ha<sup>-1</sup>) and B : C ratio (4.47) as compared to control and recommended dose of fertilizer.

Singh *et al.* (2008) indicated that the growing of clusterbean and greengram as the preceding crop resulted in significantly higher grain yield of wheat and the N and P uptake than the preceding pearl millet. Greengram gave the maximum wheat grain-equivalent yield (WGEY) and net returns, but N uptake was significantly highest with clusterbean. However, highest WGEY (5.58 t/ha) was recorded with greengram-wheat, being 10 and 31.3% higher than that of the clusterbean-wheat and pearl millet- wheat crop sequences, respectively. Net returns and benefit : cost ratio were also maximum with greengram-wheat, but maximum gain in available N and P status was noted with clusterbean wheat sequence. Integrated use of FYM @ 7.5 t/ha + 50% RDF (50 kg N + 13.25 kg P/ha) + biofertilizer (*Azotobacter* + PSB) recorded significantly highest grain yield of wheat, which was 33.2% higher than in the control. Yield and nutrient uptake by *Kharif* crops

also increased markedly due to residual effect of FYM applied either alone or in combination. The highest WGEY, net returns and benefit : cost ratio of crop sequences were recorded with combined application of FYM @ 7.5 t/ha + 50% RDF + biofertilizer. The maximum gain in available N and P status was observed with the application of FYM @ 15 t/ha, followed by FYM @ 7.5 t/ha + 50% RDF + biofertilizer. Thus, wheat grown after legumes (greengram or clusterbean) with combined application of FYM @ 7.5 t/ha + 50% RDF + biofertilizer gave maximum WGEY and monetary benefit.

Burman *et al.* (2009a) reported that the P-fertilized plants displayed higher photosynthetic efficiency, leaf metabolism and enzyme activity than unfertilized plants though decrease in plant water status was more in P-fertilized plants. Recovery upon re-watering was also more in P-fertilized than unfertilized plants with respect to all the parameters studied. Consequently, P application significantly enhanced dry matter and seed yields at all stress intensities. The results indicated the possibility of alleviation of water stress effects by P-nutrition in clusterbean, at least up to moderate stress level.

Burman *et al.* (2009b) found that the phosphorus (P) and nitrogen (N) application either alone or in combination with thiourea resulted in significantly higher net photosynthetic rates and concentrations of chlorophyll, starch, soluble protein and total free amino acids as well as nitrate reductase activity compared to control plants at both vegetative and flowering stages. However, the magnitude of favourable changes varied with soil moisture due to varying rainfall, and the effects of N, P and thiourea were generally more pronounced in the vegetative stage. Seed yield, dry matter production, harvest index, and water use efficiency were significantly enhanced by the above-mentioned treatments. It is concluded that the improvement of P and N status of arid zone soils coupled with thiourea application can significantly improve the yield of clusterbean under rainfed conditions, though the potential gains may vary with soil moisture availability.

Chaurasia *et al.* (2009 a) observed that the N, P, K and S contents were, in general, two-fold higher in seed than in stover. Particularly N and then P contents were higher both in seed and stover, whereas S content was found in the lowest

range. Among the organic sources of nutrients, poultry manure registered almost significantly higher N, P, K and S contents in grain as well as in stover. This was followed by vermicompost and then FYM. The increasing fertility levels from 50% NPK to 100% NPKZnS increased all these nutrients contents almost significantly both in grain and straw. The uptake of N, P, K and S was found significantly higher in seed and stover with poultry manure over other organic sources of nutrients. This was, however, followed by FYM and then vermicompost. Application of 100% NPKZnS enhanced the N, P, K and S uptake by Ethiopian mustard in seed and stover. At the highest fertility level of 100% NPKZnS, the total biomass (seed + stover) produced was 6193 kg/ha which removed 102.77 kg N, 23.34 kg P, 53.0 kg K and 19.27 kg S/ha.

Chaurasia *et al.* (2009 b) stated that the plant height, in general, was very fast between 30 and 90 days growth period and thereafter became slow up to 120 days. Whereas branches/ plants were enhanced actively up to 120 days period. Among the organic sources, FYM @ 10 t/ha significantly increased the height and branches at all the growth stages as well as grain yield (12.59 q/ha) and net income (Rs. 35865/ha). The second best was poultry manure and then vermicompost. Poultry manure proved significantly superior to vermicompost. Vermicompost and biofertilizers gave equal net income (Rs. 27391 to Rs. 27942/ha). The 100% fertility ( $N^{80} P^{40} K^{20} Zn^5 S^{20}$ ) increased all these parameters almost significantly, over the lower fertility levels. The treatment interactions were found non-significant. The available N, P, K and S were improved in the post-harvest soil due to applied treatments, however, S and Zn improved slightly in S and Zn included treatments.

Kumawat *et al.* (2009) observed that the total and effective number of root nodules per plant at pre-flowering stage of crop, yield attributes (viz. number of pods/plant, seeds /pod and test weight) and seed and straw yields increased significantly up to application of 2t vermicompost and 1.0 kg Mo/ha. Nitrogen, phosphorus, potassium and molybdenum uptake by seed and straw enhanced significantly up to incorporation of 2t vermicompost and 1.0 kg Mo/ha. Addition of vermicompost @2 t/ha recorded significant increase in build up of organic carbon, available N, P, K and Mo contents of soil whereas, molybdenum @1.0 kg/ha brought significant increase in organic carbon, available N, P, K and Mo contents in post harvest surface soil. The beneficial effect of vermicompost has also been reported by several workers (Karmegam and Daniel, 2000; Rajkhowa *et al.*, 2002; Rajkhowa *et*

*al.* 2003; Sailaja Kumari and Usakumari, 2002; Thanunathan *et al.*, 2002; and Vasanthi and Subramanian, 2004).

Muhammad *et al.* (2009) studied the effect of different levels of nitrogen on the yield and yield component of Guar gum, at the Agricultural Research Farm, Malakandher, NWFP Agricultural University Peshawar during the year 2004. The experiment comprised of five nitrogen levels (0, 18, 22, 26 and 30 kg ha<sup>-1</sup>). All Parameters had significant response to nitrogen fertilizers. Nitrogen level of 30 kg ha<sup>-1</sup> gave early emergence of 8 days and delayed flowering (89.67 days) and fruiting (109.7 days). Maximum number of branches plant<sup>-1</sup> (32), pods plant<sup>-1</sup> (85), grains pods<sup>-1</sup> (9), length of pods (5.69 cm), plant height (175 cm) and grain yield kg ha<sup>-1</sup> (1754.5) was obtained with the application of 30 kg N ha<sup>-1</sup>.

Shah and Namdeo (2009) stated that the plant growth and yield components and thereby grain yield (12.72 q/ha) of chickpea were found highest in T<sub>3</sub> having FYM + vermicompost + linseed cake + intercropping with mustard. The T<sub>7</sub> treatment (100% NPK + ZnSO<sub>4</sub>) recorded the grain yield (12.54 q/ha) closer to T<sub>3</sub> and a net return (Rs.18078/ha). On the basis of the findings, they concluded that T<sub>2</sub> (FYM + vermicompost + linseed cake) proved the best substitute of T<sub>7</sub> (100% NPK + ZnSO<sub>4</sub>) for growing chickpea economically under dryland conditions. Hakeem *et al.* (2007) also reported similar results.

Ayub *et al.* (2010) reported that the application of 50 kg N/ha gave significantly the maximum forage yield (63.70 kg/ha). The increase in yield was mainly due to greater plant height, number of leaves and leaf area per plant and number of branches per plant. The quality parameters like crude protein, crude fiber, total ash and dry matter percentage were also increased significantly by nitrogen application over control. Significant difference was also observed among cultivars regarding green forage and dry matter yield, plant height, number of leaves and leaf area per plant. The variety BR-99 produced significantly higher forage yield (63.00 t/ha), crude protein contents (16.63 %) and lower ash contents than cultivars cluster bean 2/1 and BR-90. Crude fibre contents were statistically similar in all cultivars. For obtaining higher cluster bean forage yield having higher protein and ash contents, the cultivar BR- 99 may be grown and fertilized at 50 kg N/ha under the agro-climatic conditions of Faisalabad.

Patel *et al.* (2010) observed that the integrated use of inorganic fertilizer, bio-fertilizer and organic manure enhanced the growth and seed yield of clusterbean. Higher yield and yield attributes as well as nutrient uptake and protein content were recorded in the treatment of 100% RDF (25 kg N + 50 kg P<sub>2</sub>O<sub>5</sub>/ha) + FYM @ 10 t/ha + seed treatment with *Rhizobium* followed by 100% RDF + Vermicompost @ 2 t/ha + seed treatment with *Rhizobium*. Application of FYM @ 10 t/ha + *Rhizobium* inoculation integrated with chemical fertilizer (100% RDF) fetched maximum net returns (Rs. 1,16,640 /ha) and BCR (6.21).

Rawat *et al.* (2010) conducted a field experiment during *Kharif* seasons of 2006 and 2007 at Agriculture College Farm, Gwalior under AICRP on Arid Legume. The results revealed that the application of 50% recommended fertilizers + FYM @ 5 tonnes/ha with PSB culture obtained higher seed yield (20.92 q/ha), net return (Rs. 28181/ha) and B:C ratio (3.97) as compared to control and recommended dose of fertilizers. Hence, the use of organic manure and bio-fertilizer can save the 50% of chemical fertilizers.

Yadav *et al.* (2011) concluded that the seed and straw yield of clusterbean increased significantly with increase in level of P and S individually as well as in various combinations. Phosphorus application increased the micronutrient uptake by 22.7 to 40.3% (Fe), 18.4 to 28.2% (Cu), 22.7 to 40.3% (Zn) and 19.1 to 35.7% (Mn) in seed, however 17.2 to 30.4% (Fe), 13.1 to 19.6% (Cu), 17.1 to 31.3% (Zn) and 11.4 to 23.6% (Mn) increase in uptake was recorded in straw.

Ayub *et al.* (2012) reported that above ground plant biomass like plant height, stem diameter, number of branches and leaf area per plant and measures of nutritional profile like crude protein, crude fibre and ash contents were significantly improved with PK application over control. The PK application at the rate of 70:70 kg/ha registered the highest value for plant height and stem diameter. Whereas, the maximum number of branches and leaf area per plant, fresh and dry matter yield was achieved with 85:85 kg PK/ha. Among the forage quality traits, the dry matter % age was not responsive to PK application. The highest crude fiber and ash contents in plant dry matter was produced with 100:100 kg PK/ha. The crude protein contents

showed a steady increase in crude protein up to 85:85 kg PK/ha and further increase in PK fertilizer significantly reduced crude protein. For obtaining high yield with good nutritional value, PK fertilizer must be applied at the rate of 85:85 kg/ha under the irrigated conditions of Faisalabad.

Selvaraj and Prasanna (2012) reported that all the crop growth stages, nitrogen levels significantly influenced the dry matter production. The highest dry matter production was registered with N<sub>3</sub> (40 kg N ha<sup>-1</sup>), while it was the lowest with N<sub>1</sub> (20 kg N ha<sup>-1</sup>). Yield attributes viz., number of clusters plant<sup>-1</sup>, number of pods cluster<sup>-1</sup>, number of pods plant<sup>-1</sup>, pod length, number of seeds pod<sup>-1</sup> and thousand seed weight were highest with N<sub>2</sub> (30 kg N ha<sup>-1</sup>), while they were at their lowest with N<sub>3</sub> (40 kg N ha<sup>-1</sup>) except clusters plant<sup>-1</sup> and pod length which were lowest with N<sub>1</sub> (20 kg N ha<sup>-1</sup>). The seed yield and stalk yield were highest with N<sub>2</sub> (30 kg N ha<sup>-1</sup>) and they were at their lowest with N<sub>1</sub> (20 kg N ha<sup>-1</sup>). Among the zinc management practices Z<sub>3</sub> (0.5 ZnSO<sub>4</sub> spray at 25 and 45 DAS) resulted in highest seed and stalk yield. Application of 20 kg ZnSO<sub>4</sub> ha<sup>-1</sup> (Z<sub>4</sub>) recorded the lowest yield. With regard to quality parameters, protein content was found to be highest with N<sub>3</sub> (40 kg N ha<sup>-1</sup>), which was however, comparable with N<sub>2</sub> (30 kg N ha<sup>-1</sup>) and it was lowest with N<sub>1</sub> (20 kg N ha<sup>-1</sup>). The highest protein content was recorded with Z<sub>3</sub> (0.5% ZnSO<sub>4</sub> spray at 25 and 45 DAS), while it was lowest with Z<sub>4</sub> (20 kg ZnSO<sub>4</sub> ha<sup>-1</sup>). The combination of nitrogen levels and zinc management practices could not influence the protein content. The highest post harvest stats of soil available phosphorus and potassium was recorded with N<sub>2</sub>(30 kg N ha<sup>-1</sup>).

Sharma and Jain (2012) concluded that an application of 100% NPKSZn significantly enhanced the seed and straw yields of clusterbean by 29.5 and 29.6 per cent over 100% NPK, respectively. This treatment also recorded significantly higher concentrations and uptake of N, P, K, S and Zn as well as improved the soil fertility status.

Shivran and Yadav (2013) conducted a field experiment during 2004-05 and 2005-06 at Agricultural Research Station, Durgapura, Jaipur to study the effect of NP fertilizers, vermicompost and sulphur on growth, yield attributes, yield and quality of clusterbean [*Cymopsis tetragonoloba* (L.) Taub] and residual effect of NP

fertilizers, vermicompost and sulphur on grain yield of succeeding wheat [*Triticum aestivum* (L.) emend. Flori & Paol.]. Application of NP fertilizers up to 75% of RDF (15 kg N + 30 kg P<sub>2</sub>O<sub>5</sub>/ha) recorded significantly higher seed yield, gum content and gum yield by 46.99 and 14.88, 11.06 and 5.26 and 63.53 and 20.29 per cent over control and 50% of RDF, respectively. Vermicompost application @ 2.0 t/ha significantly increased the yield attributes of clusterbean viz., pods per plant, seeds per pod, pod length and test weight and seed, straw and biological yields of clusterbean over vermicompost @ 1.0 t/ha, Further, the successive increase in sulphur up to 40 kg S/ha recorded significantly higher seed and straw yields of clusterbean. The combined application of NP fertilizers @ 75% RDF and vermicompost @ 2.0 t/ha significantly improved the pods per plant and seed yield of clusterbean. The 100% of RDF, vermicompost @ 2.0 t/ha and sulphur @ 60 kg S/ha applied to clusterbean recorded significantly higher grain yield of succeeding wheat crop by 21.54, 12.04 and 21.09 over control, respectively.

## **CHAPTER – III**

### **MATERIALS AND METHODS**

With a view to obtain higher precision in the results, the present experiment “Effect of varieties and nutrient management on productivity, profitability and nutrient uptake of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]” was conducted at the Research Farm, College of Agriculture, Gwalior during *Kharif* 2011 and 2012. The material used and the techniques adopted for the study were considered as the most important ones. Therefore, the ensuing account has been prepared in the same light. A detailed account of the material employed and methods followed during the course of investigation is embodied in this chapter.

#### **Location, climate and weather conditions:**

Gwalior is located at 26°13' north latitude and 74°4' east longitude and 208 metre above mean sea level. It lies in the north tract of M.P. enjoying subtropical climate, with extreme hot about 46°C in summer and minimum temperature below 1°C in the winter season. The annual rainfall ranges between 650 to 751mm, most of which received from end of June to end of September. Drought is the common feature due to the scanty and uneven distribution of rainfall. The relevant meteorological data during crop season are presented in Table 3.1 & 3.2 and Fig. 3.1a, 3.1b, 3.2a & 3.2b.

#### **Experimental site:**

The experiment was conducted at College of Agriculture Farm, Gwalior (M.P.) under AICRP on arid legumes. The topography of the field was uniform with proper drainage. The soil of the experimental field was sandy loam. Few soil samples of the surface soil up to 15 cm depth were taken randomly before sowing and a composite sample made after mixing all these, was analysed in the laboratory for mechanical and chemical composition. Data obtained are presented in Table 3.3

**Table 3.1 : Meteorological data during crop season 2011-12.**

| Met. Week | Date               | Temperature (°C) |      | Humidity (%) |         | Rainfall (mm) | Evapo ration (mm) |
|-----------|--------------------|------------------|------|--------------|---------|---------------|-------------------|
|           |                    | Max.             | Min. | Morning      | Evening |               |                   |
| 22        | 28 May to 03 Jun.  | 41.4             | 27.6 | 58.5         | 33.0    | 000.0         | 10.8              |
| 23        | 04 to 10 Jun.      | 43.7             | 27.1 | 55.0         | 31.7    | 034.0         | 12.3              |
| 24        | 11 to 17 Jun.      | 29.3             | 26.5 | 77.0         | 40.0    | 022.6         | 8.4               |
| 25        | 18 to 24 Jun.      | 35.3             | 26.1 | 83.8         | 68.0    | 052.8         | 5.0               |
| 26        | 25 Jun. to 1 Jul.  | 33.0             | 26.4 | 84.5         | 73.2    | 072.2         | 4.8               |
| 27        | 02 to 08 Jul.      | 35.5             | 27.1 | 77.8         | 59.5    | 018.2         | 7.7               |
| 28        | 09 to 15 Jul.      | 33.9             | 25.9 | 85.7         | 72.1    | 076.0         | 4.0               |
| 29        | 16 to 22 Jul.      | 32.8             | 25.1 | 85.5         | 79.2    | 149.4         | 5.2               |
| 30        | 23 to 29 Jul.      | 32.2             | 25.8 | 90.1         | 77.4    | 041.6         | 2.9               |
| 31        | 30 Jul to 05 Aug.  | 34.2             | 26.3 | 87.7         | 73.1    | 019.4         | 4.2               |
| 32        | 06 to 12 Aug.      | 31.5             | 25.3 | 92.1         | 78.8    | 071.8         | 3.1               |
| 33        | 13 to 19 Aug.      | 32.4             | 25.1 | 76           | 71.4    | 085.2         | 2.8               |
| 34        | 20 to 26 Aug.      | 33.7             | 25.8 | 85.1         | 61.7    | 006.0         | 3.4               |
| 35        | 27 Aug. to 2 Sept. | 34.8             | 26.7 | 87.1         | 69.7    | 011.2         | 4.8               |
| 36        | 03 to 09 Sept.     | 32.3             | 24.8 | 91.2         | 73.1    | 082.0         | 4.2               |
| 37        | 10 to 16 Sept.     | 33.0             | 24.9 | 92.7         | 70.2    | 083.2         | 3.0               |
| 38        | 17 to 23 Sept.     | 33.2             | 25.2 | 83.8         | 62.4    | 001.6         | 5.0               |
| 39        | 24 to 30 Sept.     | 34.3             | 26.2 | 71.7         | 49.2    | 000.0         | 7.7               |
| 40        | 01 to 07 Oct.      | 35.3             | 23.3 | 68.5         | 45.5    | 000.0         | 8.0               |
| 41        | 08 to 14 Oct.      | 35.5             | 19.6 | 78.0         | 36.5    | 000.0         | 4.9               |
| 42        | 15 to 21 Oct.      | 35.7             | 16.5 | 78.0         | 35.7    | 000.0         | 4.9               |
| 43        | 22 to 28 Oct.      | 34.5             | 16.2 | 81.7         | 36.1    | 000.0         | 4.2               |
| 44        | 29 Oct. to 4 Nov.  | 33.1             | 13.3 | 80.7         | 24.8    | 000.0         | 4.3               |
| 45        | 05 to 11 Nov.      | 32.4             | 14.9 | 78.5         | 31.5    | 000.0         | 4.0               |
| 46        | 12 to 18 Nov.      | 31.8             | 13.4 | 87.4         | 26.1    | 000.0         | 3.7               |
| 47        | 19 to 25 Nov.      | 27.8             | 13.1 | 94.5         | 51.0    | 000.0         | 2.2               |
| 48        | 26 Nov. to 2 Dec.  | 27.2             | 10.1 | 90.0         | 38.8    | 000.0         | 2.4               |
| 49        | 3 to 9 Dec.        | 29.5             | 12.3 | 87.8         | 35.7    | 000.0         | 2.4               |
| 50        | 10 to 16 Dec.      | 25.8             | 6.7  | 89.5         | 30.0    | 000.0         | 2.7               |
| 51        | 17 to 23 Dec.      | 23.3             | 3.5  | 96.1         | 36.7    | 000.0         | 1.2               |
| 52        | 24 to 31 Dec.      | 22.0             | 3.5  | 94.1         | 49.0    | 000.0         | 1.3               |

**Source:** Meteorological Observatory, College of Agriculture, Gwalior

Fig 3.1 a: Maximum & minimum temperature (°C) during crop season 2011-12.

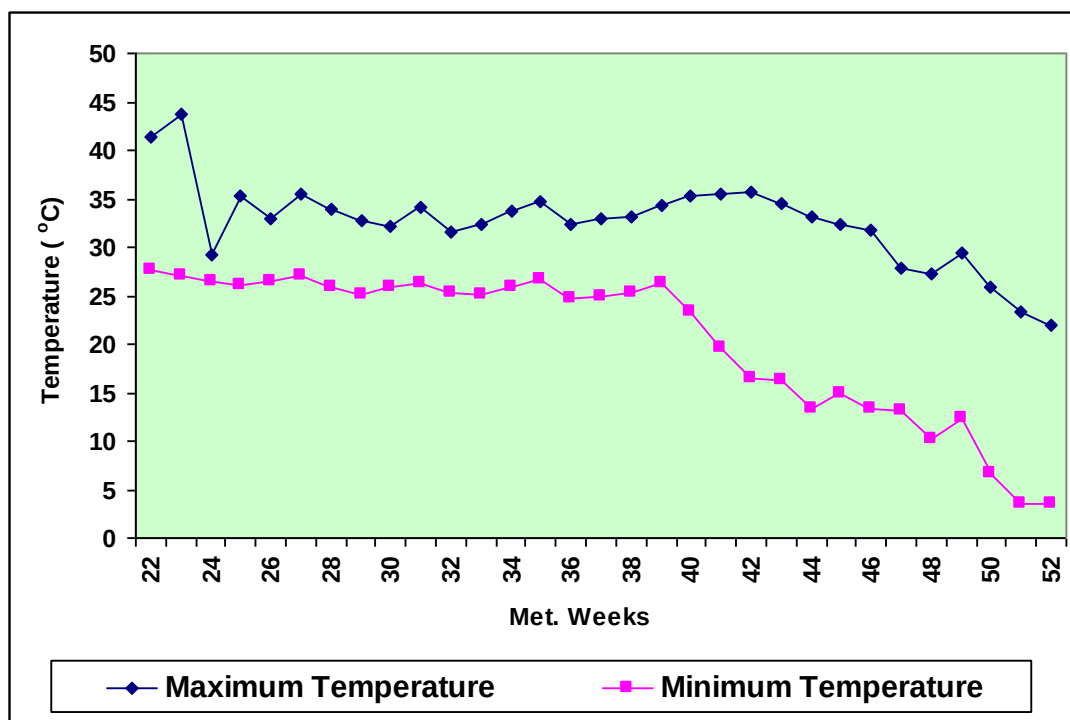


Fig 3.1b: Humidity (%) & Rainfall (mm) during crop season 2011-12.

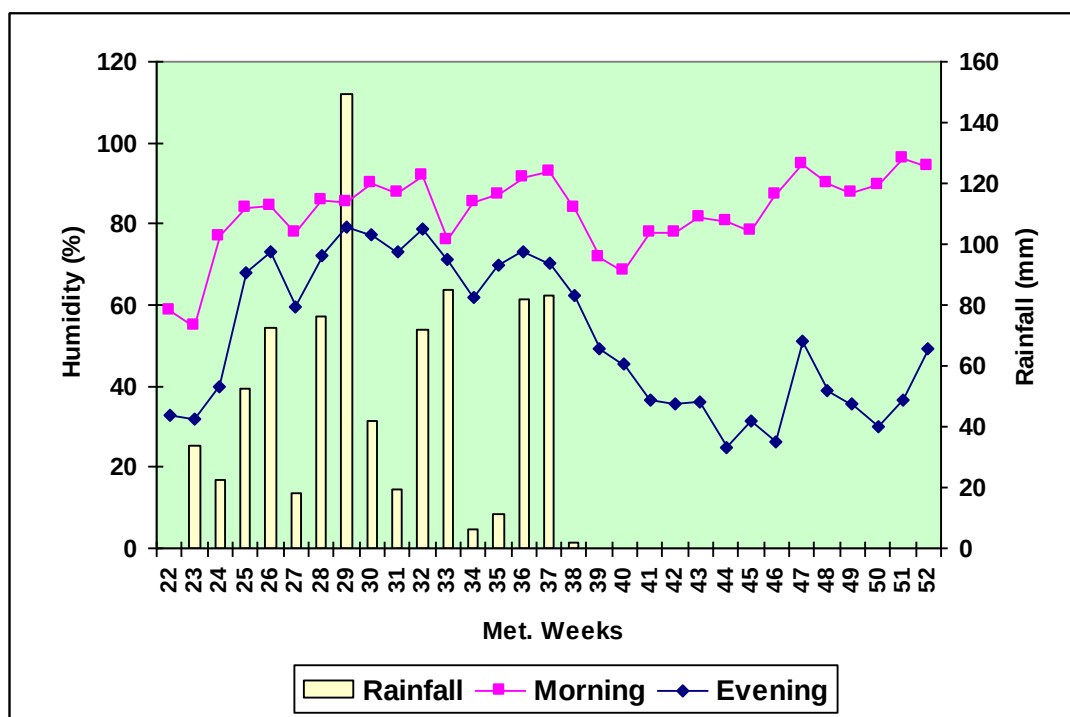


**Table 3.2: Meteorological data during crop season 2012-13.**

| Met. Week | Date               | Temperature (°C) |      | Humidity (%) |         | Rain-fall (mm) | Evapo-ration (mm) |
|-----------|--------------------|------------------|------|--------------|---------|----------------|-------------------|
|           |                    | Max.             | Min. | Morning      | Evening |                |                   |
| 22        | 28 May to 03 Jun.  | 45.5             | 27.9 | 33.2         | 16.2    | 000.0          | 18.2              |
| 23        | 04 to 10 Jun.      | 42.3             | 27.7 | 45.1         | 29.0    | 011.0          | 12.1              |
| 24        | 11 to 17 Jun.      | 43.4             | 30.7 | 46.5         | 31.8    | 000.0          | 14.4              |
| 25        | 18 to 24 Jun.      | 41.5             | 30.8 | 55.5         | 41.2    | 020.0          | 15.0              |
| 26        | 25 Jun. to 1 Jul.  | 42.7             | 32.7 | 41.8         | 31.0    | 000.0          | 16.5              |
| 27        | 02 to 08 Jul.      | 39.7             | 27.9 | 73.0         | 55.0    | 22.8           | 7.8               |
| 28        | 09 to 15 Jul.      | 34.7             | 25.5 | 89.0         | 71.0    | 92.2           | 4.0               |
| 29        | 16 to 22 Jul.      | 36.3             | 27.8 | 74.0         | 60.0    | 5.8            | 9.6               |
| 30        | 23 to 29 Jul.      | 33.0             | 26.1 | 91.0         | 75.0    | 94.2           | 3.0               |
| 31        | 30 Jul to 05 Aug.  | 32.3             | 25.6 | 89.0         | 76.0    | 40.0           | 3.5               |
| 32        | 06 to 12 Aug.      | 31.6             | 24.3 | 96.8         | 82.0    | 252.2          | 1.4               |
| 33        | 13 to 19 Aug.      | 31.4             | 24.8 | 89.5         | 73.1    | 20.2           | 3.3               |
| 34        | 20 to 26 Aug.      | 30.8             | 24.9 | 91.2         | 83.5    | 50.6           | 1.9               |
| 35        | 27 Aug. to 2 Sept. | 33.0             | 25.2 | 91.5         | 79.0    | 40.8           | 3.4               |
| 36        | 03 to 09 Sept.     | 31.6             | 24.7 | 90.7         | 75.2    | 29.5           | 2.7               |
| 37        | 10 to 16 Sept.     | 33.5             | 25.1 | 88.5         | 71.5    | 106.0          | 4.0               |
| 38        | 17 to 23 Sept.     | 32.3             | 23.7 | 84.8         | 58.8    | 000.0          | 6.2               |
| 39        | 24 to 30 Sept.     | 34.2             | 21.8 | 74.4         | 41.8    | 000.0          | 5.4               |
| 40        | 01 to 07 Oct.      | 35.9             | 18.8 | 80.0         | 29.2    | 000.0          | 4.2               |
| 41        | 08 to 14 Oct.      | 35.1             | 16.9 | 84.2         | 29.1    | 000.0          | 4.8               |
| 42        | 15 to 21 Oct.      | 34.5             | 17.1 | 80.7         | 33.4    | 000.0          | 3.5               |
| 43        | 22 to 28 Oct.      | 32.4             | 14.8 | 83.4         | 32.7    | 000.0          | 3.2               |
| 44        | 29 Oct. to 4 Nov.  | 30.7             | 12.4 | 91.2         | 39.8    | 000.0          | 3.1               |
| 45        | 05 to 11 Nov.      | 30.1             | 12.2 | 84.2         | 32.5    | 000.0          | 3.1               |
| 46        | 12 to 18 Nov.      | 29.4             | 10.3 | 90.7         | 34.4    | 000.0          | 2.5               |
| 47        | 19 to 25 Nov.      | 28.1             | 8.9  | 93.1         | 33.1    | 000.0          | 2.5               |
| 48        | 26 Nov. to 2 Dec.  | 29.2             | 8.1  | 92.0         | 40.4    | 000.0          | 2.6               |
| 49        | 3 to 9 Dec.        | 26.8             | 7.3  | 95.1         | 34.8    | 000.0          | 2.6               |
| 50        | 10 to 16 Dec.      | 26.7             | 10.6 | 92.2         | 51.7    | 000.0          | 2.0               |
| 51        | 17 to 23 Dec.      | 24.5             | 7.5  | 80.8         | 39.7    | 000.0          | 3.0               |
| 52        | 24 to 31 Dec.      | 19.1             | 5.3  | 96.3         | 67.1    | 000.0          | 1.0               |

**Source:** Meteorological Observatory, College of Agriculture, Gwalior

Fig 3.2a: Maximum & minimum temperature (°C) during crop season 2012-13.

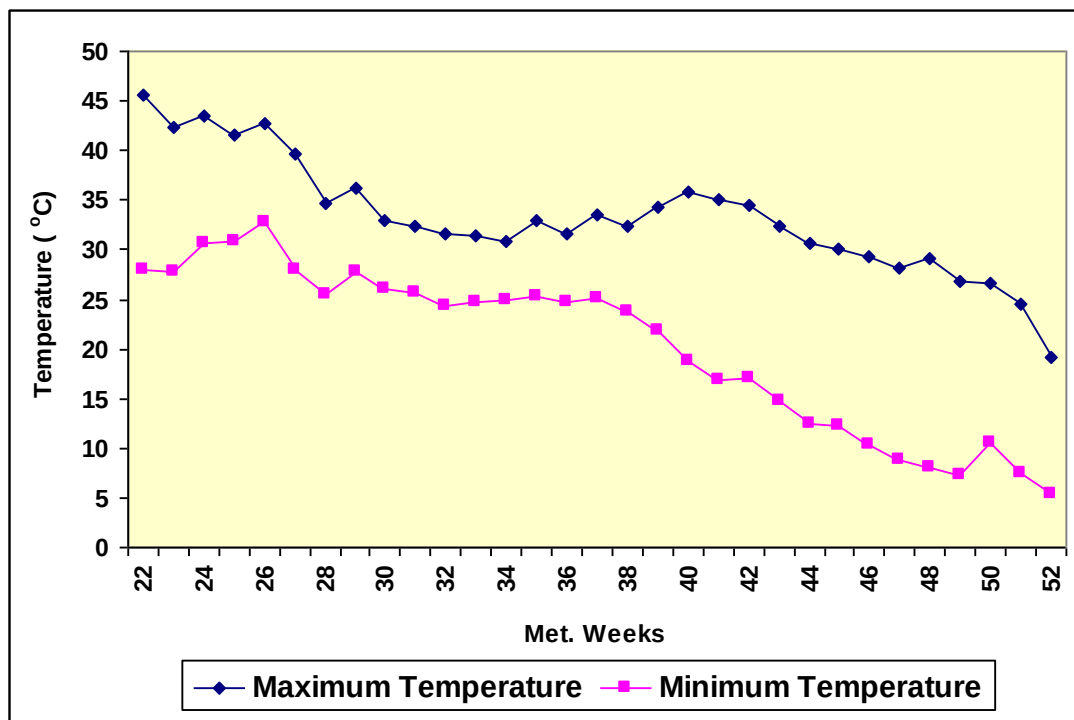


Fig 3.2b: Humidity (%) during crop season 2012-13.

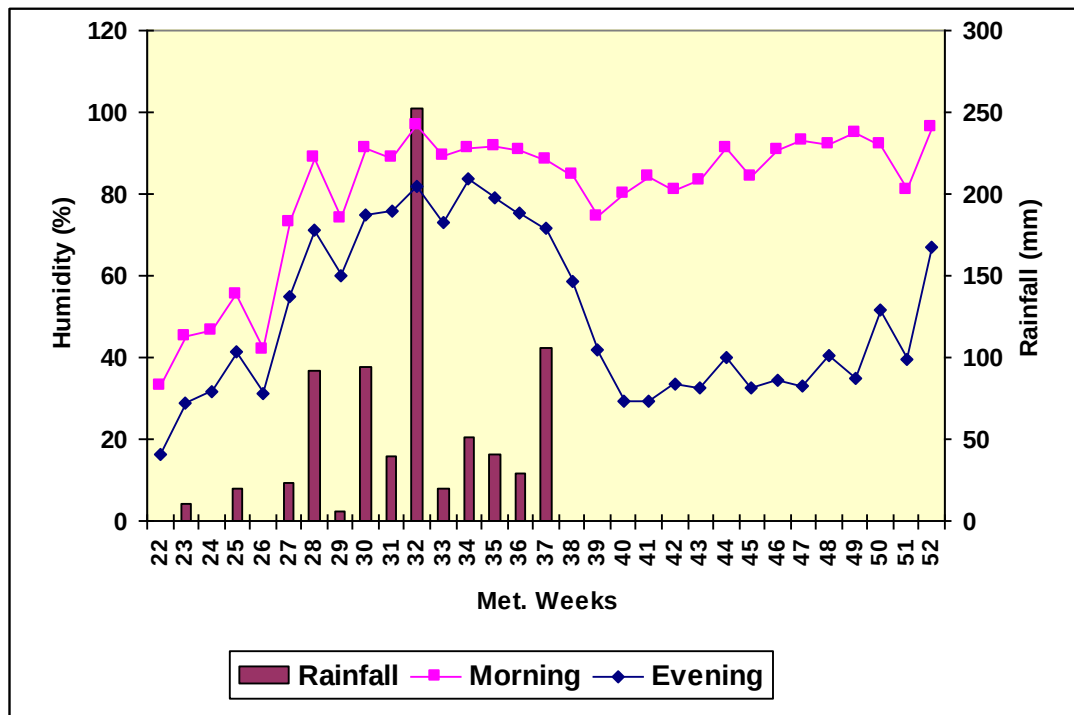


**Table 3.3: Physico-chemical properties of the soil.**

| S. No. | Mechanical Components                        | Percentage              | Methods used                                                           |
|--------|----------------------------------------------|-------------------------|------------------------------------------------------------------------|
| 1.     | Sand                                         | 60.7                    | By International Pipette method (Piper, 1950)                          |
| 2.     | Silt                                         | 22.3                    | Hydrometer                                                             |
| 3.     | Clay                                         | 17.0                    | Hydrometer                                                             |
|        | <b>Chemical Constituents</b>                 | <b>Value/ Status</b>    | <b>Methods</b>                                                         |
| 4.     | PH                                           | 8.0                     | Glass electrode                                                        |
| 5.     | Available Nitrogen                           | 212.58 kg/ha<br>(low)   | Alkline KMnO <sub>4</sub> (Subbiah and Asija, 1956)                    |
| 6.     | Available Phosphorus                         | 15.74 kg/ha<br>(medium) | Colourimetric SnCl <sub>2</sub> reduction (Olsen's <i>et al.</i> 1954) |
| 7.     | Available Potash                             | 286 kg/ha<br>(medium)   | Flame Photometer<br>Toth & Prince, 1949 &<br>Black, 1965               |
| 8.     | Organic Carbon                               | 4.56 g/ha               | Chromic acid titration<br>method (Walkey & Black<br>1934)              |
| 9.     | Electrical conductivity<br>(mmhos/cm at 25°C | 0.12                    | Conductivity method                                                    |

The cropping programme of the experimental field as followed during the last two years preceding to the experiment is given in Table 3.4

**Table 3.4: Previous history of the field.**

| S.No. | Year      | Kharif                        | Rabi  |
|-------|-----------|-------------------------------|-------|
| 1.    | 2009-2010 | Guar                          | Wheat |
| 2.    | 2010-2011 | Guar                          | Wheat |
| 3.    | 2011-2012 | Guar (Present experiment)- I  | --    |
| 4.    | 2012-2013 | Guar (Present experiment)- II | --    |

**Details of experiment :**

|     |                         |   |                                                        |
|-----|-------------------------|---|--------------------------------------------------------|
| 1.  | Design                  | - | RBD                                                    |
| 2.  | Treatments              | - | 16 (combination of 4 varieties and 4 fertility levels) |
| 3.  | Replications            | - | 04                                                     |
| 4.  | Number of plots         | - | 64                                                     |
| 5.  | Gross plot size         | - | 4.5 m × 3.6 m                                          |
| 6.  | Net plot size           | - | 4.0 m × 2.7 m                                          |
| 7.  | Distance between rows   | - | 45 cm                                                  |
| 8.  | Distance between plants | - | 10 cm                                                  |
| 9.  | Sowing date             | - | 25.07.2011 & 14.07.12                                  |
| 10. | Seed rate               | - | 20 kg/ha                                               |

**Treatments and notations :**

The studies were conducted to evaluate the effects of the following treatments of varieties and fertility levels of guar crop.

**Table 3.5: Details of the treatments:**

| Treatments                            | Symbol used    |
|---------------------------------------|----------------|
| <b>A. Varieties – 4</b>               |                |
| i. RGC – 1017                         | V <sub>1</sub> |
| ii. RGC – 1038                        | V <sub>2</sub> |
| iii. RGC – 1055                       | V <sub>3</sub> |
| iv. HG – 563                          | V <sub>4</sub> |
| <b>B. Fertility Level – 4</b>         |                |
| i. Control                            | F <sub>0</sub> |
| ii. 50% RDF + Vermicompost 5 t/ha     | F <sub>1</sub> |
| iii. 75% RDF + Vermicompost 5 t/ha    | F <sub>2</sub> |
| iv. 100% RDF (20 : 40 : 20 NPK kg/ha) | F <sub>3</sub> |
| <b>Treatment Combination – 16</b>     |                |

|                                    |                                     |                                    |                                     |
|------------------------------------|-------------------------------------|------------------------------------|-------------------------------------|
| i. V <sub>1</sub> F <sub>0</sub>   | v. V <sub>2</sub> F <sub>0</sub>    | ix. V <sub>3</sub> F <sub>0</sub>  | xiii. V <sub>4</sub> F <sub>0</sub> |
| ii. V <sub>1</sub> F <sub>1</sub>  | vi. V <sub>2</sub> F <sub>1</sub>   | x. V <sub>3</sub> F <sub>1</sub>   | xiv. V <sub>4</sub> F <sub>1</sub>  |
| iii. V <sub>1</sub> F <sub>2</sub> | vii. V <sub>2</sub> F <sub>2</sub>  | xi. V <sub>3</sub> F <sub>2</sub>  | xv. V <sub>4</sub> F <sub>2</sub>   |
| iv. V <sub>1</sub> F <sub>3</sub>  | viii. V <sub>2</sub> F <sub>3</sub> | xii. V <sub>3</sub> F <sub>3</sub> | xvi. V <sub>4</sub> F <sub>3</sub>  |

**Details of varieties:**

|                     |                                                                                                                                                                                                                                                                                   |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Variety Name</b> | <b>RGC – 1017</b>                                                                                                                                                                                                                                                                 |
| Year of release     | 2002                                                                                                                                                                                                                                                                              |
| Average Yield       | 12 – 14 q/ha                                                                                                                                                                                                                                                                      |
| Maturity            | Early (92-95 days)                                                                                                                                                                                                                                                                |
| Characteristics     | Recommended for release and cultivation in Rajasthan, Gujrat, Harayana under rainfed as well as drained soil, early maturity group, average yield under normal conditions 12-14 qt./ha. Moderately resistant to BLB, PM & RR diseases, branched, leaves margins, show slight cut. |

|                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Variety Name</b> | <b>RGC – 1038 (Rajasthan Guar)</b>                                                                                                                                                                                                                                                                                                                                                                                                                |
| Year of release     | 2006                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Parentage           | RGC- 516 x HG-75                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Average Yield       | 12 – 15 q/ha                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Maturity            | Medium (101-105 days)                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Characteristics     | Recommended for release and cultivation in states of Haryana, Maharashtra, Rajasthan, Madhya Pradesh, Uttar Pradesh and Gujarat under rainfed kharif and zaid seasons. Plant height 76-93 cm, Habit : Erect, medium tall and highly branched, Leaves : Leaves medium, broad and pubescent (Trip innate with serrated leaf margin). Grain : Seeds are dark gray in colour, round and bold, average 3.10g/100 seed. Pods/plant : 42-87 pods/ plant. |

|                 |                                                                                                                                                                                                                                                                                                               |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Variety</b>  | <b>RGC- 1055 (Guar Uday)</b>                                                                                                                                                                                                                                                                                  |
| Year of release | 2007                                                                                                                                                                                                                                                                                                          |
| Average Yield   | 08 – 11.5 q/ha                                                                                                                                                                                                                                                                                                |
| Maturity        | Medium (96-106 days)                                                                                                                                                                                                                                                                                          |
| Characteristics | Rainfed and well drained soil, plant height : medium tall (74-97 cm), habit : medium tall (74-97 cm) profusely branched and leaves pubescent (Trip innate with serrated leaf margin); Leaves : Broad leaves with pubescent, Hairy & Whitish Tinge over the surface of leaf; Grain: Dark grey and bold grains. |
| <b>Variety</b>  | <b>HG- 563</b>                                                                                                                                                                                                                                                                                                |
| Year of release | 1998                                                                                                                                                                                                                                                                                                          |
| Average Yield   | 18 – 20 q/ha                                                                                                                                                                                                                                                                                                  |
| Maturity        | Early (85-90)                                                                                                                                                                                                                                                                                                 |
| Characteristics | Recommended for release and cultivation in the states of Haryana, neighboring Rajasthan areas as well as Madhya Pradesh. & Uttar Pradesh under rainfed kharif and zaid seasons. Rich in gum content and viscosity and brisk podding behaviour. Plant height 75-100 cm, pubescent and smooth leaf margin.      |

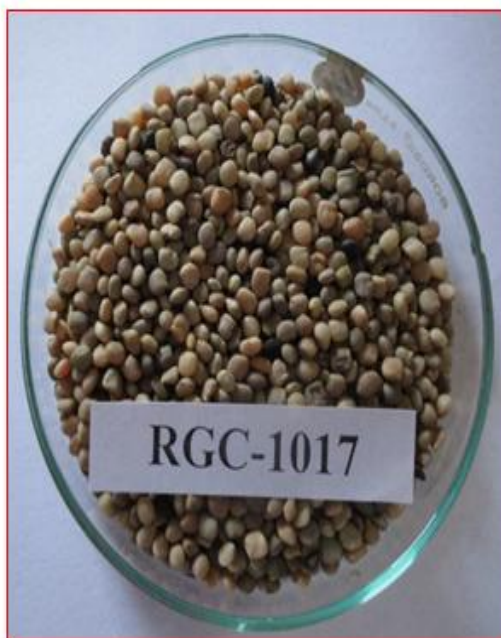


Plate: 3.1. Seed of Clusterbean Variety RGC-1017



Plate: 3.2. Seed of Clusterbean Variety RGC-1055



Plate: 3.3. Seed of Clusterbean Variety RGC-1038

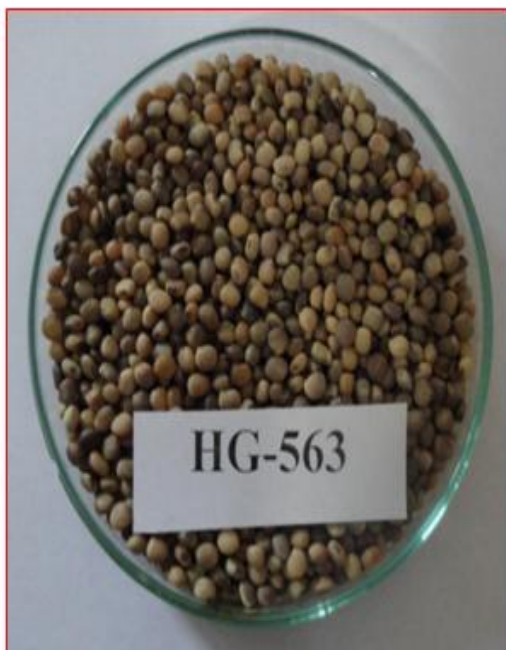


Plate: 3.4 Seed of Clusterbean Variety HG-563



Plate: 3.5 Experimental Field at Early Stage of Variety HG- 563

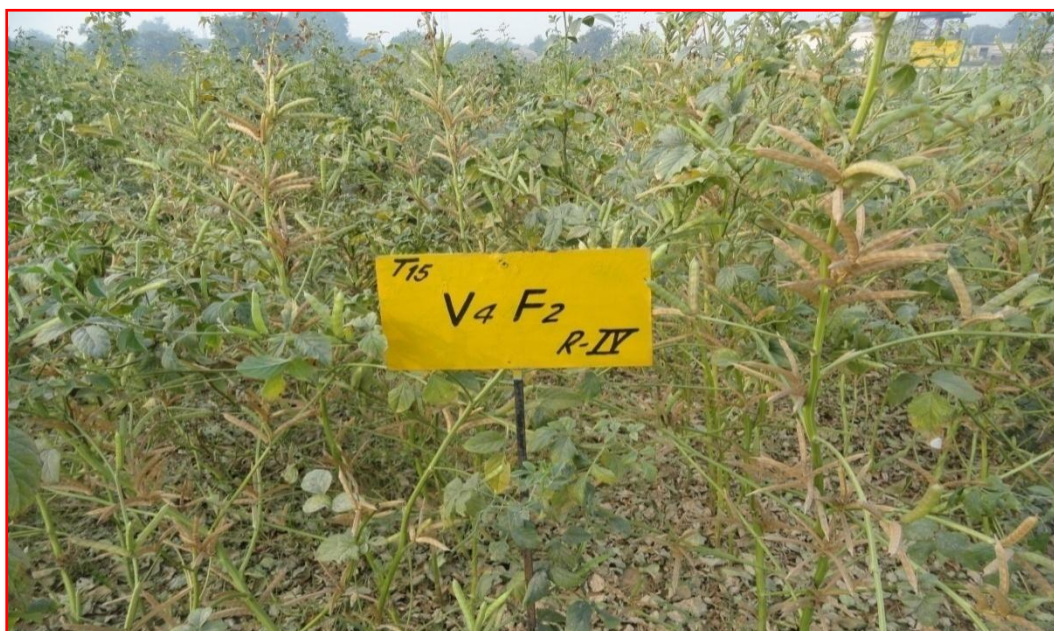


Plate: 3.6 Experimental Field at Maturity Stage of Variety HG- 563



**Plate: 3.7. Experimental Field at Early Stage of Variety RGC-1038**



**Plate: 3.8. Experimental Field at Maturity Stage of Variety RGC-1038**



**Plate: 3.9. Experimental Field at Early Stage of Variety RGC-1055**



**Plate: 3.10. Experimental Field at Maturity Stage of Variety RGC-1055**



**Plate: 3.11. Experimental Field at Early Stage of Variety RGC-1017**



**Plate: 3.12. Experimental Field at Maturity Stage of Variety RGC-1017**

**Cultural Operations:**

Cultural operations were carried out as and when required; the details are given in Table 3.6.

**Table 3.6: Schedule of cultural operations :**

| S.No. | Operations                                                                        | Date                    |                         | Remark                         |
|-------|-----------------------------------------------------------------------------------|-------------------------|-------------------------|--------------------------------|
|       |                                                                                   | 2011                    | 2012                    |                                |
| 1.    | Field preparation                                                                 | 21.7.11                 | 10.7.12                 | By Tractor                     |
| 2.    | Layout                                                                            | 24.7.11                 | 12.7.12                 | Manually                       |
| 3.    | Fertilizer application<br>(N, P <sub>2</sub> O <sub>5</sub> and K <sub>2</sub> O) | 25.7.11                 | 14.7.12                 | Manually (as<br>per treatment) |
| 4.    | Sowing                                                                            | 25.7.11                 | 14.7.12                 | Manually                       |
| 5.    | Thinning                                                                          | 08.8.11                 | 28.7.12                 | Manually                       |
| 6.    | Weeding I                                                                         | 14.8.11                 | 03.8.12                 | By Khurpi                      |
| 7.    | Weeding II                                                                        | 29.8.11                 | 18.8.12                 | By Khurpi                      |
| 8.    | Harvesting                                                                        | 22.11.11 to<br>26.11.11 | 15.11.12 to<br>21.11.12 | Manually                       |
| 9.    | Threshing and<br>winnowing                                                        | 27.11.11 to<br>03.12.11 | 24.11.12 to<br>30.11.12 | Manually                       |

**Tillage operation:**

Tillage operations were carried out by harrowing followed by discing and finally levelled by planking to get a good tilth condition of the field.

**Fertilizer application:**

Urea, single super phosphate and muriate of potash were used as the source of nitrogen, phosphorus and potassium. The dose of NPK as per treatment was given at the time of sowing as basal dose.

**Thinning operation:**

After fourteen days of sowing, plotwise thinning was done wherever it was necessary.

**Irrigation:**

The experiments were conducted under rainfed conditions hence no irrigation was given to the crop.

**Inter-culture operation:**

Cultural operation was carried out on the following days :

1<sup>st</sup> weeding done at 20 days of sowing in both the years.

2<sup>nd</sup> weeding and hoeing done at 35 days of sowing in both the years.

**Plant protection measure:**

Plant protection measures were not adopted as the attack of insect pests and the diseases were not observed.

**Harvesting:**

Before harvesting, tagged 5 plants from each plot were taken out for recording the yield contributing characters. The crop was harvested as a net plot by manual labours from 22.11.11 to 26.11.11 and 15.11.12 to 21.11.12 both the year, respectively and left for three and four days for sun drying as per treatment.

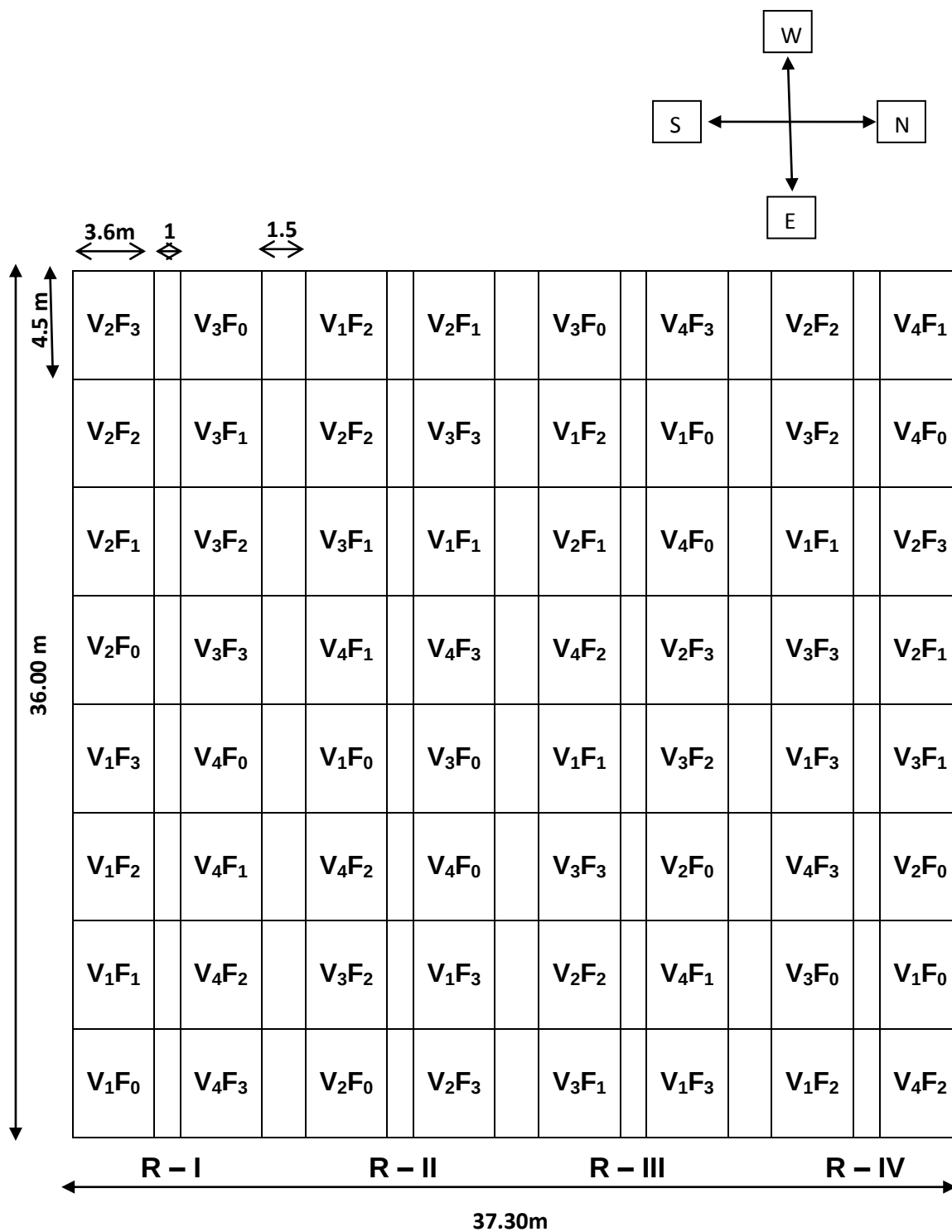


**Fig. 3.3 Plan of Layout**



**Plate: 3.13. General View of Experiment 2011**



**Plate: 3.14. General View of Experiment 2012**

**Threshing:**

Dry weight of each bundle was recorded prior to threshing. The produce of each plot was threshed separately by manual labours by beating the bundles with wooden stick. The grain obtained from each plot was cleaned and the weight was recorded.

**Details of observations:**

The observations, recorded during the course of investigation are dealt as under:-

**Plant population per metre row length at 15 DAS and maturity stage:**

With an object to see the effects of different treatments on germination this observation was taken. After 15 days of sowing when the germination was complete and at maturity, plant population was recorded by taking one metre row length at four places in each plot randomly and expressed as plant population per metre row length.

**Sampling procedures:**

Five plants from net area of each plot were selected in three successive stages by selecting row in the first stage, plants of one metre running row from selected row in the second stage and ultimate sample unit (5 plants) from selected plants of one metre running row in third stage of selection with the help of simple random sampling without replacement.

**Growth characters at 30, 60 and 90 DAS and maturity stage:**

The first observation on growth characters was recorded at 30 days after sowing and subsequent observations were recorded at an interval of 30 days. The following growth characters were studied:-

**(i) Plant height (cm):**

The height of selected plants was measured in centimetres from ground surface upto tip of the plant and then average plant height was calculated.

**(ii) Number of branches per plant:**

The number of branches of five tagged plants from each plot was recorded and mean was calculated.

**(iii) Crop Growth Rate (g/dm<sup>2</sup>/day)**

Crop growth rate (CGR) is the rate of dry matter production per unit ground area per unit time. CGR was calculated by adopting the formula as suggested by Watson (1952) and expressed as g/dm<sup>2</sup>/ day.

$$\text{CGR (g/dm}^2\text{/day)} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{A}$$

Where,

$W_1$  = Dry weight of the plant (g) at time  $t_1$

$W_2$  = Dry weight of the plant (g) at time  $t_2$

$t_2 - t_1$  = Time interval in days

$A$  = Unit land area occupied by the plant (1m<sup>2</sup>)

**(iv) Relative Growth Rate (g/g/day):**

It is the rate of increase in the dry weight per unit dry weight already present and is expressed as g/g/day (Blackman, 1919).

Relative growth rate at various stages was calculated as follows :-

$$\text{Relative Growth Rate (RGR)} = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

Where,

$W_1$  = Dry weight of plant (g) at time  $t_1$

$W_2$  = Dry weight of plant (g) at time  $t_2$

$t_2 - t_1$  = Time interval in days

**(v) Absolute Growth Rate (g/day):**

Absolute growth rate (AGR) is the dry matter production per unit time (g/day), which was calculated by using the formula as given by Radford (1967).

$$\text{Absolute Growth Rate (g/day)} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

$W_1$  = Dry weight of the plant (g) at time  $t_1$

$W_2$  = Dry weight of the plant (g) at time  $t_2$

**(vi) Leaf Area Index (LAI) at pods development:**

The leaf area index (LAI) is the ratio of leaf area per plant to the land area occupied by the plant and was calculated by using the formula as suggested by (Sestak *et al.*, 1971).

$$\text{Leaf Area Index (LAI)} = \frac{\text{Leaf area per plant (m}^2\text{)}}{\text{Land area occupied by a plant (m}^2\text{)}}$$

**(vii) Leaf Area Duration (Days):**

Leaf area duration (LAD) is nothing but relation of potential green leaf area for a particular period and worked out by the formula as suggested by Power *et al.* (1967) and expressed in days.

$$\text{LAD} = \frac{(\text{LA}_2 + \text{LA}_1)(t_2 - t_1)}{2}$$

LA<sub>1</sub> and LA<sub>2</sub> are Leaf area at times t<sub>1</sub> and t<sub>2</sub> respectively. If LAI is plotted against time, it produces a function that indicates assimilatory capacity of crop during the period.

**(viii) Net Assimilation Rate (g/dm<sup>2</sup>/day):**

Net assimilation rate (NAR) is the rate of dry weight increase per unit leaf area per unit time, which was calculated by the formula as adopted by Gregory (1925) and expressed as gdm<sup>-2</sup> day<sup>-1</sup>.

$$\text{NAR} = \frac{(W_2 - W_1)(\log_e \text{LA}_2 - \log_e \text{LA}_1)}{(t_2 - t_1)(\text{LA}_2 - \text{LA}_1)}$$

**(ix) Leaf Area Ratio (dm<sup>2</sup>/g):**

Leaf area ratio (LAR) is the ratio of the total leaf area to the whole plant dry weight and is a further measure of the efficiency of leaf surface in producing dry matter.

$$\text{LAR} = \frac{(\text{LA}_1/W_1) + (\text{LA}_2/W_2)}{2}$$

**(x) Biomass per plant (g):**

The average shoot dry weight per plant was recorded on the basis of five plants.

## **Post harvest study:**

### **Yield attributing characters and yield:**

Yield attributing characters were studied. Their details are as follows:

#### **(i) Number of pods per plant:**

The fully matured pods were picked out from each tagged plant and their numbers were counted and then average was worked out.

#### **(ii) Pod length (cm):**

Length of 10 randomly-selected pods from five tagged plants of each plot was measured and then average was worked out.

#### **(iii) Number of seeds per pod:**

The pods taken from five tagged plants were shelled out carefully; counting of the seed was done and then their average was worked out i.e. seeds/pod.

#### **(iv) 1000-seed weight (g):**

Samples were drawn from the produce of each plot and counted 1000 seeds were weighed for each sample.

#### **(v) Seed yield per plant (g):**

Seed yield of five tagged plants was recorded to calculate the average yield per plant.

#### **(vi) Stover yield per plant (g):**

Stover yield of five tagged plants was recorded to calculate the average stover yield per plant.

#### **(vii) Seed yield (kg/ha):**

Seed yield per net plot for all the plots was recorded in kilogram and converted in to kg/ha by using conversion factors.

#### **(viii) Stover yield (kg/ha):**

After threshing, seeds and stover were separated and weighed. The yield of stover was computed kg/ha by using conversion factors.

#### **(ix) Harvest index (%):**

Studied for every plot by using the formula dealt below:-

$$\text{Harvest Index (\%)} = \frac{\text{Seed Yield}}{\text{Biological Yield}} \times 100$$

#### **Analytical method adopted for quality (Protein) analysis**

Protein was computed by multiplying the N content of seed with a factor of 6.25. The total N content was determined by an adopting modified Kjeldahl's method as described by A.O.A.C. (1984).

#### **Qualitative character**

#### **Procedure for estimating protein content**

Estimation of seed protein was determined by estimating organic nitrogen using conventional micro-kjeldahl's method as per procedure given in A.O.A.C. (1984). The random samples were drawn from the bulk seeds of five plants. This random sample was used for the estimation of protein in duplicate.

Seeds were oven dried at 70°C for 48 hours and subsequently the sample was powdered by the heaved grinder to a uniform fineness 0.2mm fine; powdered sample was taken in duplicate, digested with 5ml of conc. H<sub>2</sub>SO<sub>4</sub> and small quantity of selenium mixture (viz. 600 kg K<sub>2</sub>SO<sub>4</sub> + 20g CuSO<sub>4</sub>.5H<sub>2</sub>O + 5g selenium metal) as a catalyst. The digested material was quantitatively transferred to the vacuums jacketed flask of the micro-kjeldahl's distillation assembly. The ammonia liberated by the addition of 20 ml 40% NaOH (W/V) and was collected in 25 ml of 2% boric acid (W), containing 2 drops of mixed indicator (viz., 0.2% methyl red + 0.1% bromocresol green in 95% ethanol) in a conical flask, the change of colour in the boric acid from purple to green indicated the completion of the reaction. The distilled material, thus obtained was titrated again N//10 H<sub>2</sub>SO<sub>4</sub> solution.

The protein percentage was calculated by multiplying the nitrogen percentage with the factor 6.25. The percentage of protein content was determined by the following formula:

$$\text{Nitrogen percentage} = \frac{0.014 \times \text{normality of H}_2\text{SO}_4 \times \text{volume of H}_2\text{SO}_4 \text{ required titration}}{\text{Weight of sample taken (g)}} \times 100$$

Protein percentage = Nitrogen percentage  $\times$  6.25  
(Crude protein contains 6.45% N)

**(ii) Protein yield:**

Protein yield (kg/ha) = protein content in seed (%)  $\times$  seed yield (kg/ha)/100

**Root nodulation studies**

The root nodulation study was made in each treatment at 50 days of sowing of clusterbean crop during both years. The nodules were collected when the soil was completely wet soon after the rains. This condition facilitated the early uprooting of root-nodules attached to them. For this purpose five plants were randomly selected and taken out from each plot very carefully by digging the soil upto 20-25 cm deep around the root zone. The root along with the soil stuck to it was dipped into the water kept in a bucket and washed, and the root-nodules were detached and collected in the paper envelope. The total number of root-nodules were counted and average nodule number/ plant was worked out by dividing the total counts by five.

The root length was measured in five sampled plants in each treatment and the average root length per plant was worked out. The same roots of five plants were dried in oven and the average dry weight of root per plant was calculated for each treatment.

**Chemical analysis of soil**

**Available nitrogen (N) in soil**

Available-N was determined by 'Alkaline Permanganate' method Subbiah and Asija (1956). A 20g of soil was weighed and put into an one litre round bottomed flask and added 100 ml each of potassium permanganate (0.32%) and sodium hydroxide (2.5%) solutions. Distillation was carried out for half an hour, and the distillate was collected in 250 ml conical flask containing 20 ml of boric acid (2%). Mixed indicator (green + methyl red) was used. Distillate was titrated against N/50  $\text{H}_2\text{SO}_4$ .

Available – N (kg/ha) =  $14/100 \times 1/50 \times 12/20 \times 2 \times 10 \times 1.12$

**Available Phosphorus (P) in soil**

Available-P was determined by following the procedure of Olsen *et al.* (1954). Weighed 2.5 g of soil into a 100 ml conical flask and added 0.5 gm of Dacro G-60 and 50 ml of sodium bicarbonate (0.5N solution adjusted to pH 8.5). Shaking

was done for half an hour on a mechanical shaker and filtered through Whatman No. 1 filter paper. Measured 5 ml of extract into a 25 volumetric flask, and 5 ml of chloromolybdic acid was added and stirred slowly. Reaction was allowed for 30 minutes and diluted upto 20 ml with distilled water. Added 1 ml of dilute stannous chloride and diluted to the mark of 25 ml and shaken immediately. Read the blue colour of Klett Summerson calorimeter using 660 m $\mu$  red filter. Standard curve was prepared.

$$\text{Available - P (kg/ha)} = \text{Klett reading} \times \text{slope of the curve} \times 22.4$$

### **Available Potassium (K) in Soil**

Available-K was estimated by the procedure as described by Hanwey and Heidal (1952). Weighed 5g of soil in a 50 ml volumetric flask and added 25 ml of neutral normal ammonium acetate. Shaking for five minutes on mechanical shaker was done and filtered through Whatman No.1 filter paper. Estimated potassium on a flame Photometer by adjusting on the scale as 0 ppm K on 0 and 100 ppm K on 100.

$$\text{Available - K (kg/ha)} = \text{Flame Photometer ppm K on 100.}$$

### **Laboratory studies**

Before and after harvest of crop, soil as well as plant samples were taken from each plots and analyzed for major nutrients viz., nitrogen, phosphorus and potash in the Soil Science Laboratories, RVSKVV College of Agriculture, Gwalior (M.P.). The methods used in the determination of all these nutrients in the soil, plant and seed samples are given as below.

### **Chemical analysis of plant and seed samples**

#### **N, P, K concentration and uptake by clusterbean**

The per cent concentration of nitrogen (N), phosphorus (P) and potassium (K) was determined in plant samples treatment-wise at maturity stages of crop growth. The concentration of the same nutrients were also determined in seed and stover separately, treatment-wise, From these values, the total uptake of each nutrient (N, P and K) in grain as well as in stover per hectare was worked out as per formula given after in the estimation procedure of N, P and K.

#### **(i) Estimation of nitrogen by Kjeldahl method**

Exact 1g of oven-dried plant or grain and stover sample was taken into dry clean Kjeldahl flask. To this 35 ml of conc. Sulphuric salicyclic acid mixture (35m of  $\text{H}_2\text{SO}_4$ ) was added along with one gram of copper sulphate as a catalytic agent. This flask was kept as such for  $\frac{1}{2}$  an hour. Five grams of potassium sulphate was also added to the flask and after stirring well the content was kept on low flame in digestion chamber for digestion. The contents were stirred intermittently. Digestion was adopted till the content possessed the light green colour.

After cooling the contents were transferred to distillation flask. Wash 5 to 6 times and washing beads were added to the flask to avoid the bumping. About 150 ml of 40% NaOH solution into the distillation flask was poured (content of the flask was distinctly alkaline). The distillation was carried collecting and distillate in 50 ml conical flask containing 25 ml of N/10 sulphuric acid to which few drops of methyl red indicator was added. Distillation was continued till complete ammonia was evolved. The extra acid in conical flask was back titrated against N/10 NaOH and the volume NaOH used was noted. The blank determination was also carried along with samples. The percentage of  $\text{N}_2$  was calculated by the following formula.

$$\text{Total nitrogen} = 0.0014 \times (\text{ml of } \text{H}_2\text{SO}_4 \text{ required to titrated ammonia})$$

$$\text{Crude protein} = \text{total } \text{N}_2 \times 6.25$$

## **(ii) Estimation of phosphorus by Calorimeter method**

One to 1.5 g of the plant or grains and stover digested with the acid. The digestion was done on a low flame till all the fumes of  $\text{H}_2\text{SO}_4$  and perchloric acid was given out. The digested contents were dissolved in water and transferred into 50 ml conical flask.

Five milliliter of this solution was taken into 50 ml of volumetric flask; 10 ml of Ammonium molybdate HCl solution added, mixed, then 5ml of stannous chloride dilute solution added. The final volume was made upto 50 ml. The addition of stannous chloride was adjusted in such a manner as the given constant time in interval of one minute between successive determination. After allowing the colour to develop for 10 minutes, the intensity was read in a Lumotron photo-electronic calorimeter Model 400-A using red-filter (650) . The calorimeter was adjusted to 100 with a blank, before taking reading with unknown solutions were found from a standard curve prepared from potassium dehydrogen phosphate.

### **(iii) Estimation of potassium by Flame Photometer**

One gram of plant or grain and one gram stover were digested in 2:1:5 perchloric, sulphuric and nitric acid mixture. The digested material was made up to 100 ml by repeated washing with redistilled water. Potassium was determined in wet digested plant material with the help of flame photometer.

### **N, P, K in grain and stover**

The uptake values for N, P and K per hectare in grain and stover were calculated as per formula given below

$$\text{Uptake of nutrients Grain or stover (q/ha)} = \frac{\text{Grain or Straw yield (q/ha)} \times \text{nutrient conc.(\%)}}{100}$$

### **Qualitative parameters of clusterbean grain**

#### **(i) Estimation of seed protein**

Protein content was estimated by micro-kjeldahl distillation method (Sankaran, 1973). One gram of seed sample was weighed in macro kjeldahl flask and added 20 ml of conc.  $\text{H}_2\text{SO}_4$  and 2 g of copper and potassium sulphate mixture and digested the material on burner. The digested material was transferred in 100ml volumetric flask and volume was made up to the mark. Then 10 ml. of the extract was distilled in macro distillation apparatus by adding 15 ml of 40% NaOH. Distillate was collected in 50 ml conical flask containing 20 ml of boric acid (2%) mixed indicator was used. On completion of distillation, distillate was titrated against N/14  $\text{H}_2\text{SO}_4$ .

$\text{N (\%)} = 0.001 \times \text{Amount of acid required} \times 100$  N content in the seed was multiplied by 6.25 to obtain protein content in seed.

#### **(ii) Procedure for estimating gum content**

Guar gum, also called as guaran, is a *galactomannan*. It is primarily the ground endosperm of guar beans. The guar seed are dehusked, milled and screened to obtain the guar gum. It is typically produced as a free-flowing, off-white powder.

The most reliable and accurate method of gum estimation involve extraction and purification of the galactomannan, which is then alcohol precipitated, dried and weighed, Gum can be estimated by a rapid and accurate method developed by Das *et al.* (1977) and modified by Joshi (2004).

## Reagents

1. Phenol (2% w/v) it should be colorless
2. Sulphuric acid (GR/AR grade)
3. Ethyl alcohol

## Procedure

1. Grind seed samples by using Cyclotec Grinding Mill (0.2 mm screen).
2. Weigh 0.1 g ground sample, transfer in 100 ml conical flask and add 40 ml of 0.01 M  $\text{HgCl}_2$  solution.
3. Place cotton plug and aluminium foil on the mouth of flask and autoclave at 15 psi for one hour.
4. Cool the samples and make 100 ml volume using 0.01 M  $\text{HgCl}_2$  solution.
5. After shaking the samples, centrifuge it at 5000 rpm for 20 minutes.
6. Take 0.5 ml of supernatant in a centrifuge tube and add 4.5 ml ethyl alcohol to make 90 per cent alcohol Keep the solution for overnight.
7. Next day, centrifuge it at 5000 rpm for 20 minutes and discard supernatant.
8. Dissolve the residue in 0.01 M  $\text{HgCl}_2$  (5 ml) by boiling in water bath for 1 h and cool it. Make volume to 5 ml with distilled water. Shake rigorously on vortex.
9. Take one ml of extract in a test tube of size 25x200 mm and add 2 ml of 2 per cent phenol, finally add 5 ml concentrated sulphuric acid (GR).
10. Shake samples and cool for 30 min. Run standard and blank simultaneously.
11. Record the absorbance at 190 nm on spectrophotometer.
12. Prepare standard curve using galactose : mannose (1 : 2 ratio).

Procedure adopted for determination of N, P, K contents in grain and stover samples of clusterbean.

| S.No. | Particulars                                                                                                      | Method adopted                                                          | References                                            |
|-------|------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-------------------------------------------------------|
| 01    | Plant constituents<br>(Seed & Stover)<br>Nitrogen content (%)<br>Phosphorus content (%)<br>Potassium content (%) | Old Kjeldahl method<br>Calorimeter method<br>Flame Photometer<br>method | A.O.A.C. (1984)<br>A.O.A.C. (1984)<br>A.O.A.C. (1984) |
| 02    | Seed constituents<br>Protein content (%)                                                                         | Micro-Kjeldahl method<br>( $\text{N}\% \times 6.25$ )                   | Sankaran<br>(1973) A.O.A.C.<br>(1984)                 |

|  |                 |                             |                                          |
|--|-----------------|-----------------------------|------------------------------------------|
|  | Gum Content (%) | A rapid and Accurate method | Das <i>et al.</i> (1977)<br>Joshi (2004) |
|--|-----------------|-----------------------------|------------------------------------------|

### **Economics of the treatment:**

The cost of production incurred in each treatment was worked out by considering the prevailing market price of inputs used and the produce obtained (seed and stover yields). The net income was calculated by subtracting the cost of cultivation from the gross monetary return. Different values were determined for each treatment as per details given below:

Gross monetary return = Cost of seed and stover yields

Net monetary return = Gross monetary return – Total cost of cultivation

Benefit: cost ratio = Gross monetary return / Total cost of cultivation

### **Statistical analysis:**

The all parameters were statistically analyzed by null method as Fisher (1958), Panse and Sukhatme (1978) and Gomez and Gomez (1984).

The total data of each character studied during growth period at successive interval were totaled and averaged at each stage of recording and these value were depicted through graphical curves for assessing the morphological changes in plant growth at successive stages of observation.

The interpretation of the data is based on the analysis of variance, summary tables, graphical curves and illustrations. In order to judge the significant differences between the average, critical differences ( $P=0.05$ ) level of significance was calculated for each treatment from the error mean squares by the following formula :

$$C.D. = \sqrt{\frac{2 \times MSE}{n}} \times 't'$$

Where,

C.D. = Critical differences

MSE = Mean square error

n = Number of plots coming under particular treatments

't' = t value in Fisher table is at 5% error degree of freedom

**Table 3.7: Skeleton of analysis of variance for the design of the experiment :**

| <b>Source of Variance</b> | <b>d.f.</b> | <b>S.S.</b> | <b>M.S.S.</b> | <b>F Cal</b> | <b>‘F’ Tab</b> |           |
|---------------------------|-------------|-------------|---------------|--------------|----------------|-----------|
| Replications              | 3           |             |               |              | <b>5%</b>      | <b>1%</b> |
| Varieties                 | 3           |             |               |              |                |           |
| Fertility levels          | 3           |             |               |              |                |           |
| Interaction               | 9           |             |               |              |                |           |
| Error                     | 45          |             |               |              |                |           |
| <b>Total</b>              | <b>63</b>   |             |               |              |                |           |

## **CHAPTER – IV**

### **EXPERIMENTAL RESULTS**

Endeavour's have been made here under in the ensuing chapter to present the results of the experiment carried out during the *Kharif* season 2011 and 2012 with a view to elicit the **“Effect of varieties and nutrient management on productivity, profitability and nutrient uptake of clusterbean.”** The periodical observations recorded pertaining to morphological, growth analytical, yield attributing parameters and yield as well as nutrients uptake studies have been processed statistically to assess the degree of variance due to various treatments. The analysis of variance has been appended at the end of the thesis. The mean values pertaining to various studies have been presented in the form of abridged table along with the necessary illustrations incorporated at the appropriate places.

The effects of experimental variables have been described in the order in which they occupy the positions in the analysis of variance, table i.e. varieties, fertility levels and their interactions (V×F). The mean values of only such treatment having significant differences are discussed at length in order to provide a quick grasp of trends exhibited by the parameters.

#### **4.1 Morphological observations**

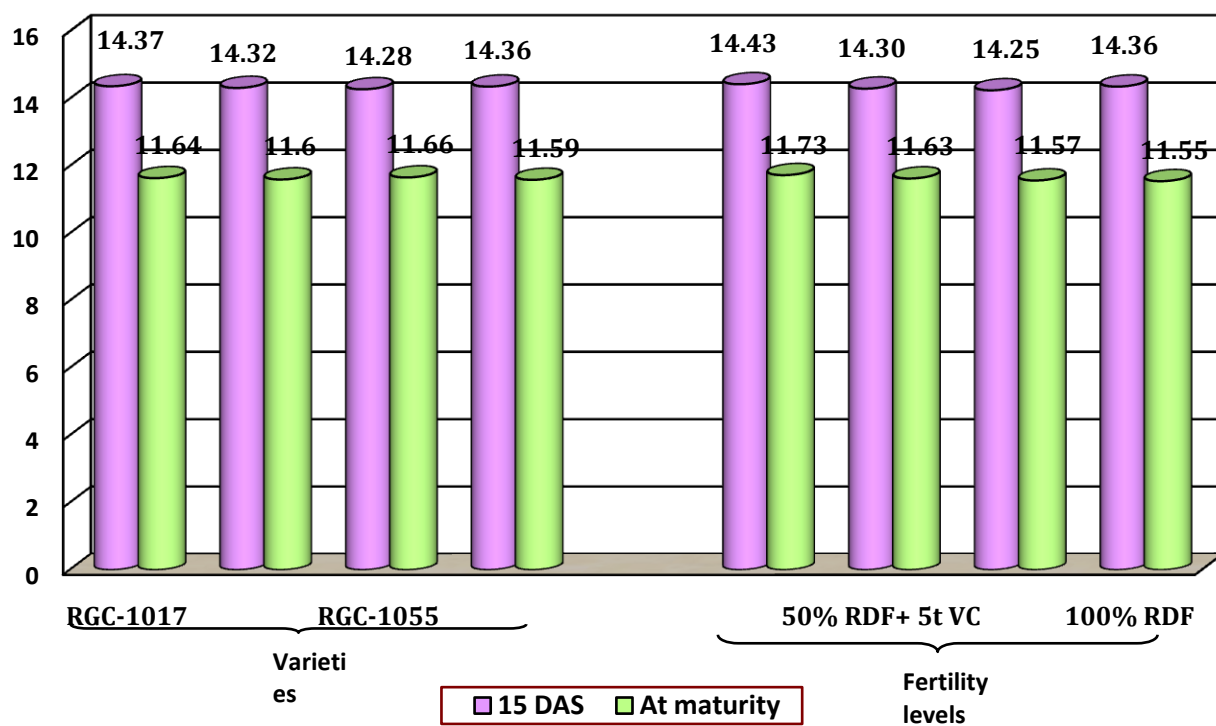
##### **4.1.1 Plant population**

The plant population per meter row length was recorded twice treatment wise and the mean data after statistical analysis are presented in Table 4.1. The data on the separate effect of treatments highlighted in Table 4.1 and depicted in Fig. 4.1 reveal that the plant population did not vary up to significant extent in both the years. At 15 DAS stage, it varied from 14.25 to 14.43 /m row length whereas at maturity it varied from 11.56 to 11.73 /m row length in various treatments. The treatment interactions also did not change the plant population up to significant extent as indicated from Table 4.1.

**Table 4.1 Plant population /m row length of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                  | 15 DAS      |             |              | 2011-12     |
|-------------------------------------------------------------|-------------|-------------|--------------|-------------|
|                                                             | 2011-12     | 2012-13     | Mean         |             |
| <b><i>Varieties</i></b>                                     |             |             |              |             |
| RGC-1017                                                    | 14.41       | 14.33       | <b>14.37</b> | 11.60       |
| RGC-1038                                                    | 14.35       | 14.29       | <b>14.32</b> | 11.60       |
| RGC-1055                                                    | 14.31       | 14.25       | <b>14.28</b> | 11.69       |
| HG-563                                                      | 14.41       | 14.31       | <b>14.36</b> | 11.56       |
| <b>SE (m)±</b>                                              | <b>0.17</b> | <b>0.15</b> | <b>0.11</b>  | <b>0.15</b> |
| <b>CD (P=0.05)</b>                                          | <b>NS</b>   | <b>NS</b>   | <b>NS</b>    | <b>NS</b>   |
| <b><i>Fertility level</i></b>                               |             |             |              |             |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )     | 14.48       | 14.37       | <b>14.43</b> | 11.71       |
| 50% RDF +VC 5t/ha.                                          | 14.29       | 14.31       | <b>14.30</b> | 11.60       |
| 75% RDF +VC 5t/ha.                                          | 14.31       | 14.18       | <b>14.25</b> | 11.66       |
| 100% RDF (N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 14.41       | 14.31       | <b>14.36</b> | 11.48       |
| <b>SE (m)±</b>                                              | <b>0.17</b> | <b>0.15</b> | <b>0.11</b>  | <b>0.15</b> |
| <b>CD (P=0.05)</b>                                          | <b>NS</b>   | <b>NS</b>   | <b>NS</b>    | <b>NS</b>   |
| <b>Interaction</b>                                          | <b>NS</b>   | <b>NS</b>   | <b>NS</b>    | <b>NS</b>   |

**Fig. 4.1 Plant population /m row length of clusterbean as**



#### 4.1.2 Plant height

Height is an index of plant growth and is known to be influenced by environmental and crop management practices. Data related to plant height at successive growth stages of crop are given in Table 4.2 and depicted in Fig. 4.2. The plant height, in general, it was increased multifold in all the treatments with the advancement of plant growth up to maturity stage. The plant height increased to nearly five times with the advancement of crop growth up to maturity stage. The data further revealed that increase in the plant height was substantially more between 30 and 60 DAS, as compared to rest of the plant growth intervals.

The mean data pertaining to plant height of different plots at 30, 60, 90 days and maturity stage were subjected to statistical calculations. The analysis of variance was worked out for all the crop growth stages which have been presented in Appendix section. The varieties and fertility levels influenced this growth parameter significantly at all the growth stages except in case of varieties at 30 DAS stage. However, the treatment interactions were found to be non-significant almost at all the stages of observations (Table 4.2).

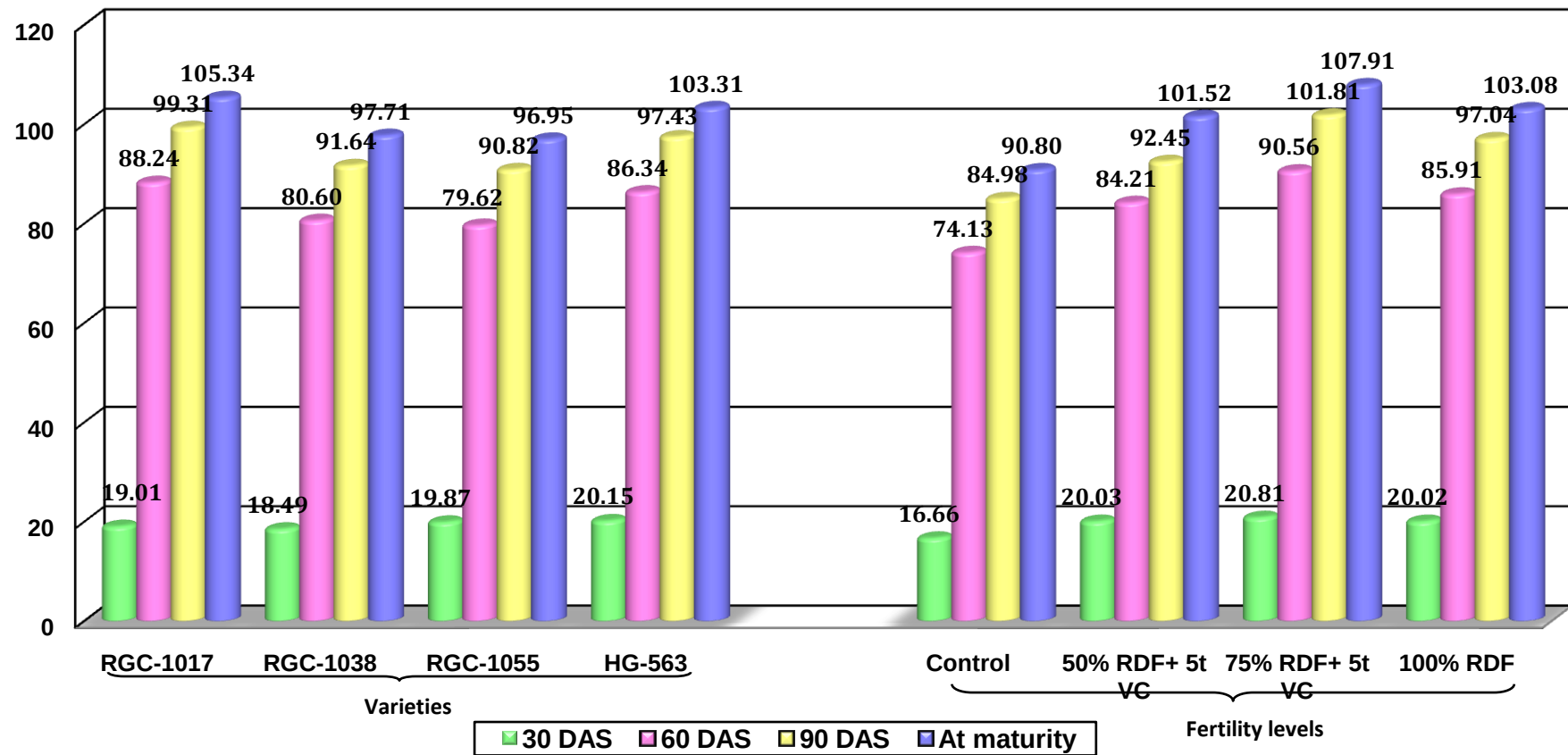
Among the varieties, RGC 1017 and HG 563 recorded the equally tallest plant at all the stages. In most cases, this parameter enhanced significantly over the other two varieties. Finally at the maturity stage, RGC 1017 and HG 563 being at par resulted in significantly tallest plant (105.34 and 103.31 cm) whereas RGC 1038 and RGC 1055 recorded significantly lowest height (97.71 and 96.95 cm).

Amongst the fertility levels, 75% RDF + VC enhanced the plant height up to significant extent over other fertility levels almost at all the stages of observations. Thus at the maturity stage, the maximum height at 75% RDF + VC was 107.91 cm, followed by 103.08 cm at 100% RDF. The significantly lowest height (90.79 cm) was recorded in case of control treatment ( $N_0P_0K_0$ ).

**Table 4.2 Plant height (cm) of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

[illegible]

Fig. 4.2 Plant height (cm) of Clusterbean as influenced by varieties and fertility levels



The treatment interactions were found to be non-significant almost under each of the stages of observations in both the years. However in first year, HG 563 grown with 75% RDF + VC performed the best, whereas in second year, RGC 1017 grown with the same fertility level performed the best producing taller plants at every stage of plant growth. It is interesting to note that in second year, the variety RGC 1017 grown either with 50% RDF + VC or with 100% RDF only produced equally taller plants. Almost similar results trend of taller plants was observed in first year also where the treatment interactions were found to be non-significant.

#### **4.1.3 Number of branches/ plant.**

The data pertaining to number of branches /plant at successive growth stages of crop are exhibited in Table 4.3 and illustrated diagrammatically in Fig. 4.3. The formation of branches per plant was augmented steadily in all the treatments with the advancement of plant growth up to 90 days stage. The branches were increased by more than two-fold up to the maturity stage.

The mean values of branches counts under different treatments at 30, 60 and 90 DAS stage were statistically analyzed. The analysis of variance was worked out for all the crop growth stages and then presented in the Appendix section. The varieties and fertility levels exerted significant impact upon this parameter at all the growth stages except in two cases. this trend was noticed in both the years, however, the treatment interactions were found to be non-significant at all the stages of observations (Table 4.3).

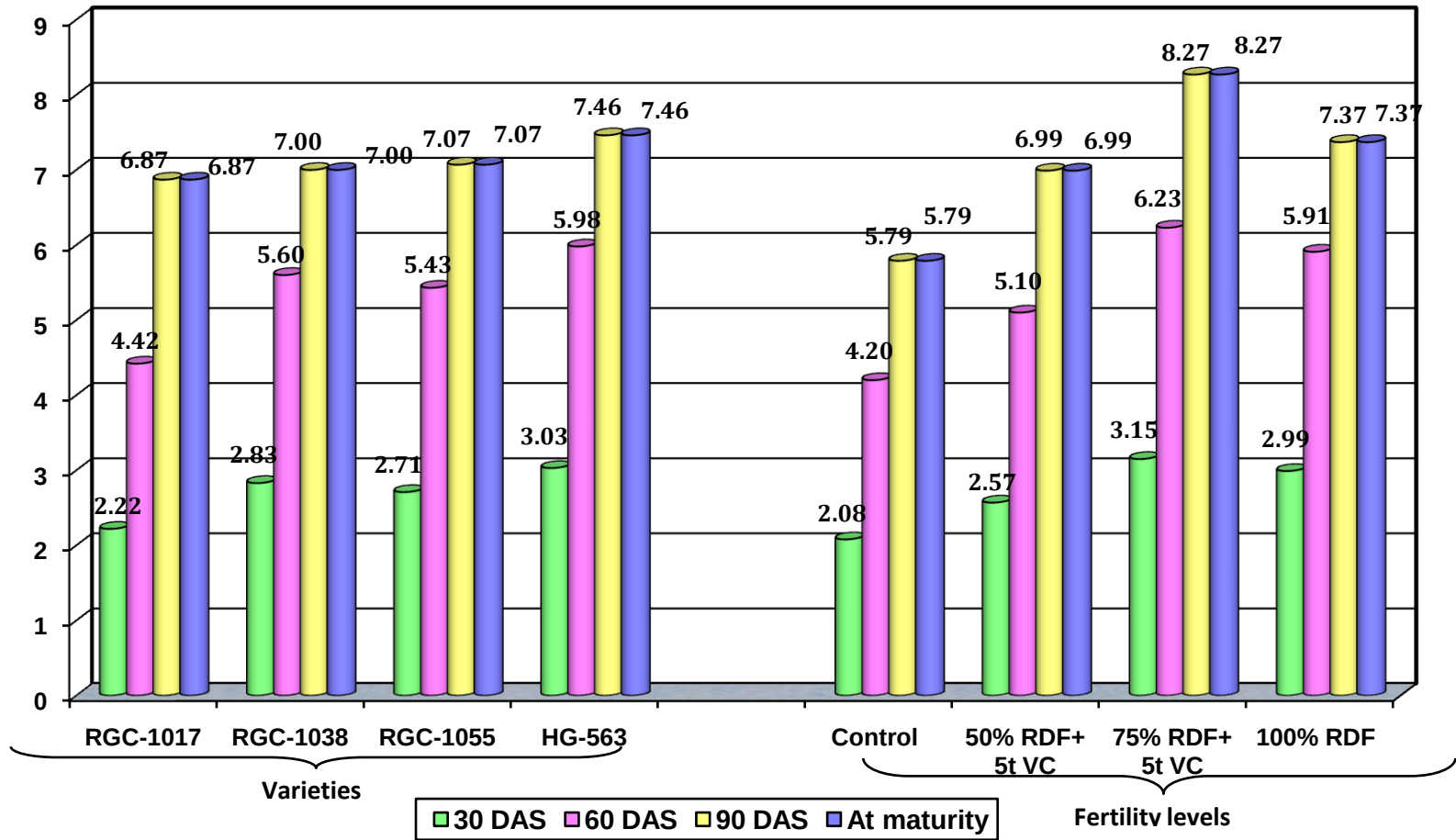
Among the varieties, HG 563 produced significantly higher number of branches/plant over the remaining varieties almost at all the stages of observations. However, the second best variety was RGC 1055. The lowest number of branches

was observed in case of RGC 1017 variety. Thus at 90 DAS stage, the maximum branches (7.46/plant) were recorded from HG 563, followed by RGC 1055 (7.07 branches/ plant) based on two years mean data. The lowest number of branches (6.87/ plant) were noted in case of RGC-1017.

**Table 4.3 Number of branches per plant of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

[illegible]

Fig 4.3 Number of branches per plant of Clusterbean as influenced by varieties and fertility



In case of fertility levels, 75% RDF + VC increased the number of branches up to significant extent over the remaining fertility levels almost at all the stages. Thus at the 90 days stage, the maximum branches (8.26/ plant) were noted from 75% RDF + VC fertility level. This was followed by 100% RDF (7.36/ plant) and then 50% RDF + VC (6.98/ plant). The significantly lowest branches (5.78/plant) were formed in control treatment having no NPK fertilizers.

The treatment interactions were found to be non-significant under each stage of observations in both the years. However, the best treatment combination in both the years was HG 563 grown with 75% RDF + VC, which resulted in 3.55 to 3.60 branches/plant at 30 DAS, 7.00 to 7.05 branches at 60 DAS and 8.25 to 9.55 branches/ plant at 90 DAS. On the other hand, the treatment combination having RGC 1017 grown without NPK fertilizers resulted in lowest branches/ plant i.e. 1.55 to 1.73 at 30 DAS, 3.33 to 3.43 at 60 DAS and 5.40 to 5.45 branches/ plant at 90 DAS and at maturity in both the years.

## **4.2 Root nodulation studies**

### **4.2.1 Root length**

The observations on root length were recorded treatment wise and the data after statistical analysis have been presented in Table 4.5 and exhibited through Fig. 4.4 the different varieties and fertility levels as well as their interactions were found to exert significant impact upon root length.

The variety HG 563 recorded significantly higher root length (32.0 to 32.5 cm) over the other varieties in both the years. However, this was followed by RGC 1038 (29.5 to 30.0 cm) and then RGC 1055. The lowest root length (24.98 to 26.18 cm) was noted from RGC 1017.

Amongst the fertility levels, 75% RDF +VC registered significantly higher root length (33.98 to 34.73 cm) over the remaining fertility level in both the years. However the second best fertility level was 100% RDF (31.5 to 32.13 cm) and then 50% RDF + VC (25.88 to 26.60 cm). The root length further lowered down significantly in case of control treatment (22.13 to 22.65) in both the years.

**Table 4.4 Root nodulation of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                     | Root length (cm) |             |              | Root weight (g) |              |              | Root nodules/plant |             |              |
|----------------------------------------------------------------|------------------|-------------|--------------|-----------------|--------------|--------------|--------------------|-------------|--------------|
|                                                                | 2011-12          | 2012-13     | Mean         | 2011-12         | 2012-13      | Mean         | 2011-12            | 2012-13     | Mean         |
| <b><i>Varities</i></b>                                         |                  |             |              |                 |              |              |                    |             |              |
| RGC-1017                                                       | 24.98            | 26.18       | <b>25.58</b> | 0.24            | 0.25         | <b>0.25</b>  | 9.50               | 8.75        | <b>9.13</b>  |
| RGC-1038                                                       | 29.50            | 30.00       | <b>29.75</b> | 0.35            | 0.36         | <b>0.36</b>  | 13.75              | 12.00       | <b>12.88</b> |
| RGC-1055                                                       | 27.00            | 27.43       | <b>27.21</b> | 0.30            | 0.31         | <b>0.31</b>  | 7.75               | 10.00       | <b>8.88</b>  |
| HG-563                                                         | 32.00            | 32.50       | <b>32.25</b> | 0.44            | 0.45         | <b>0.45</b>  | 15.50              | 15.50       | <b>15.50</b> |
| <b>SE(m) ±</b>                                                 | <b>0.85</b>      | <b>0.70</b> | <b>0.55</b>  | <b>0.001</b>    | <b>0.001</b> | <b>0.001</b> | <b>0.46</b>        | <b>0.44</b> | <b>0.32</b>  |
| <b>CD (P=0.05)</b>                                             | <b>2.41</b>      | <b>2.00</b> | <b>1.54</b>  | <b>0.003</b>    | <b>0.002</b> | <b>0.002</b> | <b>1.32</b>        | <b>1.26</b> | <b>0.90</b>  |
| <b><i>Fertility level</i></b>                                  |                  |             |              |                 |              |              |                    |             |              |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )        | 22.13            | 22.65       | <b>22.39</b> | 0.18            | 0.18         | <b>0.18</b>  | 7.00               | 6.75        | <b>6.88</b>  |
| 50% RDF +VC 5t/ha.                                             | 25.88            | 26.60       | <b>26.24</b> | 0.30            | 0.31         | <b>0.31</b>  | 11.25              | 12.50       | <b>11.88</b> |
| 75% RDF +VC 5t/ha.                                             | 33.98            | 34.73       | <b>34.35</b> | 0.44            | 0.45         | <b>0.45</b>  | 15.00              | 14.50       | <b>14.75</b> |
| 100% RDF<br>(N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 31.50            | 32.13       | <b>31.81</b> | 0.42            | 0.43         | <b>0.42</b>  | 13.25              | 12.50       | <b>12.88</b> |
| <b>SE(m) ±</b>                                                 | <b>0.85</b>      | <b>0.70</b> | <b>0.55</b>  | <b>0.001</b>    | <b>0.001</b> | <b>0.001</b> | <b>0.46</b>        | <b>0.44</b> | <b>0.32</b>  |
| <b>CD (P=0.05)</b>                                             | <b>2.41</b>      | <b>2.00</b> | <b>1.54</b>  | <b>0.003</b>    | <b>0.002</b> | <b>0.002</b> | <b>1.32</b>        | <b>1.26</b> | <b>0.90</b>  |
| <b>Interaction</b>                                             | <b>4.82</b>      | <b>4.00</b> | <b>3.07</b>  | <b>0.006</b>    | <b>0.005</b> | <b>0.004</b> | <b>2.64</b>        | <b>2.52</b> | <b>1.79</b>  |

**Fig. 4.4 Root length (cm) of clusterbean as influenced by varieties and fertility**

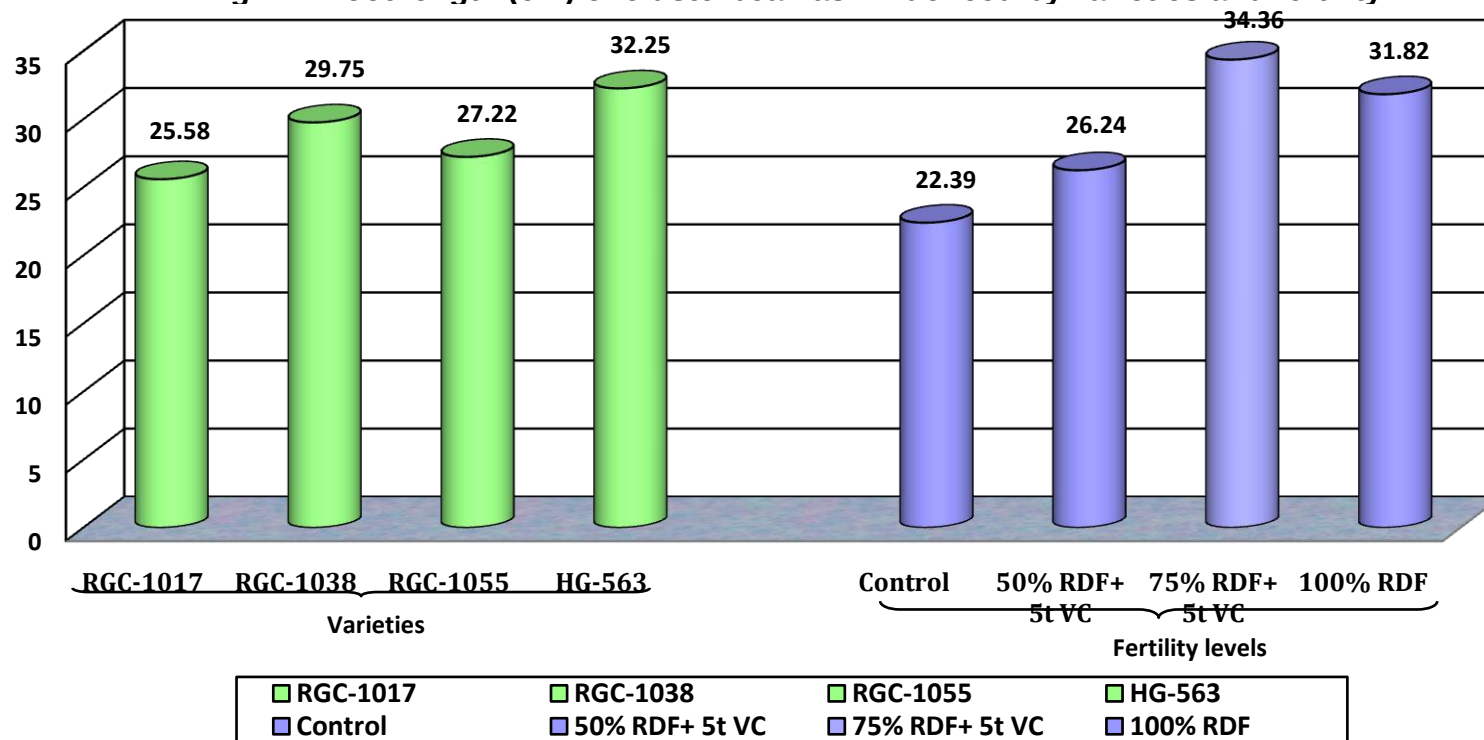


**Fig. 4.5 Root weight (g) of clusterbean as influenced by varieties and fertility**

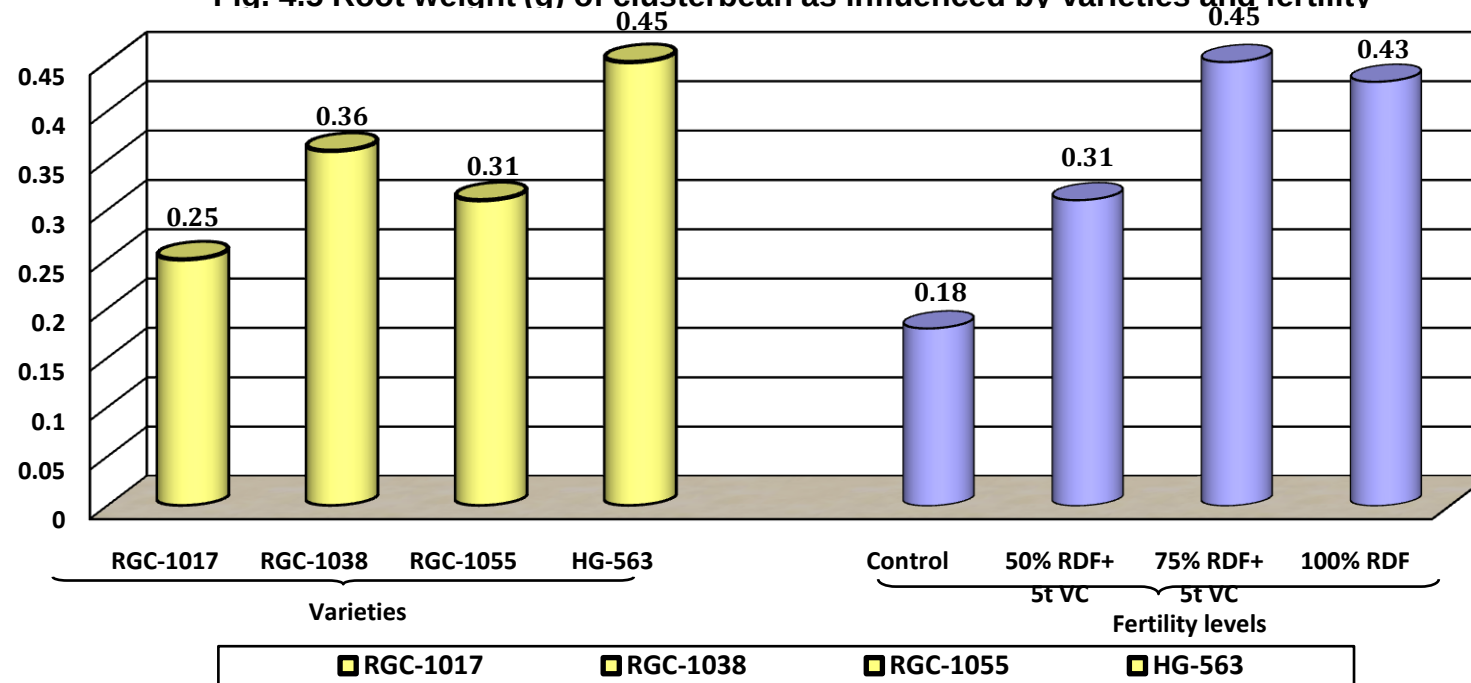


Fig. 4.6 Root nodules per plant of clusterbean as influenced by varieties and fertility

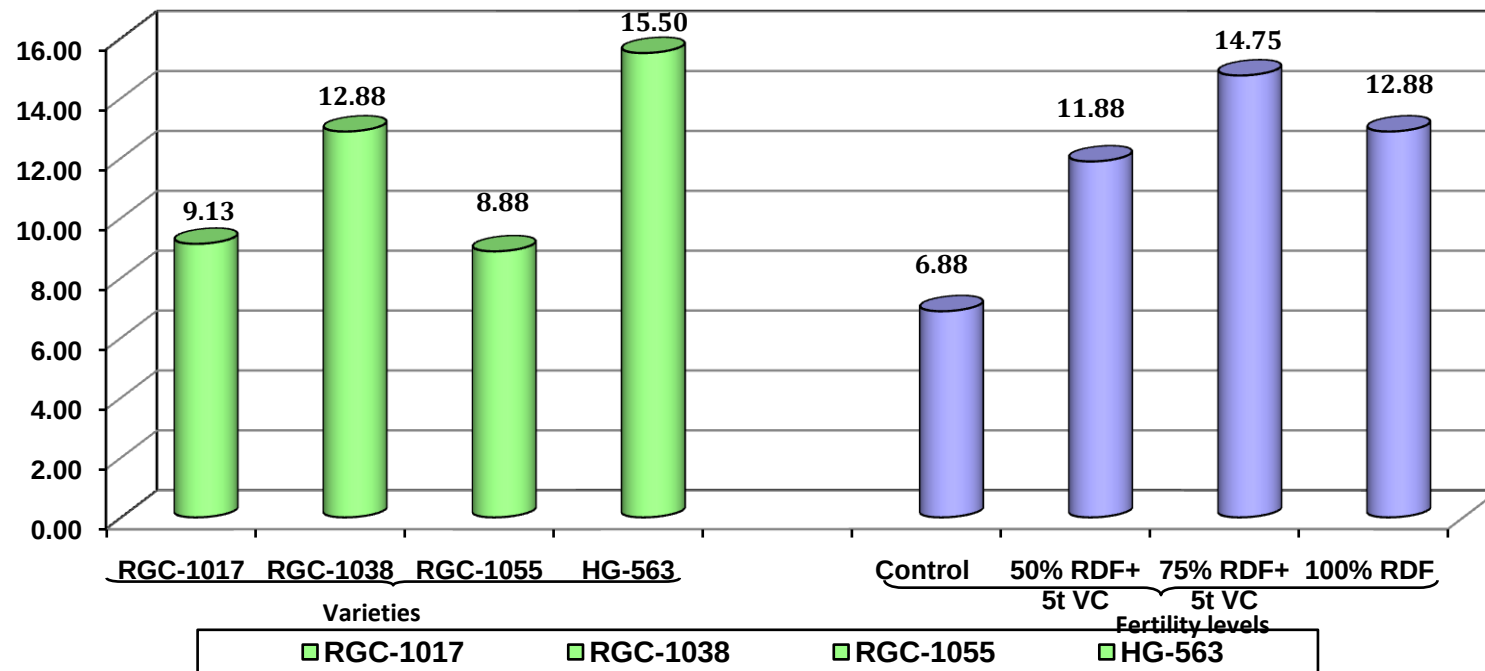


**Table 4.5 Interaction effect on root length (cm) of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                                    | Varieties    |              |              |              |              |
|-------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|
|                                                                                     | RGC- 1017    | RGC-1038     | RGC- 1055    | HG-563       | Mean         |
|                                                                                     | First Year   |              |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 19.50        | 24.00        | 22.00        | 23.00        | <b>22.13</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 24.00        | 27.00        | 26.00        | 26.50        | <b>25.88</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 27.40        | 35.00        | 31.50        | 42.00        | <b>33.98</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 29.00        | 32.00        | 28.50        | 36.50        | <b>31.50</b> |
| <b>Mean</b>                                                                         | <b>24.98</b> | <b>29.50</b> | <b>27.00</b> | <b>32.00</b> |              |
| Second Year                                                                         |              |              |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 20.60        | 24.30        | 22.30        | 23.40        | <b>22.65</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 25.20        | 27.70        | 26.50        | 27.00        | <b>26.60</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 28.60        | 35.60        | 31.90        | 42.80        | <b>34.73</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 30.30        | 32.40        | 29.00        | 36.80        | <b>32.13</b> |
| <b>Mean</b>                                                                         | <b>26.18</b> | <b>30.00</b> | <b>27.43</b> | <b>32.50</b> |              |
| Pooled                                                                              |              |              |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 20.05        | 24.15        | 22.15        | 23.20        | <b>22.39</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 24.60        | 27.35        | 26.25        | 26.75        | <b>26.24</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost            | 28.00        | 35.30        | 31.70        | 42.40        | <b>34.35</b> |

|                                                         |                  |                  |              |              |              |
|---------------------------------------------------------|------------------|------------------|--------------|--------------|--------------|
| 5 t/ha.                                                 |                  |                  |              |              |              |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub> | 29.65            | 32.20            | 28.75        | 36.65        | <b>31.81</b> |
| <b>Mean</b>                                             | <b>25.58</b>     | <b>29.75</b>     | <b>27.21</b> | <b>32.25</b> |              |
|                                                         |                  |                  |              |              |              |
|                                                         | <b>Varieties</b> | <b>Fertility</b> | <b>V×F</b>   |              |              |
| <b>First year SE(m)±</b>                                | 0.845            | 0.845            | 1.689        |              |              |
| <b>C D (P=0.05)</b>                                     | 2.410            | 2.410            | 4.821        |              |              |
|                                                         |                  |                  |              |              |              |
| <b>Second year SE(m)±</b>                               | 0.701            | 0.701            | 1.402        |              |              |
| <b>C D (P=0.05)</b>                                     | 2.000            | 2.000            | 4.000        |              |              |
|                                                         |                  |                  |              |              |              |
| <b>Pooled SE(m)±</b>                                    | 0.549            | 0.549            | 1.098        |              |              |
| <b>C D (P=0.05)</b>                                     | 1.537            | 1.537            | 3.073        |              |              |

Amongst the treatment combinations, HG 563 grown with 75% RDF + VC resulted in further enhancement of this parameters synergistically, root length being significantly higher (42.0 to 42.8 cm) over the remaining treatment combinations. However, the second best combination was HG 563 grown with 100% RDF (36.5 to 36.8 cm) in both the years. On the other hand, the lowest root length (19.5 to 20.6 cm) was recorded in case of RGC 1017 grown without fertilizers (control) in both the years. This trend was also noticed for other varieties grown without fertilizers. Amongst all the fertility levels, the varieties responded differently up to significant extent with respect to root length. This was the overall interesting feature observed in both the years.

#### **4.2.2 Root dry weight**

The weight of dried root was measured in each treatment and then the data were subjected to statistical computation, thereafter presented in Table 4.6 and illustrated through Fig. 4.5 The results trend continued to be the same as it was noted in case of root length in both the years. The various treatments as well as their interactions exhibited significant differences towards this parameter in both the years.

The root dry weight was found significantly higher (0.443 to 0.450g) in case of HG 563 variety as compared to the remaining varieties. However, this was followed by RGC 1038 (0.350 to 0.363 g) and then RGC 1055 (0.300 to 0.315 g). The significantly lowest root weight (0.250 to 0.253g) was noted in case of RGC 1017 in both the years.

In case of fertility levels, 75% RDF + VC recorded significantly higher root weight (0.445 to 0.460 g) over the remaining fertility levels in both the years. However, the second best fertility level was 100% RDF which recorded 0.420 to 0.430g root weight in both the years. This was followed by 50% RDF + VC (0.300 to 0.310 g), whereas the significantly lowest root weight (0.180 to 0.185 g) was noted in case of control treatment ( $N_0P_0K_0$ ).

Both the experimental variables significantly interacted to each other with regard to this growth parameter in both years. Sowing of HG 563 with 75% RDF + VC

recorded significantly higher root weight(0.590 to 0.600g) over all the remaining treatment combinations in both the years. However, the second best combination was HG 563 grown with 100% RDF (0.560 g). The third best combination was RGC 1038 grown with 75% RDF + VC which recorded 0.480 to 0.490 g root weight in both the years. All these treatment combinations differed significantly. The significantly lowest root weight (0.140 g) was recorded in both the years when RGC 1017 was grown without fertilizer application. This was followed by RGC 1055 grown without fertilizers (0.150 to 0.160 g).

**Table 4.6 Interaction effect on root dry weight (g) of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                                    | Varieties        |                  |              |              |              |
|-------------------------------------------------------------------------------------|------------------|------------------|--------------|--------------|--------------|
|                                                                                     | RGC-1017         | RGC-1038         | RGC-1055     | HG-563       | Mean         |
|                                                                                     | First Year       |                  |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.138            | 0.178            | 0.147        | 0.243        | <b>0.177</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.246            | 0.294            | 0.278        | 0.376        | <b>0.299</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.305            | 0.476            | 0.396        | 0.589        | <b>0.442</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.290            | 0.450            | 0.373        | 0.557        | <b>0.418</b> |
| <b>Mean</b>                                                                         | <b>0.245</b>     | <b>0.350</b>     | <b>0.299</b> | <b>0.441</b> |              |
| <b>Second Year</b>                                                                  |                  |                  |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.143            | 0.185            | 0.155        | 0.249        | <b>0.183</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.253            | 0.307            | 0.291        | 0.392        | <b>0.311</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.316            | 0.487            | 0.415        | 0.597        | <b>0.454</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.297            | 0.461            | 0.389        | 0.563        | <b>0.428</b> |
| <b>Mean</b>                                                                         | <b>0.252</b>     | <b>0.360</b>     | <b>0.313</b> | <b>0.450</b> |              |
| <b>Pooled</b>                                                                       |                  |                  |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.141            | 0.182            | 0.151        | 0.246        | <b>0.180</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.250            | 0.301            | 0.285        | 0.384        | <b>0.305</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.311            | 0.482            | 0.406        | 0.593        | <b>0.448</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.294            | 0.456            | 0.381        | 0.560        | <b>0.423</b> |
| <b>Mean</b>                                                                         | <b>0.249</b>     | <b>0.355</b>     | <b>0.306</b> | <b>0.446</b> |              |
|                                                                                     | <b>Varieties</b> | <b>Fertility</b> | <b>V×F</b>   |              |              |
| <b>First year SE(m)±</b>                                                            | 0.001            | 0.001            | 0.002        |              |              |
| <b>C D (P=0.05)</b>                                                                 | 0.003            | 0.003            | 0.006        |              |              |
|                                                                                     |                  |                  |              |              |              |
| <b>Second year SE(m)±</b>                                                           | 0.001            | 0.001            | 0.002        |              |              |
| <b>C D (P=0.05)</b>                                                                 | 0.002            | 0.002            | 0.005        |              |              |
|                                                                                     |                  |                  |              |              |              |
| <b>Pooled SE(m)±</b>                                                                | 0.001            | 0.001            | 0.001        |              |              |
| <b>C D (P=0.05)</b>                                                                 | 0.002            | 0.002            | 0.004        |              |              |

### 4.2.3 Root nodules/ plant

The root nodules were counted per plant in different treatments and the data so obtained were subjected to statistical analysis. Thereafter the data have been presented in Table 4.7 and exhibited through Fig.4.6. This parameter was influenced significantly due to different varieties and fertility levels as well as their interactions in both the years.

Among the varieties, HG 563 formed significantly higher number of root nodules (15.50/plant) over rest of the varieties in both the years. However, this was followed by RGC 1038 (12.0 to 13.75/ plant) and than RGC 1055 (9.50 to 10.00 / plant). The significantly lowest nodules number (7.75 to 8.75 /plant) was noted in case of RGC 1017 variety of clusterbean.

In case of fertility levels, 75% RDF +VC resulted in significantly higher number of root nodules (14.50 to 15.0 /plant) over the remaining fertility levels in both the years. However, the second best fertility level was 100% RDF (12.50 to 13.25/plant) and then 50% RDF + VC (11.25 to 12.50 / plant) in both the years. The significantly lowest root nodules (6.75 to 7.0 /plant) were formed in case of control ( $N_0P_0K_0$ ).

Amongst the treatment combinations, HG 563 grown with 75% RDF + VC performed the best, the root nodules formation was enhanced up to maximum extent synergistically. The significantly higher number of root nodules were 20.0 to 21.0 / plant over rest of the interactions in both the years. This was equally followed by 50% RDF + VC and 75% RDF + VC (15.0 to 17.0 / plant) in first year and (15.0 to 16.0 / plant) in the second year.

**Table 4.7 Interaction effect on root nodules per plant of clusterbean as influenced by varieties and fertility levels**

| Fertility levels                                         | Varieties  |          |          |        |              |
|----------------------------------------------------------|------------|----------|----------|--------|--------------|
|                                                          | RGC-1017   | RGC-1038 | RGC-1055 | HG-563 | Mean         |
|                                                          | First Year |          |          |        |              |
| Control $N_0P_0K_0$                                      | 5.00       | 8.00     | 6.00     | 9.00   | <b>7.00</b>  |
| 50% RDF<br>$N_{10}P_{20}K_{10}$ +Vermicompost<br>5 t/ha. | 8.00       | 12.00    | 10.00    | 15.00  | <b>11.25</b> |
| 75% RDF<br>$N_{15}P_{30}K_{15}$ +Vermicompost<br>5 t/ha. | 8.00       | 18.00    | 13.00    | 21.00  | <b>15.00</b> |

|                                                                                     |                  |                  |              |              |              |
|-------------------------------------------------------------------------------------|------------------|------------------|--------------|--------------|--------------|
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 10.00            | 17.00            | 9.00         | 17.00        | <b>13.25</b> |
| <b>Mean</b>                                                                         | <b>7.75</b>      | <b>13.75</b>     | <b>9.50</b>  | <b>15.50</b> |              |
| <b>Second Year</b>                                                                  |                  |                  |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 5.00             | 5.00             | 6.00         | 11.00        | <b>6.75</b>  |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 11.00            | 13.00            | 10.00        | 16.00        | <b>12.50</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 12.00            | 14.00            | 12.00        | 20.00        | <b>14.50</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 7.00             | 16.00            | 12.00        | 15.00        | <b>12.50</b> |
| <b>Mean</b>                                                                         | <b>8.75</b>      | <b>12.00</b>     | <b>10.00</b> | <b>15.50</b> |              |
| <b>Pooled</b>                                                                       |                  |                  |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 5.50             | 6.50             | 5.50         | 10.00        | <b>6.88</b>  |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 10.50            | 12.50            | 9.00         | 15.50        | <b>11.88</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 12.50            | 16.00            | 10.00        | 20.50        | <b>14.75</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 8.00             | 16.50            | 11.00        | 16.00        | <b>12.88</b> |
| <b>Mean</b>                                                                         | <b>9.13</b>      | <b>12.88</b>     | <b>8.88</b>  | <b>15.50</b> |              |
|                                                                                     |                  |                  |              |              |              |
|                                                                                     | <b>Varieties</b> | <b>Fertility</b> | <b>V×F</b>   |              |              |
| <b>First year SE(m)±</b>                                                            | 0.462            | 0.462            | 0.925        |              |              |
| <b>C D (P=0.05)</b>                                                                 | 1.319            | 1.319            | 2.639        |              |              |
|                                                                                     |                  |                  |              |              |              |
| <b>Second year SE(m)±</b>                                                           | 0.442            | 0.442            | 0.884        |              |              |
| <b>C D (P=0.05)</b>                                                                 | 1.261            | 1.261            | 2.523        |              |              |
|                                                                                     |                  |                  |              |              |              |
| <b>Pooled SE(m)±</b>                                                                | 0.320            | 0.320            | 0.640        |              |              |
| <b>C D (P=0.05)</b>                                                                 | 0.895            | 0.895            | 1.791        |              |              |

RGC 1038 with the same fertility levels also recorded this parameter up to the similar range (12.0 to 17.0/ plant in first year and 13.0 to 16.0/plant in the second year). The significantly lowest values were obtained in case of varieties when grown without fertilization.

The overall results pertaining to root nodulation studies have been summarized in Table 4.4. Among the varieties HG 563 resulted in significantly higher root length (32.25 cm), root weight (0.445 g) and root nodules (15.5/plant) over the remaining varieties. Similarly 75% RDF + VC recorded almost significantly higher values in respect of these parameters over the remaining

fertility levels. The treatment interactions were found significant, wherein HG 563 grown with 75% RDF + VC resulted in maximum root nodulation parameters over the remaining interactions.

### **4.3 Biomass Production**

#### **4.3.1 Biomass /plant**

The biomass per plant of clusterbean was recorded from each treatment at different growth intervals and the mean data after statistical analysis are depicted in Table 4.8. The data on the separate effect of the treatments are highlighted in Table 4.8 and exhibited through Fig. 4.7. The perusal of data reveal that the biomass /plant in general, increased by multifold with the increase of plant growth from 30 days stage up to the maturity stage. At 30 days stage, it ranged from 1.68 to 2.32 g/plant, while it reached up to the maximum ranging from 38.75 to 49.35 g/plant at maturity stage in various treatments.

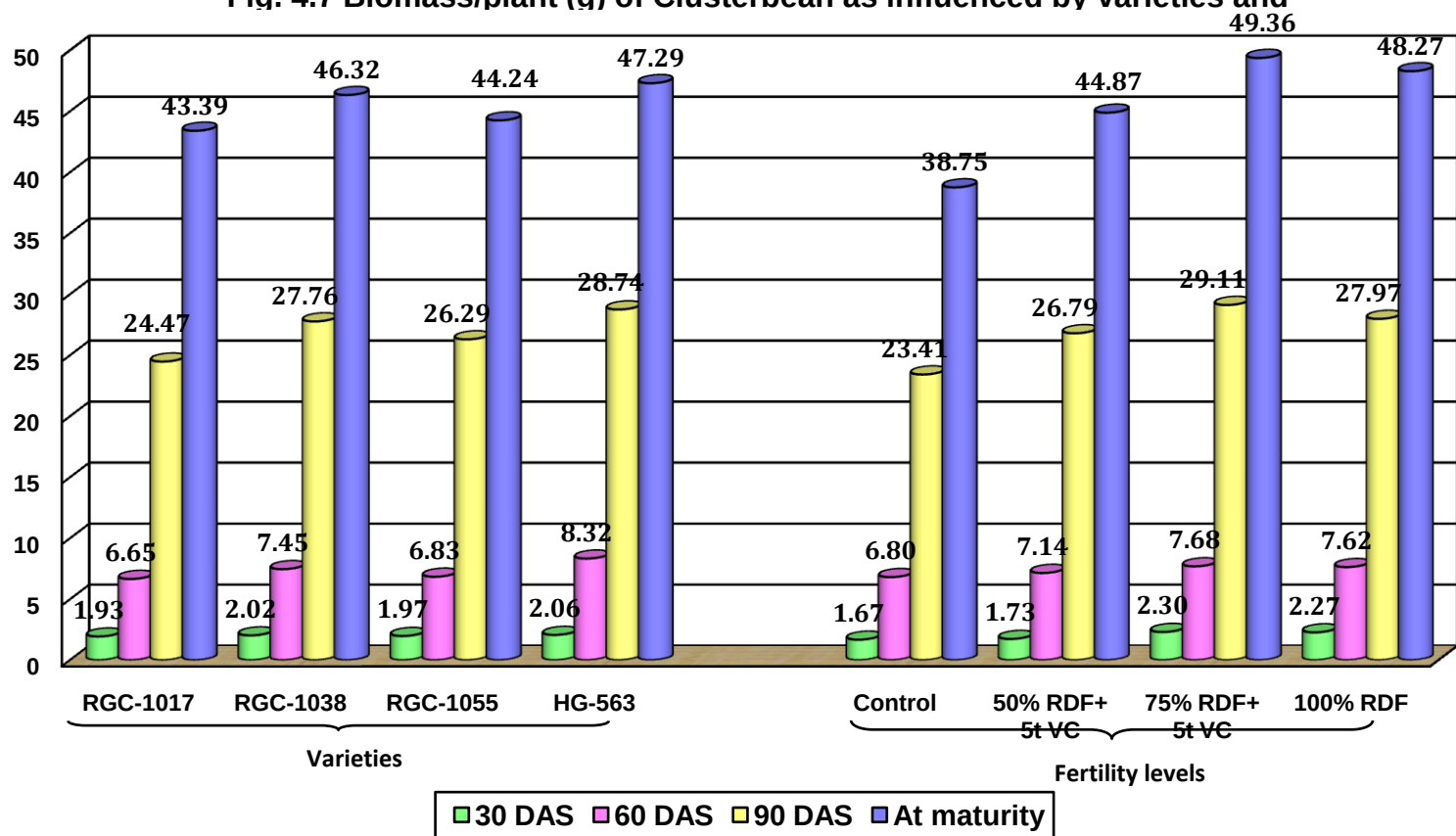
The varieties and fertility levels influenced this parameter significantly at all the growth stages except in case of varieties at 30 days stage. However, the treatment interactions were found to be non-significant at all the stages of observations (Table 4.8).

Amongst the varieties, the production of biomass per plant was found significantly higher in case of HG 563 over others in both the years. Based on two years mean values it was 2.06, 8.32, 28.78 and 47.28 g/plant at 30, 60, 90 days and maturity stages, respectively. However, the second best variety was RGC 1038, the lowest biomass production was noticed in case of RGC 1017 variety in both the years.

**Table 4.8 Biomass/plant (g) of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

[illegible]

Fig. 4.7 Biomass/plant (g) of Clusterbean as influenced by varieties and



Amongst the fertility levels, biomass production was statistically identical in case of 75% RDF + VC and 100% RDF fertility levels. This was observed at all the stages of observations in both the years. This parameter in both these treatments ranged from 2.26 to 2.30 g at 30 DAS, 7.62 to 7.68 g at 60 DAS, 27.96 to 29.10 g at 90 DAS and 48.26 to 49.35 g/plant at maturity stage, based on two years mean values. These treatments were followed by 50% RDF + VC treatment and at the last, the significantly lowest biomass production was obtained from the control treatment. It was 1.67, 6.79, 23.40 and 38.75 g/plant at 30, 60, 90 days and at maturity stages, respectively.

Clusterbean varieties did not respond to fertility levels in both the years. However, HG 563 grown with 75% RDF + VC or 100% RDF resulted in higher biomass production per plant at every stage of observations. At maturity stage it ranged from 50.13 to 51.37 g/plant in both the years. On the other hand, the varieties grown without fertilization resulted in the lowest biomass production wherein at maturity stage, the biomass ranged from 37.30 to 40.21 g/plant in both the years.

#### **4.4 Growth analysis parameters**

##### **4.4.1 Leaf area index**

The LAI of clusterbean was recorded under each treatment at different growth intervals and the mean values after statistical analysis are exhibited in Table 4.9. The data on the separate effect of the treatments are presented in Table 4.9 and exhibited through Fig.4.8. The perusal of data in Table 4.9 indicate that the LAI, in general, increased by multi-fold with the increase of plant growth from 30 days stage to 90 days stage. Thereafter it tended to decrease very fast and up to maturity stage it reached to the level as observed at 30 days stage in the various treatments. At 30 days stage, LAI ranged from 0.11 to 0.15, whereas at 90 days stage 0.45 to 0.80, and then at maturity stage reduced LAI ranged from 0.11 to 0.19 in various treatments in both the years. These values are based on two years mean data.

**Table 4.9 LAI of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                     | 30 DAS       |              |              | 60 DAS       |              |              | 90 DAS       |              |              | At maturity  |              |              |
|----------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
|                                                                | 2011-12      | 2012-13      | Mean         | 2011-12      | 2012-13      | Mean         | 2011-12      | 2012-13      | Mean         | 2011-12      | 2012-13      | Mean         |
| <b>Varities</b>                                                |              |              |              |              |              |              |              |              |              |              |              |              |
| RGC-1017                                                       | 0.13         | 0.13         | <b>0.13</b>  | 0.35         | 0.37         | <b>0.36</b>  | 0.46         | 0.49         | <b>0.48</b>  | 0.12         | 0.14         | <b>0.13</b>  |
| RGC-1038                                                       | 0.12         | 0.12         | <b>0.12</b>  | 0.56         | 0.58         | <b>0.57</b>  | 0.66         | 0.70         | <b>0.68</b>  | 0.14         | 0.16         | <b>0.15</b>  |
| RGC-1055                                                       | 0.12         | 0.13         | <b>0.13</b>  | 0.47         | 0.49         | <b>0.48</b>  | 0.55         | 0.58         | <b>0.57</b>  | 0.14         | 0.16         | <b>0.15</b>  |
| HG-563                                                         | 0.14         | 0.15         | <b>0.15</b>  | 0.63         | 0.66         | <b>0.65</b>  | 0.78         | 0.81         | <b>0.80</b>  | 0.17         | 0.19         | <b>0.18</b>  |
| <b>SE(m)±</b>                                                  | <b>0.006</b> | <b>0.005</b> | <b>0.004</b> | <b>0.007</b> | <b>0.007</b> | <b>0.005</b> | <b>0.006</b> | <b>0.009</b> | <b>0.005</b> | <b>0.007</b> | <b>0.006</b> | <b>0.005</b> |
| <b>CD (P=0.05)</b>                                             | <b>NS</b>    | <b>0.013</b> | <b>0.010</b> | <b>0.019</b> | <b>0.019</b> | <b>0.013</b> | <b>0.018</b> | <b>0.024</b> | <b>0.015</b> | <b>0.019</b> | <b>0.018</b> | <b>0.013</b> |
| <b>Fertility level</b>                                         |              |              |              |              |              |              |              |              |              |              |              |              |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )        | 0.11         | 0.11         | <b>0.11</b>  | 0.39         | 0.40         | <b>0.39</b>  | 0.43         | 0.46         | <b>0.45</b>  | 0.10         | 0.12         | <b>0.11</b>  |
| 50% RDF +VC<br>5t/ha.                                          | 0.13         | 0.13         | <b>0.13</b>  | 0.49         | 0.51         | <b>0.50</b>  | 0.55         | 0.58         | <b>0.57</b>  | 0.13         | 0.14         | <b>0.14</b>  |
| 75% RDF +VC<br>5t/ha.                                          | 0.13         | 0.13         | <b>0.13</b>  | 0.56         | 0.59         | <b>0.58</b>  | 0.69         | 0.72         | <b>0.71</b>  | 0.16         | 0.18         | <b>0.17</b>  |
| 100% RDF<br>(N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 0.14         | 0.14         | <b>0.14</b>  | 0.58         | 0.61         | <b>0.60</b>  | 0.78         | 0.82         | <b>0.80</b>  | 0.18         | 0.20         | <b>0.19</b>  |
| <b>SE(m)±</b>                                                  | <b>0.006</b> | <b>0.005</b> | <b>0.004</b> | <b>0.007</b> | <b>0.007</b> | <b>0.005</b> | <b>0.006</b> | <b>0.009</b> | <b>0.005</b> | <b>0.007</b> | <b>0.006</b> | <b>0.005</b> |
| <b>CD (P=0.05)</b>                                             | <b>0.016</b> | <b>0.013</b> | <b>0.010</b> | <b>0.019</b> | <b>0.019</b> | <b>0.013</b> | <b>0.018</b> | <b>0.024</b> | <b>0.015</b> | <b>0.019</b> | <b>0.018</b> | <b>0.013</b> |
| <b>Interaction</b>                                             | <b>NS</b>    | <b>0.026</b> | <b>NS</b>    | <b>0.037</b> | <b>0.037</b> | <b>0.026</b> | <b>0.036</b> | <b>0.049</b> | <b>0.030</b> | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    |

Fig. 4.8 LAI of Clusterbean as influenced by varieties and fertility levels.

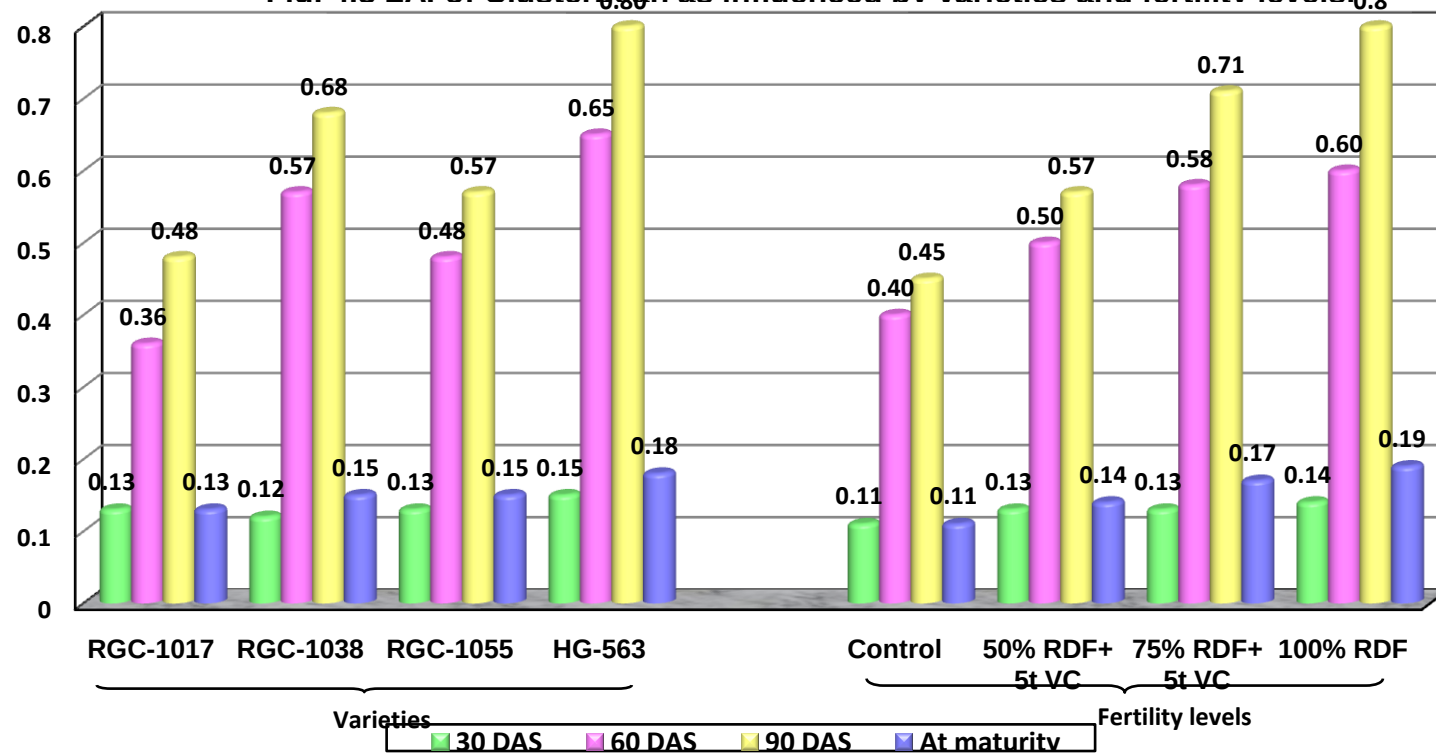


**Table 4.10 Interaction effect on LAI at 30 days of clusterbean as influenced by varieties and fertility levels in the year 2012.**

| Fertility levels                                                                    | Varieties    |             |             |             |             |
|-------------------------------------------------------------------------------------|--------------|-------------|-------------|-------------|-------------|
|                                                                                     | RGC-1017     | RGC-1038    | RGC-1055    | HG-563      | Mean        |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.10         | 0.09        | 0.13        | 0.12        | <b>0.11</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.13         | 0.13        | 0.11        | 0.16        | <b>0.13</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.13         | 0.13        | 0.12        | 0.15        | <b>0.13</b> |
| 100% RDF N <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                            | 0.16         | 0.11        | 0.14        | 0.17        | <b>0.14</b> |
| <b>Mean</b>                                                                         | <b>0.13</b>  | <b>0.12</b> | <b>0.13</b> | <b>0.15</b> |             |
| <b>C.D. for Variety</b>                                                             | <b>0.013</b> |             |             |             |             |
| <b>C.D. for Fertility</b>                                                           | <b>0.013</b> |             |             |             |             |
| <b>C.D. for Interaction</b>                                                         | <b>0.026</b> |             |             |             |             |

The different varieties as well as fertility levels exerted significant impact upon LAI almost at all the stages of observations, whereas the treatment interactions were found significant only at 60 and 90 days stages of plant growth (Table 4.9).

Amongst the varieties, LAI of clusterbean was found almost significantly higher in variety HG 563 as compared to the remaining varieties at every stage of observations. The second best variety was RGC 1038 and then RGC 1055. Almost significantly lowest LAI was noted in case of RGC 1017 variety. Accordingly at 90 DAS, the maximum LAI was found in case of HG 563 (0.80) as against only 0.48 in case of RGC 1017.

In case of fertility levels, this parameter deviated significantly due to differences in fertility levels at every stage of observations. Application of 75% RDF + VC or 100% RDF performed equally well under every stage of observations except at 90 DAS stage. At this stage, 100% RDF enhanced the LAI up to maximum extent (0.80), being significantly superior to the remaining fertility levels. However, the second best was 75% RDF + VC (0.71 LAI). The lowest LAI was 0.45 at N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> level of fertility. The significantly lowest LAI was recorded in case of N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> at every stage of observations.

**Table 4.11 Interaction effect on LAI at 60 days of clusterbean as influenced by varieties and fertility levels**

| Fertility levels                                                                    | Varieties  |           |          |        |      |
|-------------------------------------------------------------------------------------|------------|-----------|----------|--------|------|
|                                                                                     | RGC-1017   | RGC-1038  | RGC-1055 | HG-563 | Mean |
|                                                                                     | First Year |           |          |        |      |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.29       | 0.43      | 0.35     | 0.47   | 0.39 |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.34       | 0.56      | 0.47     | 0.59   | 0.49 |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.38       | 0.60      | 0.54     | 0.72   | 0.56 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.40       | 0.65      | 0.52     | 0.75   | 0.58 |
| Mean                                                                                | 0.35       | 0.56      | 0.47     | 0.63   |      |
| Second Year                                                                         |            |           |          |        |      |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.31       | 0.43      | 0.37     | 0.48   | 0.40 |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.35       | 0.58      | 0.49     | 0.62   | 0.51 |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.40       | 0.63      | 0.57     | 0.74   | 0.59 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.42       | 0.68      | 0.54     | 0.79   | 0.61 |
| Mean                                                                                | 0.37       | 0.58      | 0.49     | 0.66   |      |
| Pooled                                                                              |            |           |          |        |      |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.30       | 0.43      | 0.36     | 0.48   | 0.39 |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.35       | 0.57      | 0.48     | 0.61   | 0.50 |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.39       | 0.62      | 0.56     | 0.73   | 0.58 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.41       | 0.67      | 0.53     | 0.77   | 0.60 |
| Mean                                                                                | 0.36       | 0.57      | 0.48     | 0.65   |      |
|                                                                                     |            |           |          |        |      |
|                                                                                     | Varieties  | Fertility | V×F      |        |      |
| First year SE(m)±                                                                   | 0.007      | 0.007     | 0.013    |        |      |
| C D (P=0.05)                                                                        | 0.019      | 0.019     | 0.037    |        |      |
|                                                                                     |            |           |          |        |      |
| Second year SE(m)±                                                                  | 0.007      | 0.007     | 0.013    |        |      |
| C D (P=0.05)                                                                        | 0.019      | 0.019     | 0.037    |        |      |
|                                                                                     |            |           |          |        |      |
| Pooled SE(m)±                                                                       | 0.005      | 0.005     | 0.009    |        |      |
| C D (P=0.05)                                                                        | 0.013      | 0.013     | 0.026    |        |      |

**Table 4.12 Interaction effect on LAI at 90 days of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                                    | Varieties   |             |             |             |             |
|-------------------------------------------------------------------------------------|-------------|-------------|-------------|-------------|-------------|
|                                                                                     | RGC-1017    | RGC-1038    | RGC-1055    | HG-563      | Mean        |
|                                                                                     | First Year  |             |             |             |             |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.35        | 0.45        | 0.38        | 0.54        | <b>0.43</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.41        | 0.61        | 0.50        | 0.68        | <b>0.55</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.50        | 0.75        | 0.62        | 0.88        | <b>0.69</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.59        | 0.83        | 0.70        | 1.00        | <b>0.78</b> |
| Mean                                                                                | <b>0.46</b> | <b>0.66</b> | <b>0.55</b> | <b>0.78</b> |             |
| Second Year                                                                         |             |             |             |             |             |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.37        | 0.48        | 0.40        | 0.57        | <b>0.46</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.43        | 0.65        | 0.53        | 0.72        | <b>0.58</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.54        | 0.78        | 0.65        | 0.91        | <b>0.72</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.62        | 0.87        | 0.74        | 1.05        | <b>0.82</b> |
| Mean                                                                                | <b>0.49</b> | <b>0.70</b> | <b>0.58</b> | <b>0.81</b> |             |
| Pooled                                                                              |             |             |             |             |             |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.36        | 0.47        | 0.39        | 0.56        | <b>0.45</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.42        | 0.63        | 0.51        | 0.70        | <b>0.57</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.52        | 0.77        | 0.64        | 0.90        | <b>0.71</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.61        | 0.85        | 0.72        | 1.03        | <b>0.80</b> |
| Mean                                                                                | <b>0.48</b> | <b>0.68</b> | <b>0.57</b> | <b>0.80</b> |             |
|                                                                                     |             |             |             |             |             |
|                                                                                     | Varieties   | Fertility   | V×F         |             |             |
| First year SE(m)±                                                                   | 0.006       | 0.006       | 0.013       |             |             |
| C D (P=0.05)                                                                        | 0.018       | 0.018       | 0.036       |             |             |
|                                                                                     |             |             |             |             |             |
| Second year SE(m)±                                                                  | 0.009       | 0.009       | 0.017       |             |             |
| C D (P=0.05)                                                                        | 0.024       | 0.024       | 0.049       |             |             |
|                                                                                     |             |             |             |             |             |
| Pooled SE(m)±                                                                       | 0.005       | 0.005       | 0.011       |             |             |
| C D (P=0.05)                                                                        | 0.015       | 0.015       | 0.030       |             |             |

The data pertaining to interaction effects (Table 4.10 to 4.12) indicate that the best treatment combination at 60 and 90 DAS were HG 563 grown with 100% RDF (N<sub>20</sub>P<sub>40</sub>K<sub>20</sub>), the maximum LAI being 0.75 to 0.79 in first year and 1.00 to 1.05 in the second year. This was followed by HG 563 grown with 75% RDF + VC. The significantly lowest LAI values (0.29 to 0.31 in first year and 0.35 to 0.37 in second year) were noted in case of RGC 1017 grown without fertilizers. Almost the similar trend was observed in case of 30 DAS and maturity stages in both the years where interactions were found non-significant.

#### **4.4.2 Leaf area ratio (dm<sup>2</sup>/g)**

The leaf area ratio was obtained by calculations under each treatment at 30, 60, 90 DAS and maturity stages. The mean values of both the years were subjected to statistical computation. The data pertaining to separate effect of treatments are highlighted in Table 4.13 and exhibited through Fig. 4.9. The data on interaction effect of treatments of each stage are presented in Tables 4.14 to 4.16. The examination of data in Table 4.13 reveal that the LAR, in general, tended to decrease up to 60 DAS and then increased up to 90 DAS and then again decreased up to maturity stage in all the treatments in both the years. At 30 days stage, LAR ranged from 1.67 to 2.11, at 60 days 0.97 to 1.47, at 90 DAS 1.17 to 2.13 and at maturity 1.27 to 1.76 in different treatments based on two years mean values.

The different varieties as well as fertility levels exerted significant influence upon LAR at all the stages of observations. However, the treatment interactions were found significant only at 90 DAS in both the years, whereas at 30 DAS and maturity stages only in one year (Table 4.13).

**Table 4.13 LAR of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                     | 30 DAS      |             |             | 60 DAS      |             |             | 90 DAS      |             |             | At maturity  |              |              |
|----------------------------------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------|--------------|--------------|
|                                                                | 2011-12     | 2012-13     | Mean        | 2011-12     | 2012-13     | Mean        | 2011-12     | 2012-13     | Mean        | 2011-12      | 2012-13      | Mean         |
| <b>Varities</b>                                                |             |             |             |             |             |             |             |             |             |              |              |              |
| RGC-1017                                                       | 1.65        | 1.69        | <b>1.67</b> | 1.06        | 1.10        | <b>1.08</b> | 1.50        | 1.57        | <b>1.54</b> | 1.38         | 1.44         | <b>1.41</b>  |
| RGC-1038                                                       | 1.91        | 1.97        | <b>1.94</b> | 1.27        | 1.32        | <b>1.30</b> | 1.73        | 1.78        | <b>1.76</b> | 1.53         | 1.58         | <b>1.56</b>  |
| RGC-1055                                                       | 1.80        | 1.86        | <b>1.83</b> | 1.20        | 1.27        | <b>1.24</b> | 1.62        | 1.66        | <b>1.64</b> | 1.45         | 1.51         | <b>1.48</b>  |
| HG-563                                                         | 2.09        | 2.12        | <b>2.11</b> | 1.39        | 1.45        | <b>1.42</b> | 1.87        | 1.93        | <b>1.90</b> | 1.64         | 1.69         | <b>1.67</b>  |
| <b>SE(m)±</b>                                                  | <b>0.01</b> | <b>0.02</b> | <b>0.01</b> | <b>0.02</b> | <b>0.02</b> | <b>0.01</b> | <b>0.01</b> | <b>0.02</b> | <b>0.01</b> | <b>0.016</b> | <b>0.004</b> | <b>0.008</b> |
| <b>CD (P=0.05)</b>                                             | <b>0.03</b> | <b>0.06</b> | <b>0.03</b> | <b>0.06</b> | <b>0.05</b> | <b>0.03</b> | <b>0.03</b> | <b>0.05</b> | <b>0.02</b> | <b>0.045</b> | <b>0.013</b> | <b>0.023</b> |
| <b>Fertility level</b>                                         |             |             |             |             |             |             |             |             |             |              |              |              |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )        | 1.67        | 1.72        | <b>1.70</b> | 0.95        | 0.99        | <b>0.97</b> | 1.15        | 1.18        | <b>1.17</b> | 1.24         | 1.29         | <b>1.27</b>  |
| 50% RDF +VC 5t/ha.                                             | 1.81        | 1.85        | <b>1.83</b> | 1.19        | 1.23        | <b>1.21</b> | 1.60        | 1.64        | <b>1.62</b> | 1.42         | 1.47         | <b>1.45</b>  |
| 75% RDF +VC 5t/ha.                                             | 1.92        | 1.98        | <b>1.95</b> | 1.35        | 1.41        | <b>1.38</b> | 1.87        | 1.94        | <b>1.91</b> | 1.61         | 1.67         | <b>1.64</b>  |
| 100% RDF<br>(N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 2.05        | 2.09        | <b>2.07</b> | 1.44        | 1.50        | <b>1.47</b> | 2.10        | 2.16        | <b>2.13</b> | 1.72         | 1.79         | <b>1.76</b>  |
| <b>SE(m)±</b>                                                  | <b>0.01</b> | <b>0.02</b> | <b>0.01</b> | <b>0.02</b> | <b>0.02</b> | <b>0.01</b> | <b>0.01</b> | <b>0.02</b> | <b>0.01</b> | <b>0.016</b> | <b>0.004</b> | <b>0.008</b> |
| <b>CD (P=0.05)</b>                                             | <b>0.03</b> | <b>0.06</b> | <b>0.03</b> | <b>0.06</b> | <b>0.05</b> | <b>0.03</b> | <b>0.03</b> | <b>0.05</b> | <b>0.02</b> | <b>0.045</b> | <b>0.013</b> | <b>0.023</b> |
| Interaction                                                    | 0.06        | NS          | 0.07        | NS          | NS          | NS          | 0.05        | 0.09        | 0.05        | NS           | 0.03         | 0.05         |

Fig. 4.9 LAR of Clusterbean as influenced by varieties and fertility levels.

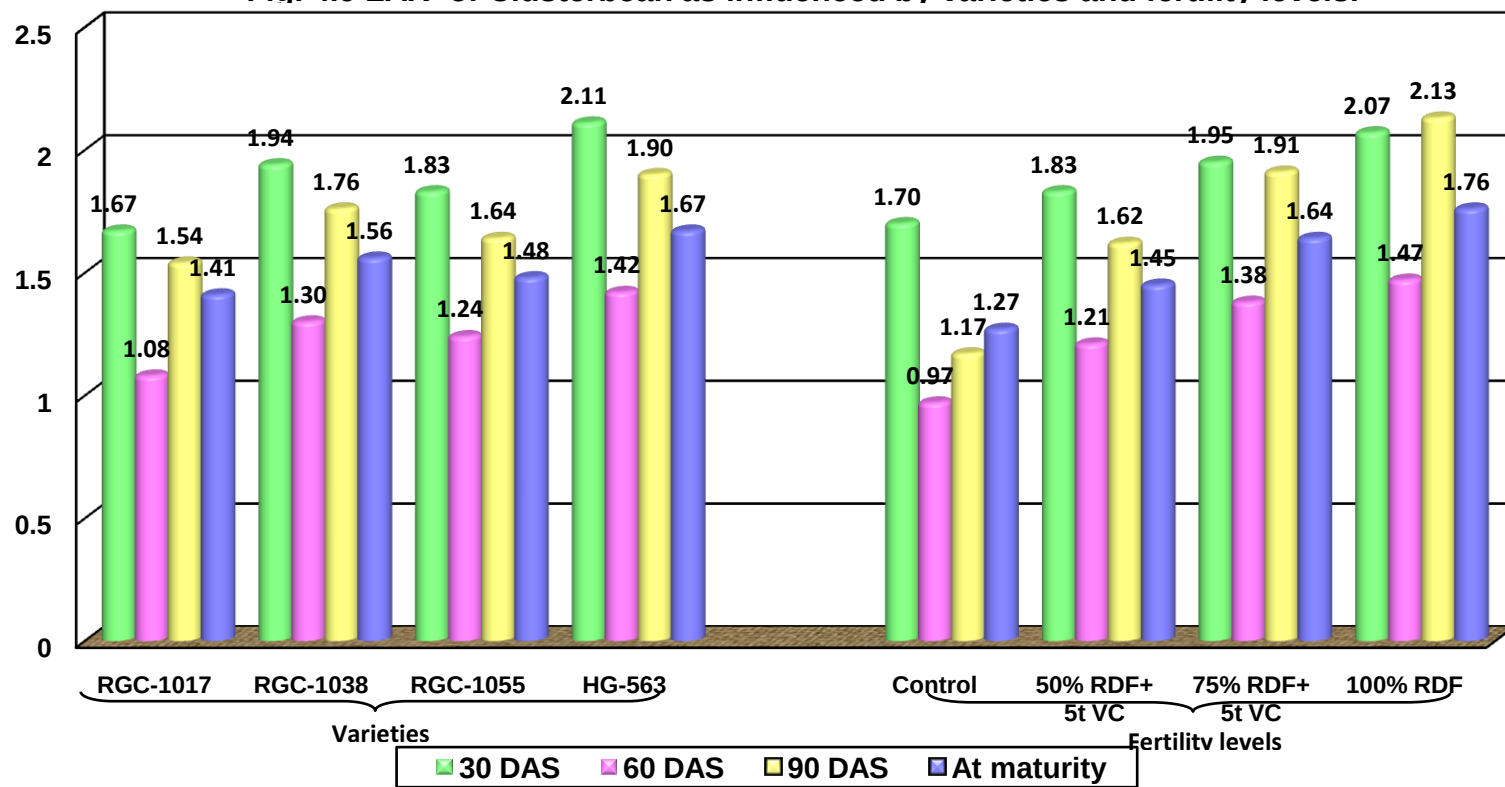


**Table 4.14 Interaction effect on LAR at 30 days of clusterbean as influenced by varieties and fertility levels in the year 2011 and pooled of two years data.**

| Fertility levels                                                              | Varieties    |             |             |             |             |
|-------------------------------------------------------------------------------|--------------|-------------|-------------|-------------|-------------|
|                                                                               | RGC-1017     | RGC-1038    | RGC- 1055   | HG-563      | Mean        |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                          | 1.52         | 1.70        | 1.63        | 1.84        | <b>1.67</b> |
| 50% N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost 5 t/ha. RDF | 1.62         | 1.85        | 1.72        | 2.04        | <b>1.81</b> |
| 75% N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost 5 t/ha. RDF | 1.69         | 1.98        | 1.87        | 2.15        | <b>1.92</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                       | 1.78         | 2.10        | 1.98        | 2.33        | <b>2.05</b> |
| <b>Mean</b>                                                                   | <b>1.65</b>  | <b>1.91</b> | <b>1.80</b> | <b>2.09</b> |             |
| <b>C.D. for Varieties</b>                                                     | <b>0.031</b> |             |             |             |             |
| <b>C.D. for Fertility</b>                                                     | <b>0.031</b> |             |             |             |             |
| <b>C.D. for Interaction</b>                                                   | <b>0.063</b> |             |             |             |             |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                          | 1.54         | 1.72        | 1.66        | 1.87        | <b>1.70</b> |
| 50% N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost 5 t/ha. RDF | 1.64         | 1.88        | 1.74        | 2.06        | <b>1.83</b> |
| 75% N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost 5 t/ha. RDF | 1.72         | 2.02        | 1.90        | 2.18        | <b>1.95</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                       | 1.81         | 2.13        | 2.02        | 2.32        | <b>2.07</b> |
| <b>Mean</b>                                                                   | <b>1.67</b>  | <b>1.94</b> | <b>1.83</b> | <b>2.11</b> |             |
| <b>C.D. for Varieties</b>                                                     | <b>0.034</b> |             |             |             |             |
| <b>C.D. for Fertility</b>                                                     | <b>0.034</b> |             |             |             |             |
| <b>C.D. for Interaction</b>                                                   | <b>0.069</b> |             |             |             |             |

Amongst the varieties, LAR of clusterbean was found to be significantly higher in variety HG 563 as compared to the rest of the varieties at every stage of observations. The second best variety was RGC 1038 and then RGC 1055. Almost significantly lowest LAR was observed in case of RGC 1017 variety. Accordingly at 30 days stage, the maximum LAR was found in case of HG 563 (2.11) as against only 1.67 in case of RGC 1017. At 60 days stage, in the same varieties the highest LAR was 1.42 and the lowest 1.08 based on mean values of two years. At 90 days stage, the corresponding LAR values were 1.90 and 1.54 and then at maturity 1.67 and 1.41 in case of HG 563 and RGC 1017, respectively.

**Table 4.15 Interaction effect on LAR at 90 days of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                                    | Varieties   |             |             |             |             |
|-------------------------------------------------------------------------------------|-------------|-------------|-------------|-------------|-------------|
|                                                                                     | RGC-1017    | RGC-1038    | RGC-1055    | HG-563      | Mean        |
|                                                                                     | First Year  |             |             |             |             |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.92        | 1.21        | 1.16        | 1.29        | <b>1.15</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 1.43        | 1.62        | 1.52        | 1.82        | <b>1.60</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 1.75        | 1.90        | 1.83        | 2.00        | <b>1.87</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 1.91        | 2.17        | 1.95        | 2.38        | <b>2.10</b> |
| Mean                                                                                | <b>1.50</b> | <b>1.73</b> | <b>1.62</b> | <b>1.87</b> |             |
| Second Year                                                                         |             |             |             |             |             |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.97        | 1.25        | 1.19        | 1.32        | <b>1.18</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 1.48        | 1.67        | 1.56        | 1.86        | <b>1.64</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 1.81        | 1.97        | 1.88        | 2.10        | <b>1.94</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 2.00        | 2.23        | 1.99        | 2.42        | <b>2.16</b> |
| Mean                                                                                | <b>1.57</b> | <b>1.78</b> | <b>1.66</b> | <b>1.93</b> |             |
| Pooled                                                                              |             |             |             |             |             |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.95        | 1.23        | 1.18        | 1.31        | <b>1.17</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 1.46        | 1.65        | 1.54        | 1.84        | <b>1.62</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 1.78        | 1.94        | 1.86        | 2.05        | <b>1.91</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 1.96        | 2.20        | 1.97        | 2.40        | <b>2.13</b> |
| Mean                                                                                | <b>1.54</b> | <b>1.76</b> | <b>1.64</b> | <b>1.90</b> |             |
|                                                                                     |             |             |             |             |             |
|                                                                                     | Varieties   | Fertility   | V×F         |             |             |
| First year SE(m)±                                                                   | 0.009       | 0.009       | 0.019       |             |             |
| C D (P=0.05)                                                                        | 0.027       | 0.027       | 0.053       |             |             |
|                                                                                     |             |             |             |             |             |
| Second year SE(m)±                                                                  | 0.016       | 0.016       | 0.033       |             |             |
| C D (P=0.05)                                                                        | 0.047       | 0.047       | 0.094       |             |             |
|                                                                                     |             |             |             |             |             |
| Pooled SE(m)±                                                                       | 0.009       | 0.009       | 0.019       |             |             |
| C D (P=0.05)                                                                        | 0.026       | 0.026       | 0.053       |             |             |

**Table 4.16 Interaction effect on LAR at maturity of clusterbean as influenced by varieties and fertility levels in the year 2012 and pooled of two years data.**

| Fertility levels                                                                    | Varieties    |             |             |             |             |
|-------------------------------------------------------------------------------------|--------------|-------------|-------------|-------------|-------------|
|                                                                                     | RGC-1017     | RGC-1038    | RGC-1055    | HG-563      | Mean        |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 1.21         | 1.32        | 1.26        | 1.37        | <b>1.29</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 1.38         | 1.47        | 1.42        | 1.62        | <b>1.47</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 1.52         | 1.71        | 1.59        | 1.86        | <b>1.67</b> |
| 100% RDF N <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                            | 1.65         | 1.83        | 1.75        | 1.91        | <b>1.79</b> |
| <b>Mean</b>                                                                         | <b>1.44</b>  | <b>1.58</b> | <b>1.51</b> | <b>1.69</b> |             |
| <b>C.D. for Varieties</b>                                                           | <b>0.013</b> |             |             |             |             |
| <b>C.D. for Fertility</b>                                                           | <b>0.013</b> |             |             |             |             |
| <b>C.D. for Interaction</b>                                                         | <b>0.025</b> |             |             |             |             |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 1.19         | 1.30        | 1.24        | 1.35        | <b>1.27</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 1.35         | 1.44        | 1.40        | 1.60        | <b>1.45</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 1.50         | 1.68        | 1.57        | 1.83        | <b>1.64</b> |
| 100% RDF N <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                            | 1.62         | 1.80        | 1.72        | 1.88        | <b>1.76</b> |
| <b>Mean</b>                                                                         | <b>1.41</b>  | <b>1.56</b> | <b>1.48</b> | <b>1.67</b> |             |
| <b>C.D. for Varieties</b>                                                           | <b>0.023</b> |             |             |             |             |
| <b>C.D. for Fertility</b>                                                           | <b>0.023</b> |             |             |             |             |
| <b>C.D. for Interaction</b>                                                         | <b>0.046</b> |             |             |             |             |

In case of fertility levels, 100% RDF resulted in significantly higher LAR over the remaining fertility levels at every stage of observations in both the years. However, this was followed by 75% RDF + VC and then 50% RDF + VC. The significantly lowest LAR was noted in case of N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> at every stage in both the years. At 30 DAS, the LAR values were in the highest range as compared to other stages, hence at this early stage, 100% RDF (N<sub>20</sub>P<sub>40</sub>K<sub>20</sub>) resulted in highest LAR (2.07) and N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> gave the lowest value (1.70).

Amongst the treatment interactions (Table 4.14 to 4.16), these were found significant and non-significant at different intervals in both the years. Accordingly, the overall trends indicate that 100% RDF applied to HG 563 recorded highest LAR at every stage of observations in both the years. At 30, 60, 90 days and at maturity stage the LAR values were 2.31 to 2.33, 1.58 to 1.67, 2.42 and then 1.85 to 1.91, respectively in both the years. On the other hand, the lowest LAR values were recorded in case of RGC 1017 grown without fertilizer application, the corresponding values at different intervals (stages) were 1.52 to 1.55, 0.78 to 0.80, 0.92 to 0.97 and then 1.16 to 1.21, respectively.

#### **4.4.3 Leaf area duration (days)**

The leaf area duration was determined through the calculation under each treatment at 30-60, 60-90 DAS and at 90-maturity stages. The mean values of both the years were subjected to statistical analysis. The data related to separate effect of treatments are highlighted in Table 4.17 and illustrated through Fig. 4.10. The data on interaction effect of treatments of each stage are presented in Tables 4.18 to 4.19.

The perusal of data in Table 4.17 reveals that the LAD, in general, tended to increase up to 60-90 DAS and then decreased up to 90 DAS- maturity stage in all the treatments in both the years. At 30-60 DAS stage, LAD ranged from 7.18 to 12.01, at 60-90 DAS 12.22 to 21.26 and at 90 DAS-maturity stage 8.61 to 15.63 in different treatments based on two years mean values.

The different varieties of clusterbean as well as fertility levels brought about significant impact upon this parameter at all the three stages of observations. However, the treatment interactions were found significant only at 30-60 DAS and only in first year at 60-90 DAS stage. At 90 DAS- maturity stage, the treatment interactions were non-significant in both the years (Table 4.17).

**Table 4.17 LAD of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                     | 30-60 DAS   |             |              | 60-90 DAS   |             |              | 90- at maturity |             |              |
|----------------------------------------------------------------|-------------|-------------|--------------|-------------|-------------|--------------|-----------------|-------------|--------------|
|                                                                | 2011-12     | 2012-13     | Mean         | 2011-12     | 2012-13     | Mean         | 2011-12         | 2012-13     | Mean         |
| <b>Varities</b>                                                |             |             |              |             |             |              |                 |             |              |
| RGC-1017                                                       | 8.45        | 8.57        | <b>8.51</b>  | 13.28       | 13.36       | <b>13.32</b> | 10.43           | 10.59       | <b>10.51</b> |
| RGC-1038                                                       | 10.05       | 10.20       | <b>10.13</b> | 17.88       | 18.33       | <b>18.11</b> | 13.01           | 13.17       | <b>13.09</b> |
| RGC-1055                                                       | 9.49        | 9.59        | <b>9.54</b>  | 15.41       | 15.67       | <b>15.54</b> | 11.36           | 11.62       | <b>11.49</b> |
| HG-563                                                         | 11.06       | 11.17       | <b>11.11</b> | 19.19       | 19.32       | <b>19.26</b> | 14.27           | 14.45       | <b>14.36</b> |
| <b>SE(m) ±</b>                                                 | <b>0.02</b> | <b>0.10</b> | <b>0.05</b>  | <b>0.19</b> | <b>0.86</b> | <b>0.44</b>  | <b>0.70</b>     | <b>0.26</b> | <b>0.37</b>  |
| <b>CD (P=0.05)</b>                                             | <b>0.05</b> | <b>0.30</b> | <b>0.15</b>  | <b>0.55</b> | <b>2.45</b> | <b>1.23</b>  | <b>2.00</b>     | <b>0.75</b> | <b>1.05</b>  |
| <b>Fertility level</b>                                         |             |             |              |             |             |              |                 |             |              |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )        | 7.12        | 7.23        | <b>7.18</b>  | 12.11       | 12.22       | <b>12.17</b> | 8.51            | 8.70        | <b>8.61</b>  |
| 50% RDF +VC 5t/ha.                                             | 9.07        | 9.19        | <b>9.13</b>  | 14.81       | 15.18       | <b>15.00</b> | 11.23           | 11.44       | <b>11.34</b> |
| 75% RDF +VC 5t/ha.                                             | 10.90       | 11.03       | <b>10.97</b> | 17.77       | 18.03       | <b>17.90</b> | 13.77           | 14.00       | <b>13.89</b> |
| 100% RDF<br>(N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 11.95       | 12.07       | <b>12.01</b> | 21.07       | 21.26       | <b>21.17</b> | 15.55           | 15.70       | <b>15.63</b> |
| <b>SE(m) ±</b>                                                 | <b>0.02</b> | <b>0.10</b> | <b>0.05</b>  | <b>0.19</b> | <b>0.86</b> | <b>0.44</b>  | <b>0.70</b>     | <b>0.26</b> | <b>0.37</b>  |
| <b>CD (P=0.05)</b>                                             | <b>0.05</b> | <b>0.30</b> | <b>0.15</b>  | <b>0.55</b> | <b>2.45</b> | <b>1.23</b>  | <b>2.00</b>     | <b>0.75</b> | <b>1.05</b>  |
| <b>Interaction</b>                                             | <b>0.11</b> | <b>0.59</b> | <b>0.30</b>  | <b>1.11</b> | <b>NS</b>   | <b>NS</b>    | <b>NS</b>       | <b>NS</b>   | <b>NS</b>    |

Fig. 4.10 LAD of Clusterbean as influenced by varieties and fertility levels.

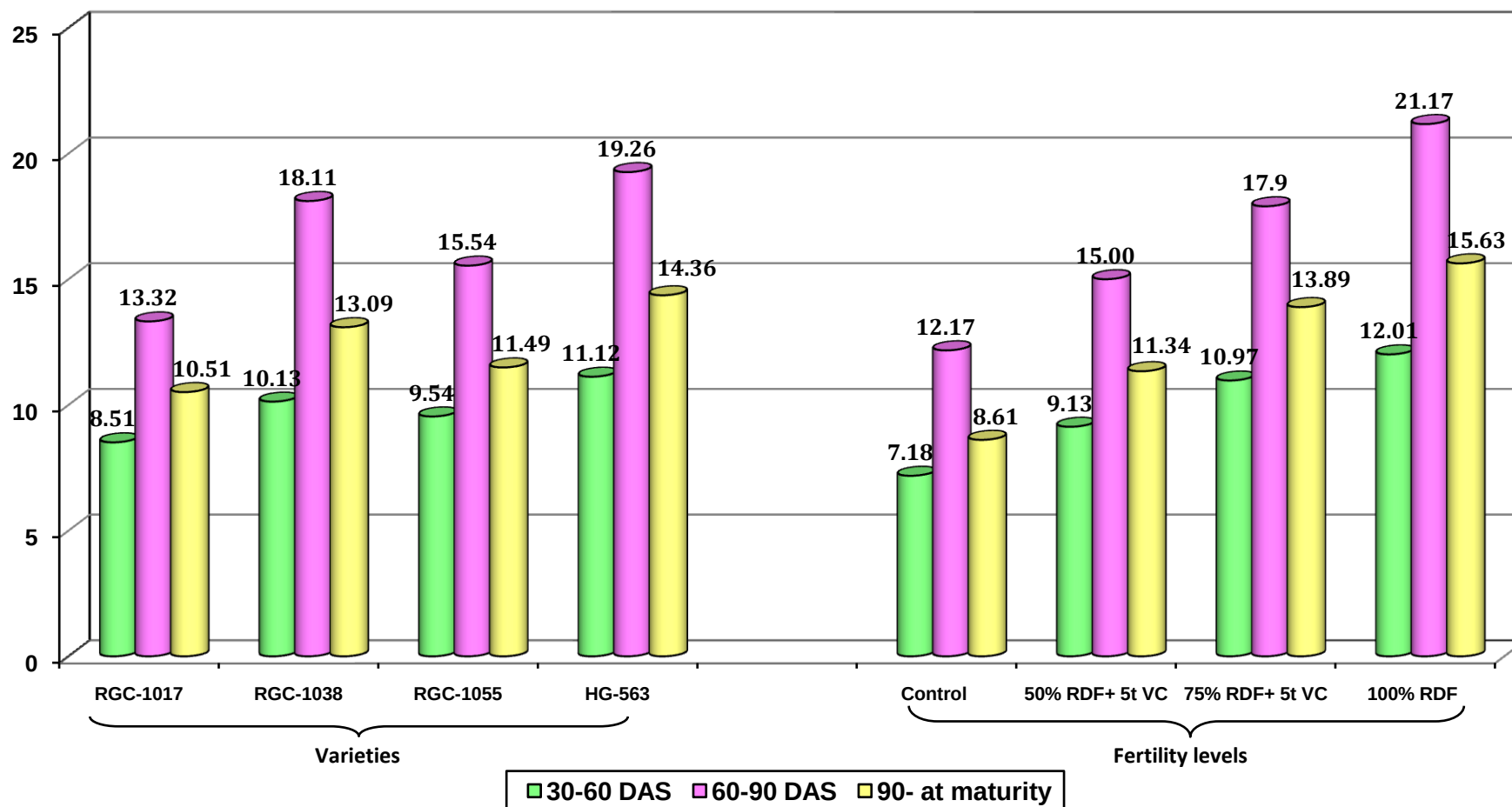


**Table 4.18 Interaction effect on LAD at 30-60 days of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                                    | Varieties  |           |          |        |       |
|-------------------------------------------------------------------------------------|------------|-----------|----------|--------|-------|
|                                                                                     | RGC-1017   | RGC-1038  | RGC-1055 | HG-563 | Mean  |
|                                                                                     | First Year |           |          |        |       |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 6.40       | 7.20      | 6.72     | 8.15   | 7.12  |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 7.87       | 8.96      | 8.78     | 10.68  | 9.07  |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 9.56       | 11.24     | 10.64    | 12.17  | 10.90 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 9.98       | 12.79     | 11.80    | 13.22  | 11.95 |
| Mean                                                                                | 8.45       | 10.05     | 9.49     | 11.06  |       |
| Second Year                                                                         |            |           |          |        |       |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 6.50       | 7.35      | 6.85     | 8.23   | 7.23  |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 7.96       | 9.10      | 8.89     | 10.82  | 9.19  |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 9.60       | 11.46     | 10.69    | 12.36  | 11.03 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 10.21      | 12.88     | 11.92    | 13.25  | 12.07 |
| Mean                                                                                | 8.57       | 10.20     | 9.59     | 11.17  |       |
| Pooled                                                                              |            |           |          |        |       |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 6.45       | 7.28      | 6.79     | 8.19   | 7.18  |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 7.92       | 9.03      | 8.84     | 10.75  | 9.13  |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 9.58       | 11.35     | 10.67    | 12.27  | 10.97 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 10.10      | 12.84     | 11.86    | 13.24  | 12.01 |
| Mean                                                                                | 8.51       | 10.13     | 9.54     | 11.11  |       |
|                                                                                     |            |           |          |        |       |
|                                                                                     | Varieties  | Fertility | V×F      |        |       |
| First year SE(m)±                                                                   | 0.019      | 0.019     | 0.038    |        |       |
| C D (P=0.05)                                                                        | 0.054      | 0.054     | 0.107    |        |       |
|                                                                                     |            |           |          |        |       |
| Second year SE(m)±                                                                  | 0.103      | 0.103     | 0.207    |        |       |
| C D (P=0.05)                                                                        | 0.295      | 0.295     | 0.591    |        |       |
|                                                                                     |            |           |          |        |       |
| Pooled SE(m)±                                                                       | 0.053      | 0.053     | 0.105    |        |       |
| C D (P=0.05)                                                                        | 0.147      | 0.147     | 0.295    |        |       |

**Table 4.19 Interaction effect on LAD at 60-90 days of influenced by varieties and fertility levels in the year 2011.**

| Fertility levels                                                                    | Varieties    |              |              |              |              |
|-------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|
|                                                                                     | RGC-1017     | RGC-1038     | RGC-1055     | HG-563       | Mean         |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 9.93         | 12.90        | 11.84        | 13.75        | <b>12.11</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 12.33        | 16.47        | 13.80        | 16.64        | <b>14.81</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 14.15        | 19.73        | 16.35        | 20.85        | <b>17.77</b> |
| 100% RDF N <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                            | 16.71        | 22.40        | 19.66        | 25.51        | <b>21.07</b> |
| <b>Mean</b>                                                                         | <b>13.28</b> | <b>17.88</b> | <b>15.41</b> | <b>19.19</b> |              |
| <b>C.D. for Varieties</b>                                                           | <b>0.553</b> |              |              |              |              |
| <b>C.D. for Fertility</b>                                                           | <b>0.553</b> |              |              |              |              |
| <b>C.D. for Interaction</b>                                                         | <b>1.106</b> |              |              |              |              |

The LAD of clusterbean was found to be significantly higher in case of HG 563 variety over the remaining varieties at every stage in both the years. However, the second best variety was RGC 1038 and then RGC 1055. The significantly lowest LAD was recorded in case of RGC 1017 variety. Accordingly at 30-60 DAS stage, the highest LAD was found in case of HG 563 (11.12) as against only 8.51 in case of RGC 1017. At 60-90 DAS, the same varieties recorded the highest LAD 19.26 and the lowest 13.32 respectively based on two years mean values. At 90 DAS- maturity stage, the corresponding LAD values were 14.36 and 10.51 in case of HG 563 and RGC 1017, respectively.

As regards with the fertility levels, 100% RDF (N<sub>20</sub>P<sub>40</sub>K<sub>20</sub>) resulted in significantly higher LAD over the remaining fertility levels at every stage of observations in both the years. However, the second best fertility level was 75% RDF + VC and then 50% RDF + VC. The significantly lowest LAD was recorded from the control treatment at every stage in both the years. At 60-90 DAS, the LAD values were in the highest range as compared to other stages, hence at this stage, 100% RDF brought about maximum LAD (21.17) and N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> gave the lowest LAD (12.17).

In case of variety x fertility interactions (Table 4.18 to 4.19), the best interaction was HG 563 grown with 100% RDF which gave maximum LAD (13.22-13.25 at 30-60 DAS, 25.51-25.56 at 60-90 DAS and 17.69-17.73 at 90 DAS-maturity stage). The LAD in this interaction was found significantly higher at 30-60 DAS to those of other interactions in both the years. The second best interaction was RGC 1038 grown with 100% RDF in both the years. At 30-60 DAS, the significantly lowest LAD was noted in case of RGC 1017 grown without fertilizers. The similar results trend was also noticed at the other stages of observations in both the years where the interactions were almost non-significant.

#### **4.4.4 Net assimilation rate (g/dm<sup>2</sup>/day)**

The net assimilation rate was estimated by the prescribed formula for each treatment at 30-60, 60-90 DAS and at 90- maturity stages. The mean data of both the years were subjected to statistical analysis. The data with respect to separate effect of varieties and fertility levels are exhibited in Table 4.20 and illustrated through Fig. 4.11. The data pertaining to treatment interactions of each stage are highlighted in Table 4.21.

The scrutiny of data in Table 4.20 reveal that the NAR, in general, tended to decrease up to 60-90 DAS and then increased up to 90 DAS-maturity stage in all the treatments in both the years. At 30-60 DAS stage, NAR ranged from 0.130 to 0.150, at 60-90 DAS 0.017 to 0.024 and at 90- maturity stage 0.108 to 0.173 in different treatments based on two years mean values.

The different varieties of clusterbean as well as fertility levels resulted in significant influence upon NAR at all the three stages of observations except in case of varieties at 30-60 DAS in first year. However, the treatment interactions were found non-significant at all the stages in both the years except at maturity in the second year (Table 4.20).

Table 4.20 NAR of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)

| Treatments                                                     | 30-60 DAS    |              |              | 60-90 DAS    |              |              | 90-at maturity |              |              |
|----------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|----------------|--------------|--------------|
|                                                                | 2011-12      | 2012-13      | Mean         | 2011-12      | 2012-13      | Mean         | 2011-12        | 2012-13      | Mean         |
| <b>Varities</b>                                                |              |              |              |              |              |              |                |              |              |
| RGC-1017                                                       | 0.130        | 0.130        | <b>0.130</b> | 0.015        | 0.018        | <b>0.017</b> | 0.110          | 0.113        | <b>0.111</b> |
| RGC-1038                                                       | 0.140        | 0.150        | <b>0.145</b> | 0.020        | 0.020        | <b>0.021</b> | 0.145          | 0.150        | <b>0.147</b> |
| RGC-1055                                                       | 0.140        | 0.140        | <b>0.140</b> | 0.020        | 0.020        | <b>0.020</b> | 0.130          | 0.138        | <b>0.132</b> |
| HG-563                                                         | 0.150        | 0.150        | <b>0.150</b> | 0.023        | 0.025        | <b>0.023</b> | 0.168          | 0.178        | <b>0.172</b> |
| <b>SE(m) ±</b>                                                 | <b>0.005</b> | <b>0.004</b> | <b>0.003</b> | <b>0.001</b> | <b>0.002</b> | <b>0.001</b> | <b>0.002</b>   | <b>0.000</b> | <b>0.001</b> |
| <b>CD (P=0.05)</b>                                             | <b>NS</b>    | <b>0.011</b> | <b>0.009</b> | <b>0.003</b> | <b>0.004</b> | <b>0.003</b> | <b>0.004</b>   | <b>0.001</b> | <b>0.002</b> |
| <b>Fertility level</b>                                         |              |              |              |              |              |              |                |              |              |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )        | 0.130        | 0.130        | <b>0.130</b> | 0.018        | 0.018        | <b>0.017</b> | 0.105          | 0.110        | <b>0.106</b> |
| 50% RDF +VC 5t/ha.                                             | 0.140        | 0.140        | <b>0.140</b> | 0.018        | 0.020        | <b>0.019</b> | 0.130          | 0.138        | <b>0.133</b> |
| 75% RDF +VC 5t/ha.                                             | 0.150        | 0.150        | <b>0.150</b> | 0.020        | 0.023        | <b>0.022</b> | 0.158          | 0.160        | <b>0.158</b> |
| 100% RDF<br>(N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 0.150        | 0.150        | <b>0.150</b> | 0.023        | 0.023        | <b>0.023</b> | 0.160          | 0.170        | <b>0.165</b> |
| <b>SE(m) ±</b>                                                 | <b>0.005</b> | <b>0.004</b> | <b>0.003</b> | <b>0.001</b> | <b>0.002</b> | <b>0.001</b> | <b>0.002</b>   | <b>0.000</b> | <b>0.001</b> |
| <b>CD (P=0.05)</b>                                             | <b>0.015</b> | <b>0.011</b> | <b>0.009</b> | <b>0.003</b> | <b>0.004</b> | <b>0.003</b> | <b>0.004</b>   | <b>0.001</b> | <b>0.002</b> |
| <b>Interaction</b>                                             | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    | <b>NS</b>      | <b>0.002</b> | <b>0.004</b> |

Fig. 4.11 NAR of Clusterbean as influenced by varieties and fertility

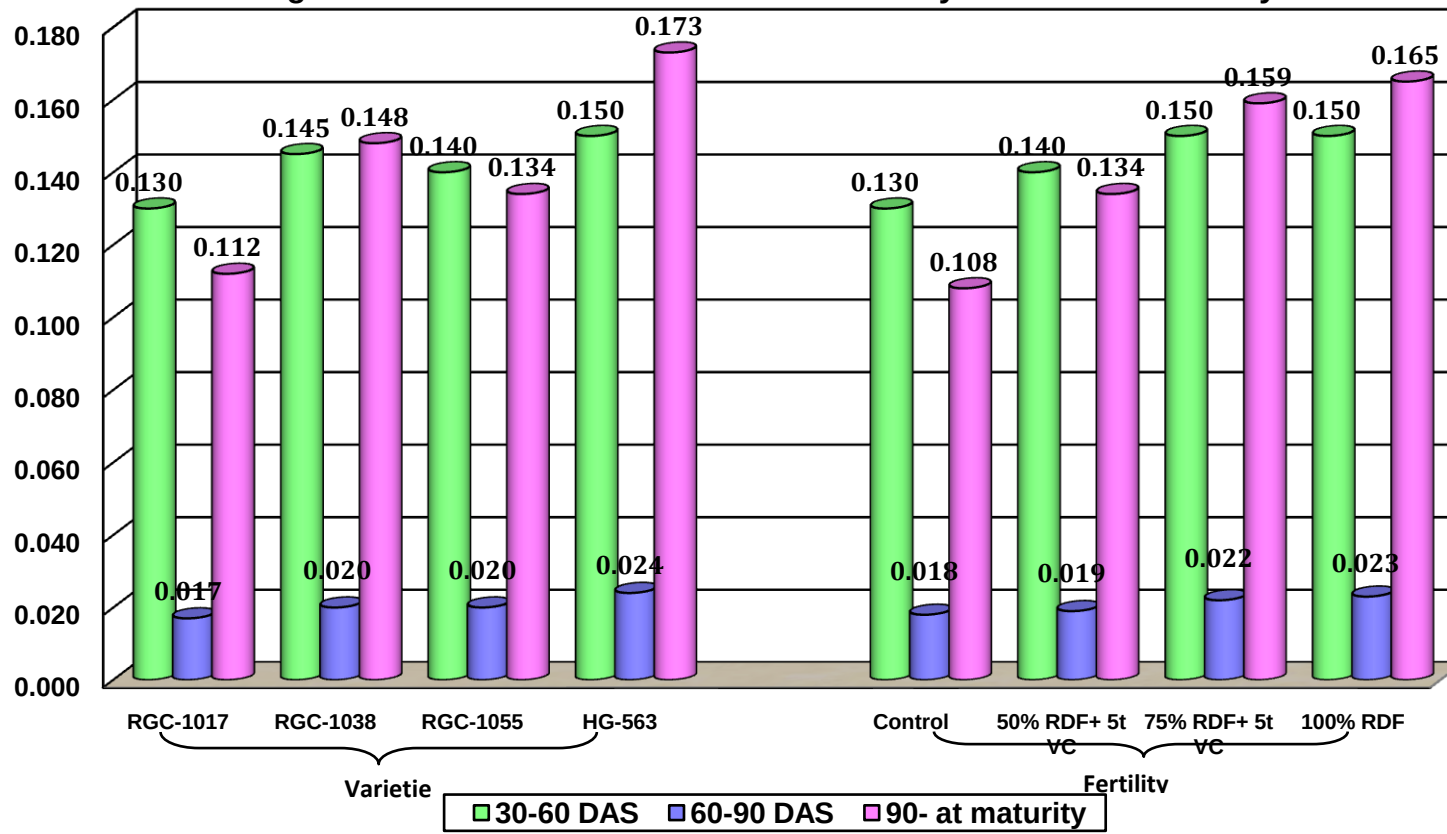


**Table 4.21 Interaction effect on NAR at 90-maturity of clusterbean as influenced by varieties and fertility levels in the year 2012 and pooled of two years data.**

| Fertility levels                                                                    | Varieties    |              |              |              |              |
|-------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|
|                                                                                     | RGC-1017     | RGC-1038     | RGC-1055     | HG-563       | Mean         |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.080        | 0.112        | 0.105        | 0.137        | <b>0.109</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.101        | 0.137        | 0.127        | 0.177        | <b>0.136</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.132        | 0.171        | 0.149        | 0.189        | <b>0.160</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.136        | 0.179        | 0.158        | 0.196        | <b>0.167</b> |
| <b>Mean</b>                                                                         | <b>0.112</b> | <b>0.150</b> | <b>0.135</b> | <b>0.175</b> |              |
| <b>C.D. for Varieties</b>                                                           | <b>0.001</b> |              |              |              |              |
| <b>C.D. for Fertility</b>                                                           | <b>0.001</b> |              |              |              |              |
| <b>C.D. for Interaction</b>                                                         | <b>0.002</b> |              |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.079        | 0.110        | 0.101        | 0.135        | <b>0.106</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.100        | 0.135        | 0.123        | 0.172        | <b>0.133</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.131        | 0.168        | 0.147        | 0.186        | <b>0.158</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.134        | 0.176        | 0.156        | 0.195        | <b>0.165</b> |
| <b>Mean</b>                                                                         | <b>0.111</b> | <b>0.147</b> | <b>0.132</b> | <b>0.172</b> |              |
| <b>C.D. for Varieties</b>                                                           | <b>0.002</b> |              |              |              |              |
| <b>C.D. for Fertility</b>                                                           | <b>0.002</b> |              |              |              |              |
| <b>C.D. for Interaction</b>                                                         | <b>0.004</b> |              |              |              |              |

Among the varieties, HG 563 brought about significantly higher NAR over the remaining varieties at every stage of observations in both the years. However, the second best variety was RGC 1038 and then RGC 1055. The significantly minimum NAR was noted in case of RGC 1017 variety. Accordingly at 30-60 DAS stage, the maximum NAR was recorded in case of HG 563 (0.150) as against only 0.130 in case of RGC 1017. At 60-90 DAS, the same varieties recorded the highest NAR 0.024 and the lowest 0.017, respectively based on two years mean values. At 90 DAS–maturity stage, the corresponding NAR values were 0.173 and 0.112 in case of HG 563 and RGC 1017, respectively.

Amongst the fertility levels, 75% RDF + VC and 100% RDF performed equally best, thereby enhanced NAR up to significant extent over the other two fertility levels. This was noticed at every stage of observations in both the years. However, the third best fertility level was 50% RDF + VC and then  $N_0P_0K_0$ . Thus the significantly lowest NAR was recorded from the control ( $N_0P_0K_0$ ) treatment. At 60-90 DAS, the NAR values were in the highest range, hence at this stage 75% RDF + VC and 100% RDF brought about the NAR values in the highest range (0.022 to 0.023) whereas  $N_0P_0K_0$  gave the lowest NAR (0.018).

In case of variety  $\times$  fertility interactions (Table 4.21), there was no any significant differences appeared at any of the stages in both the years except in case of maturity stage in second year. However, HG 563 grown with 100% RDF tended to exhibit highest value of NAR at every stage. On the other hand, the lowest NAR values were recorded in case of RGC 1017 grown without fertilizer application ( $N_0P_0K_0$ ) at every stage of observations.

#### **4.4.5 Crop growth rate (g/dm<sup>2</sup>/day)**

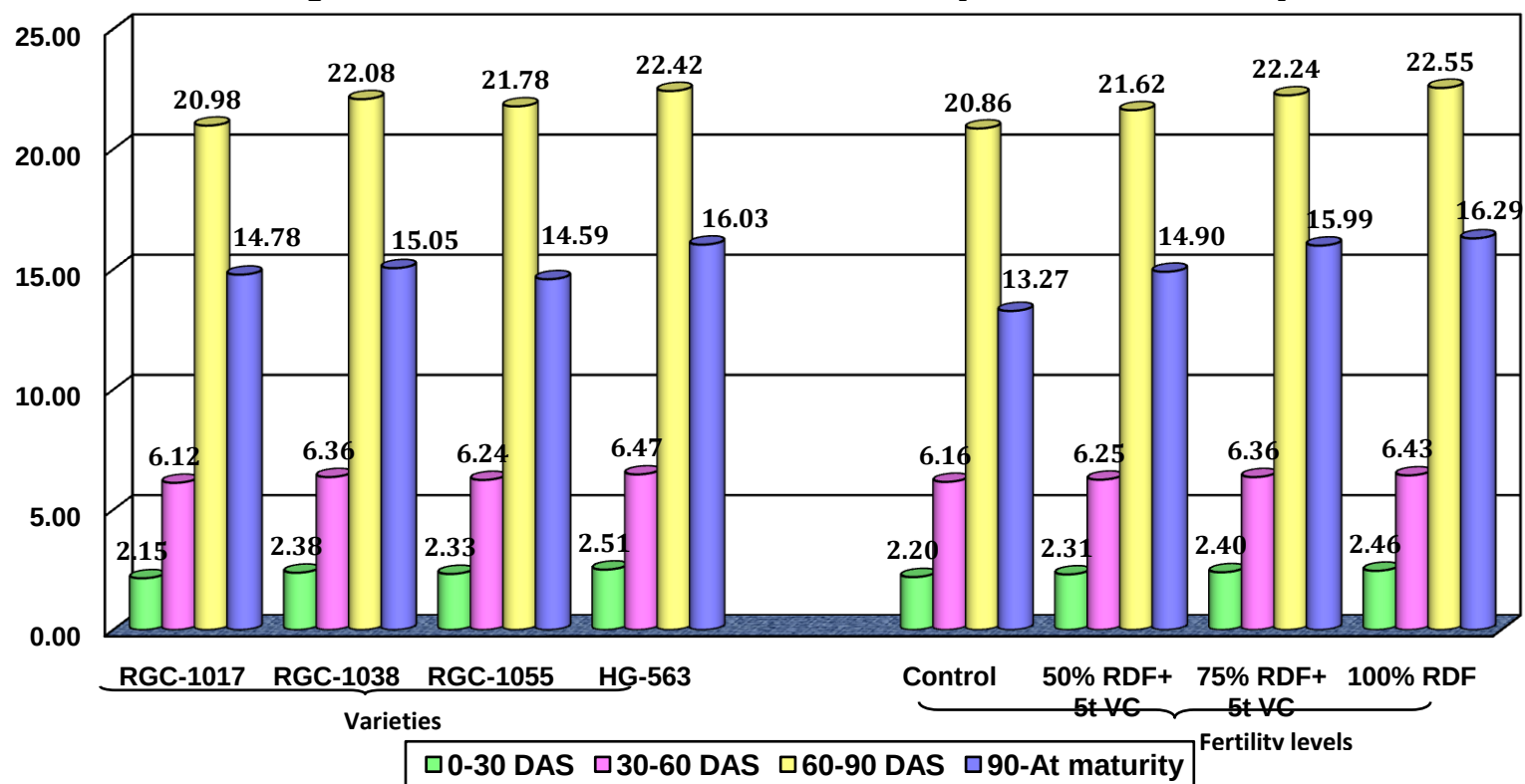
The CGR of clusterbean was computed under every treatment at different growth intervals and the mean values, after statistical analysis. The consolidated data on the separate effect of treatments are presented in Table 4.22 and exhibited through Fig. 4.12. The scrutiny of data in Table 4.40 reveal that the CGR, in general, increased by multi-fold with the increase in plant growth from 0-30 DAS to 60-90 DAS stage. Thereafter it tended to decline up to 90- maturity stage under the various treatments. At 0-30 DAS stage, CGR ranged from 2.15 to 2.51, whereas at 60-90 DAS stage, 20.86 to 22.55 and then at 90-maturity stage reduced CGR ranged from 13.27 to 16.29 in various treatments based on the mean of both the years.

The different varieties as well as fertility levels did not exert any significant impact upon CGR at all that growth stages of observations. The treatment interactions were also found to be non-significant at all the stages in both the years (Table 4.22). However, among the varieties, HG 563 recorded maximum CGR values at every stage. This was followed by RGC 1038 and then RGC 1055. The lowest values were observed in case of RGC 1017 variety of clusterbean.

**Table 4.22 CGR of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

[illegible]

Fig. 4.12 CGR of Clusterbean as influenced by varieties and fertility levels.



In case of fertility levels, 100% RDF ( $N_{20}P_{40}K_{20}$ ) resulted in highest CGR values, followed by 75% RDF + VC and then 50% RDF + VC. The lowest values were noted in case of  $N_0P_0K_0$ . These results were recorded at every stage of observation in both the years.

In case of treatment interactions, (Tables 4.22) although non-significant, HG 563 grown with 100% NPK resulted in maximum CGR at every stage in both the years. This was followed by HG 563 grown with 75% RDF + VC. The lowest values were observed in case of RGC 1017 grown without NPK fertilization (control).

#### **4.4.6 Relative growth rate (g/g/day)**

The RGR of clusterbean was calculated under each treatment at different growth intervals and the mean values, after statistical analysis, are highlighted in Tables 4.23 to 4.26. The consolidated data on the separate effect of treatments are shown in Table 4.23 and illustrated through Fig. 4.13. The perusal of data in Table 4.23 indicate that the RGR, in general, increased by more than twice with the increase in plant growth from 30 DAS to 60 DAS stage. Thereafter the RGR tended to decrease slowly up to 90 DAS and then very fast up to the crop maturity stage. This was observed under the various treatments in general. At 30 DAS stage, RGR ranged from 0.0155 to 0.0234, whereas at 60 DAS stage, 0.0369 to 0.0468 and then at maturity stage, decreased RGR ranged from 0.0117 to 0.0141 in various treatments based on the mean values of both the years.

The different varieties as well as fertility levels exerted significant influence upon RGR at all the growth stages of observations. The treatment interactions were found to be significant only at the maturity stage in both the years and at 60 and 90 DAS in second year (Table 4.23).

Amongst the varieties, HG 563 recorded almost significantly higher RGR at every stage in both the years. This was followed by RGR at every stage in both the years. This was followed by RGC 1038 and then RGC 1055. The significantly minimum RGR was obtained in case of RGC 1017 variety of clusterbean at every stage.

**Table 4.23 RGR of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                     | 30 DAS        |               |               | 60 DAS        |               |               | 90 DAS        |               |               | At maturity   |               |               |
|----------------------------------------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                                                                | 2011-12       | 2012-13       | Mean          | 2011-12       | 2012-13       | Mean          | 2011-12       | 2012-13       | Mean          | 2011-12       | 2012-13       | Mean          |
| <b>Varities</b>                                                |               |               |               |               |               |               |               |               |               |               |               |               |
| RGC-1017                                                       | 0.0144        | 0.0165        | <b>0.0155</b> | 0.0359        | 0.0380        | <b>0.0370</b> | 0.0334        | 0.0355        | <b>0.0345</b> | 0.0120        | 0.0128        | <b>0.0124</b> |
| RGC-1038                                                       | 0.0186        | 0.0208        | <b>0.0197</b> | 0.0427        | 0.0450        | <b>0.0438</b> | 0.0395        | 0.0420        | <b>0.0408</b> | 0.0128        | 0.0138        | <b>0.0133</b> |
| RGC-1055                                                       | 0.0171        | 0.0193        | <b>0.0182</b> | 0.0382        | 0.0410        | <b>0.0396</b> | 0.0353        | 0.0373        | <b>0.0363</b> | 0.0125        | 0.0134        | <b>0.0130</b> |
| HG-563                                                         | 0.0229        | 0.0240        | <b>0.0234</b> | 0.0455        | 0.0480        | <b>0.0468</b> | 0.0407        | 0.0428        | <b>0.0417</b> | 0.0132        | 0.0141        | <b>0.0136</b> |
| <b>SE(m) ±</b>                                                 | <b>0.0006</b> | <b>0.0012</b> | <b>0.0007</b> | <b>0.0005</b> | <b>0.0004</b> | <b>0.0003</b> | <b>0.0006</b> | <b>0.0003</b> | <b>0.0003</b> | <b>0.0001</b> | <b>0.0000</b> | <b>0.0000</b> |
| <b>CD (P=0.05)</b>                                             | <b>0.0017</b> | <b>0.0035</b> | <b>0.0019</b> | <b>0.0014</b> | <b>0.0011</b> | <b>0.0009</b> | <b>0.0018</b> | <b>0.0007</b> | <b>0.0010</b> | <b>0.0002</b> | <b>0.0001</b> | <b>0.0001</b> |
| <b>Fertility level</b>                                         |               |               |               |               |               |               |               |               |               |               |               |               |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )        | 0.0151        | 0.0173        | <b>0.0162</b> | 0.0356        | 0.0383        | <b>0.0369</b> | 0.0323        | 0.0345        | <b>0.0334</b> | 0.0112        | 0.0122        | <b>0.0117</b> |
| 50% RDF +VC 5t/ha.                                             | 0.0173        | 0.0193        | <b>0.0183</b> | 0.0384        | 0.0408        | <b>0.0396</b> | 0.0356        | 0.0375        | <b>0.0365</b> | 0.0123        | 0.0131        | <b>0.0127</b> |
| 75% RDF +VC 5t/ha.                                             | 0.0191        | 0.0210        | <b>0.0201</b> | 0.0427        | 0.0450        | <b>0.0438</b> | 0.0388        | 0.0413        | <b>0.0400</b> | 0.0133        | 0.0143        | <b>0.0138</b> |
| 100% RDF<br>(N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 0.0216        | 0.0230        | <b>0.0223</b> | 0.0457        | 0.0480        | <b>0.0468</b> | 0.0423        | 0.0443        | <b>0.0433</b> | 0.0136        | 0.0146        | <b>0.0141</b> |
| <b>SE(m) ±</b>                                                 | <b>0.0006</b> | <b>0.0012</b> | <b>0.0007</b> | <b>0.0005</b> | <b>0.0004</b> | <b>0.0003</b> | <b>0.0006</b> | <b>0.0003</b> | <b>0.0003</b> | <b>0.0001</b> | <b>0.0000</b> | <b>0.0000</b> |
| <b>CD (P=0.05)</b>                                             | <b>0.0017</b> | <b>0.0035</b> | <b>0.0019</b> | <b>0.0014</b> | <b>0.0011</b> | <b>0.0009</b> | <b>0.0018</b> | <b>0.0007</b> | <b>0.0010</b> | <b>0.0002</b> | <b>0.0001</b> | <b>0.0001</b> |
| <b>Interaction</b>                                             | <b>NS</b>     | <b>NS</b>     | <b>NS</b>     | <b>NS</b>     | <b>0.0022</b> | <b>0.0018</b> | <b>NS</b>     | <b>0.0015</b> | <b>NS</b>     | <b>0.0003</b> | <b>0.0001</b> | <b>0.0002</b> |

Fig. 4.13 RGR of Clusterbean as influenced by varieties and fertility levels.

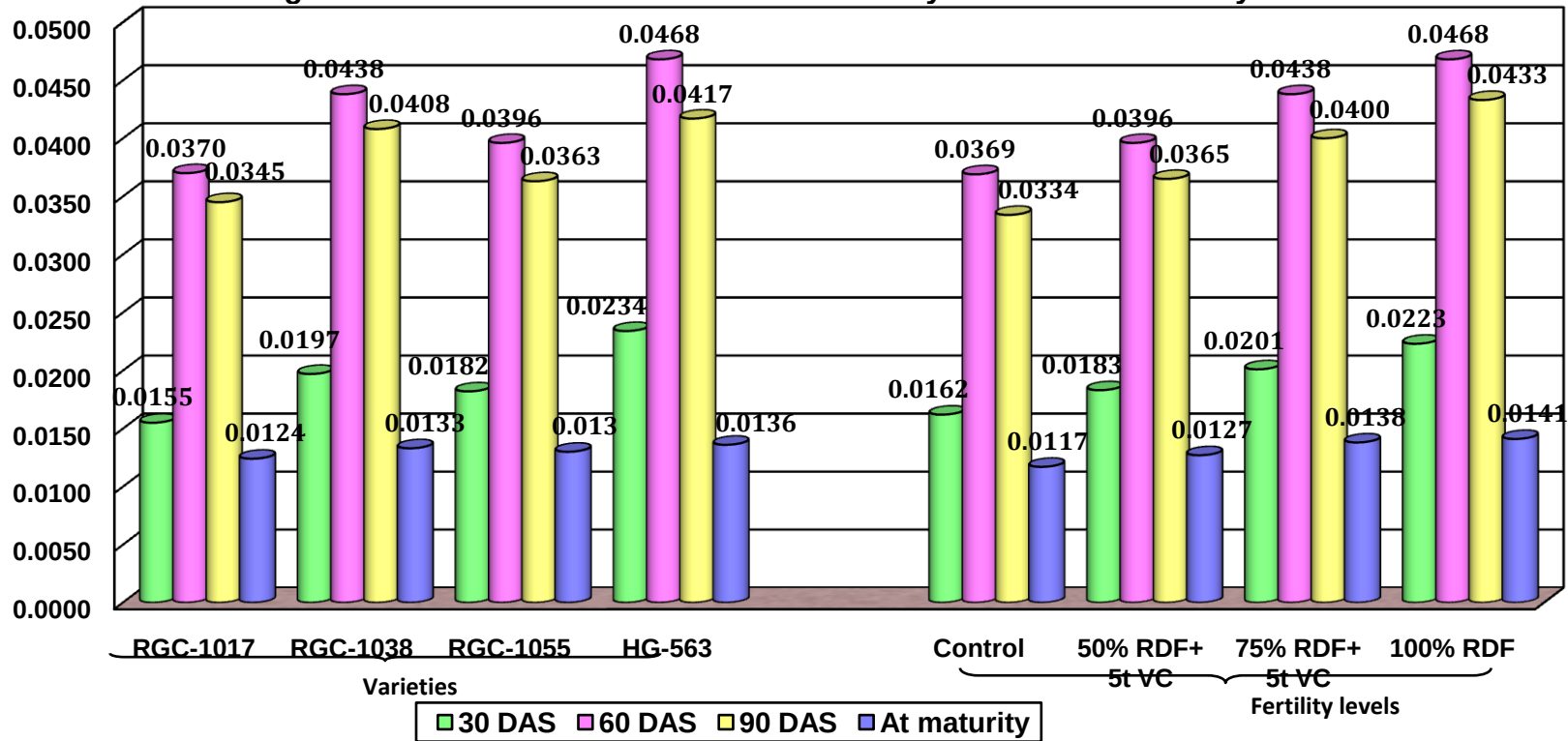


**Table 4.24 Interaction effect on RGR at 60 DAS of clusterbean as influenced by varieties and fertility levels in the year 2012 and pooled of two years data.**

| Fertility levels                                                              | Varieties     |               |               |               |               |
|-------------------------------------------------------------------------------|---------------|---------------|---------------|---------------|---------------|
|                                                                               | RGC- 1017     | RGC- 1038     | RGC- 1055     | HG-563        | Mean          |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                          | 0.0340        | 0.0400        | 0.0370        | 0.0420        | <b>0.0383</b> |
| 50% N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost 5 t/ha. RDF | 0.0370        | 0.0430        | 0.0380        | 0.0450        | <b>0.0408</b> |
| 75% N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost 5 t/ha. RDF | 0.0390        | 0.0470        | 0.0420        | 0.0520        | <b>0.0450</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                       | 0.0420        | 0.0500        | 0.0470        | 0.0530        | <b>0.0480</b> |
| <b>Mean</b>                                                                   | <b>0.0380</b> | <b>0.0450</b> | <b>0.0410</b> | <b>0.0480</b> |               |
| <b>C.D. for Varieties</b>                                                     | <b>0.0011</b> |               |               |               |               |
| <b>C.D. for Fertility</b>                                                     | <b>0.0011</b> |               |               |               |               |
| <b>C.D. for Interaction</b>                                                   | <b>0.0022</b> |               |               |               |               |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                          | 0.0331        | 0.0386        | 0.0353        | 0.0406        | <b>0.0369</b> |
| 50% N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost 5 t/ha. RDF | 0.0358        | 0.0418        | 0.0369        | 0.0439        | <b>0.0396</b> |
| 75% N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost 5 t/ha. RDF | 0.0379        | 0.0459        | 0.0410        | 0.0506        | <b>0.0438</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                       | 0.0411        | 0.0491        | 0.0453        | 0.0519        | <b>0.0468</b> |
| <b>Mean</b>                                                                   | <b>0.0370</b> | <b>0.0438</b> | <b>0.0396</b> | <b>0.0468</b> |               |
| <b>C.D. for Varieties</b>                                                     | <b>0.0009</b> |               |               |               |               |
| <b>C.D. for Fertility</b>                                                     | <b>0.0009</b> |               |               |               |               |
| <b>C.D. for Interaction</b>                                                   | <b>0.0018</b> |               |               |               |               |

**Table 4.25 Interaction effect on RGR at 90 DAS of clusterbean as influenced by varieties and fertility levels in the year 2012.**

| Fertility levels                                                              | Varieties     |               |               |               |               |
|-------------------------------------------------------------------------------|---------------|---------------|---------------|---------------|---------------|
|                                                                               | RGC- 1017     | RGC- 1038     | RGC- 1055     | HG-563        | Mean          |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                          | 0.0310        | 0.0370        | 0.0330        | 0.0370        | <b>0.0345</b> |
| 50% N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost 5 t/ha. RDF | 0.0340        | 0.0400        | 0.0340        | 0.0420        | <b>0.0375</b> |
| 75% N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost 5 t/ha. RDF | 0.0370        | 0.0430        | 0.0400        | 0.0450        | <b>0.0413</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                       | 0.0400        | 0.0480        | 0.0420        | 0.0470        | <b>0.0443</b> |
| <b>Mean</b>                                                                   | <b>0.0355</b> | <b>0.0420</b> | <b>0.0373</b> | <b>0.0428</b> |               |
| <b>C.D. for Varieties</b>                                                     | <b>0.0007</b> |               |               |               |               |
| <b>C.D. for Fertility</b>                                                     | <b>0.0007</b> |               |               |               |               |
| <b>C.D. for Interaction</b>                                                   | <b>0.0015</b> |               |               |               |               |

**Table 4.26 Interaction effect on RGR at maturity of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                              | Varieties      |                |                |                |                |
|-------------------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|
|                                                                               | RGC- 1017      | RGC- 1038      | RGC- 1055      | HG-563         | Mean           |
|                                                                               | First Year     |                |                |                |                |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                          | 0.01003        | 0.01155        | 0.01103        | 0.01203        | <b>0.01116</b> |
| 50% N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost 5 t/ha. RDF | 0.01165        | 0.01255        | 0.01210        | 0.01308        | <b>0.01234</b> |
| 75% N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost 5 t/ha. RDF | 0.01298        | 0.01340        | 0.01330        | 0.01360        | <b>0.01332</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                       | 0.01328        | 0.01375        | 0.01358        | 0.01390        | <b>0.01363</b> |
| <b>Mean</b>                                                                   | <b>0.01198</b> | <b>0.01281</b> | <b>0.01250</b> | <b>0.01315</b> |                |

| Second Year                                                                   |                  |                  |                |                |                |
|-------------------------------------------------------------------------------|------------------|------------------|----------------|----------------|----------------|
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                          | 0.01100          | 0.01260          | 0.01200        | 0.01300        | <b>0.01215</b> |
| 50% N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost 5 t/ha. RDF | 0.01200          | 0.01350          | 0.01300        | 0.01400        | <b>0.01313</b> |
| 75% N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost 5 t/ha. RDF | 0.01400          | 0.01440          | 0.01420        | 0.01450        | <b>0.01428</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                       | 0.01420          | 0.01480          | 0.01450        | 0.01480        | <b>0.01458</b> |
| <b>Mean</b>                                                                   | <b>0.01280</b>   | <b>0.01383</b>   | <b>0.01343</b> | <b>0.01408</b> |                |
| Pooled                                                                        |                  |                  |                |                |                |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                          | 0.01051          | 0.01208          | 0.01151        | 0.01251        | <b>0.01165</b> |
| 50% N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost 5 t/ha. RDF | 0.01183          | 0.01303          | 0.01255        | 0.01354        | <b>0.01273</b> |
| 75% N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost 5 t/ha. RDF | 0.01349          | 0.01390          | 0.01375        | 0.01405        | <b>0.01380</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                       | 0.01374          | 0.01428          | 0.01404        | 0.01435        | <b>0.01410</b> |
| <b>Mean</b>                                                                   | <b>0.01239</b>   | <b>0.01332</b>   | <b>0.01296</b> | <b>0.01361</b> |                |
|                                                                               |                  |                  |                |                |                |
|                                                                               | <b>Varieties</b> | <b>Fertility</b> | <b>V×F</b>     |                |                |
| <b>First year SE(m)±</b>                                                      | 0.00006          | 0.00006          | 0.00012        |                |                |
| <b>C D (P=0.05)</b>                                                           | 0.00017          | 0.00017          | 0.00033        |                |                |
|                                                                               |                  |                  |                |                |                |
| <b>Second year SE(m)±</b>                                                     | 0.00002          | 0.00002          | 0.00005        |                |                |
| <b>C D (P=0.05)</b>                                                           | 0.00007          | 0.00007          | 0.00013        |                |                |
|                                                                               |                  |                  |                |                |                |
| <b>Pooled SE(m)±</b>                                                          | 0.00003          | 0.00003          | 0.00006        |                |                |
| <b>C D (P=0.05)</b>                                                           | 0.00009          | 0.00009          | 0.00018        |                |                |

Amongst the fertility levels, 100% RDF ( $N_{20}P_{40}K_{20}$ ) resulted in maximum RGR, being significantly higher to the remaining fertility levels. However, this was followed by 75% RDF +VC and then 50% RDF + VC. The significantly lowest RGR was noted in case of  $N_0P_0K_0$  at every stage of observations in both the years.

In case of treatment interactions, (Tables 4.24 to 4.26) HG 563 grown with 100% RDF ( $N_{20}P_{40}K_{20}$ ) performed the best at every stage, however the treatment interactions were found significant only at the maturity stage. The second best interaction was HG 53 grown with 75% RDF+ VC. This was followed by RGC 1038 grown with 100% RDF. At maturity stage, these interactions proved significantly superior to the remaining interactions. The same trend was also noticed in case of 60 and 90 DAS stages in second year where the interactions were significant. The lowest RGR was noted in case of RGC 1017 grown without NPK application.

#### **4.4.7 Absolute growth rate (g/day)**

The AGR of clusterbean was worked out under each treatment at different growth intervals and the mean values, after statistical computation, are shown in Tables 4.27 to 4.29. The compiled data on the separate effect of treatments are highlighted in Table 4.27 and illustrated through Fig. 4.14. The scrutiny of data in Table 4.27 reveals that the AGR, in general, increased by multi-fold with the advancement of plant growth from 0-30 DAS to 60-90 DAS stage. Thereafter the AGR exhibited decreasing trend up to 90-maturity stage. This was observed under the various treatments in general in both the years. At 0-30 DAS stage, AGR ranged from 0.059 to 0.072, whereas at 60-90 DAS stage, 0.628 to 0.707 and then at 90- maturity stage, reduced AGR deviated from 0.439 to 0.501 in various treatments based on two years mean data.

The different varieties as well as fertility levels brought about significant changes in this parameter at all the growth stages of observations. The treatment interactions were found to be significant only at 60-90 DAS stage and at 90-maturity stage in first year (Table 4.27).

**Table 4.27 AGR of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                     | 0-30 DAS     |              |              | 30-60 DAS    |              |              | 60-90        |              |              | 90-At maturity |              |              |
|----------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|----------------|--------------|--------------|
|                                                                | 2011-12      | 2012-13      | Mean         | 2011-12      | 2012-13      | Mean         | 2011-12      | 2012-13      | Mean         | 2011-12        | 2012-13      | Mean         |
| <b>Varities</b>                                                |              |              |              |              |              |              |              |              |              |                |              |              |
| RGC-1017                                                       | 0.056        | 0.061        | <b>0.059</b> | 0.174        | 0.177        | <b>0.175</b> | 0.626        | 0.630        | <b>0.628</b> | 0.442          | 0.446        | <b>0.444</b> |
| RGC-1038                                                       | 0.065        | 0.069        | <b>0.067</b> | 0.189        | 0.192        | <b>0.190</b> | 0.683        | 0.687        | <b>0.685</b> | 0.487          | 0.490        | <b>0.488</b> |
| RGC-1055                                                       | 0.062        | 0.067        | <b>0.065</b> | 0.182        | 0.179        | <b>0.181</b> | 0.669        | 0.673        | <b>0.671</b> | 0.474          | 0.478        | <b>0.476</b> |
| HG-563                                                         | 0.072        | 0.073        | <b>0.072</b> | 0.202        | 0.193        | <b>0.197</b> | 0.705        | 0.709        | <b>0.707</b> | 0.499          | 0.502        | <b>0.500</b> |
| <b>SE (m) ±</b>                                                | <b>0.001</b> | <b>0.003</b> | <b>0.001</b> | <b>0.006</b> | <b>0.001</b> | <b>0.003</b> | <b>0.004</b> | <b>0.001</b> | <b>0.002</b> | <b>0.003</b>   | <b>0.005</b> | <b>0.003</b> |
| <b>CD (P=0.05)</b>                                             | <b>0.004</b> | <b>0.007</b> | <b>0.004</b> | <b>0.017</b> | <b>0.003</b> | <b>0.009</b> | <b>0.013</b> | <b>0.003</b> | <b>0.006</b> | <b>0.009</b>   | <b>0.015</b> | <b>0.009</b> |
| <b>Fertility level</b>                                         |              |              |              |              |              |              |              |              |              |                |              |              |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )        | 0.058        | 0.063        | <b>0.061</b> | 0.174        | 0.177        | <b>0.176</b> | 0.630        | 0.634        | <b>0.632</b> | 0.437          | 0.442        | <b>0.439</b> |
| 50% RDF +VC 5t/ha.                                             | 0.062        | 0.066        | <b>0.064</b> | 0.183        | 0.183        | <b>0.183</b> | 0.658        | 0.662        | <b>0.660</b> | 0.471          | 0.475        | <b>0.473</b> |
| 75% RDF +VC 5t/ha.                                             | 0.067        | 0.069        | <b>0.068</b> | 0.193        | 0.189        | <b>0.191</b> | 0.695        | 0.699        | <b>0.697</b> | 0.493          | 0.497        | <b>0.495</b> |
| 100% RDF<br>(N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 0.068        | 0.072        | <b>0.070</b> | 0.196        | 0.192        | <b>0.194</b> | 0.699        | 0.703        | <b>0.701</b> | 0.500          | 0.503        | <b>0.501</b> |
| <b>SE (m) ±</b>                                                | <b>0.001</b> | <b>0.003</b> | <b>0.001</b> | <b>0.006</b> | <b>0.001</b> | <b>0.003</b> | <b>0.004</b> | <b>0.001</b> | <b>0.002</b> | <b>0.003</b>   | <b>0.005</b> | <b>0.003</b> |
| <b>CD (P=0.05)</b>                                             | <b>0.004</b> | <b>0.007</b> | <b>0.004</b> | <b>0.017</b> | <b>0.003</b> | <b>0.009</b> | <b>0.013</b> | <b>0.003</b> | <b>0.006</b> | <b>0.009</b>   | <b>0.015</b> | <b>0.009</b> |
| <b>Interaction</b>                                             | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    | <b>0.026</b> | <b>0.006</b> | <b>0.013</b> | <b>NS</b>      | <b>NS</b>    | <b>0.017</b> |

Fig. 4.14 AGR of Clusterbean as influenced by varieties and fertility levels.

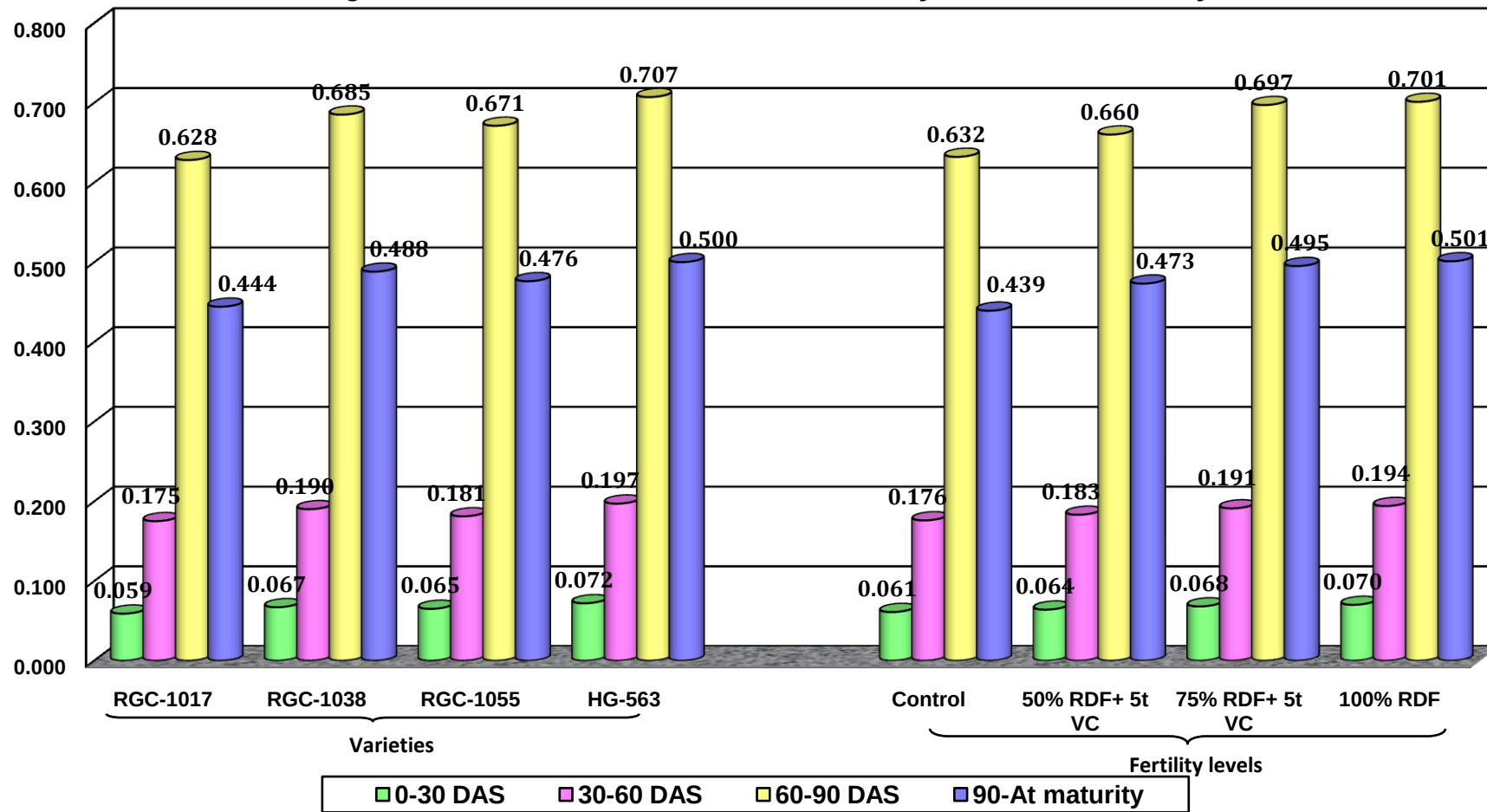


**Table 4.28 Interaction effect on AGR at 60-90 days of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                                    | Varieties    |              |              |              |              |
|-------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|
|                                                                                     | RGC-1017     | RGC-1038     | RGC-1055     | HG-563       | Mean         |
|                                                                                     | First Year   |              |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.558        | 0.659        | 0.638        | 0.665        | <b>0.630</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.598        | 0.674        | 0.669        | 0.691        | <b>0.658</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.671        | 0.696        | 0.684        | 0.729        | <b>0.695</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.675        | 0.702        | 0.685        | 0.733        | <b>0.699</b> |
| Mean                                                                                | <b>0.626</b> | <b>0.683</b> | <b>0.669</b> | <b>0.705</b> |              |
| Second Year                                                                         |              |              |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.562        | 0.663        | 0.642        | 0.669        | <b>0.634</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.602        | 0.678        | 0.673        | 0.695        | <b>0.662</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.675        | 0.700        | 0.688        | 0.733        | <b>0.699</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.679        | 0.706        | 0.690        | 0.737        | <b>0.703</b> |
| Mean                                                                                | <b>0.630</b> | <b>0.687</b> | <b>0.673</b> | <b>0.709</b> |              |
| Pooled                                                                              |              |              |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.560        | 0.661        | 0.640        | 0.667        | <b>0.632</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.600        | 0.676        | 0.671        | 0.693        | <b>0.660</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.673        | 0.698        | 0.686        | 0.731        | <b>0.697</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.677        | 0.704        | 0.688        | 0.735        | <b>0.701</b> |
| Mean                                                                                | <b>0.628</b> | <b>0.685</b> | <b>0.671</b> | <b>0.707</b> |              |
|                                                                                     |              |              |              |              |              |
|                                                                                     | Varieties    | Fertility    | V×F          |              |              |
| First year SE(m)±                                                                   | 0.004        | 0.004        | 0.009        |              |              |
| C D (P=0.05)                                                                        | 0.013        | 0.013        | 0.026        |              |              |
|                                                                                     |              |              |              |              |              |
| Second year SE(m)±                                                                  | 0.001        | 0.001        | 0.002        |              |              |
| C D (P=0.05)                                                                        | 0.003        | 0.003        | 0.006        |              |              |
|                                                                                     |              |              |              |              |              |
| Pooled SE(m)±                                                                       | 0.002        | 0.002        | 0.005        |              |              |
| C D (P=0.05)                                                                        | 0.006        | 0.006        | 0.013        |              |              |

**Table 4.29 Interaction effect on AGR at 90-maturity of clusterbean as influenced by varieties and fertility levels pooled of two years data.**

| Fertility levels                                                                    | Varieties    |              |              |              |              |
|-------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|
|                                                                                     | RGC-1017     | RGC-1038     | RGC-1055     | HG-563       | Mean         |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.388        | 0.454        | 0.448        | 0.468        | <b>0.439</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.449        | 0.479        | 0.472        | 0.492        | <b>0.473</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.467        | 0.504        | 0.491        | 0.519        | <b>0.495</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.472        | 0.517        | 0.494        | 0.523        | <b>0.501</b> |
| <b>Mean</b>                                                                         | <b>0.444</b> | <b>0.488</b> | <b>0.476</b> | <b>0.500</b> |              |
| <b>C.D. for Varieties</b>                                                           | <b>0.009</b> |              |              |              |              |
| <b>C.D. for Fertility</b>                                                           | <b>0.009</b> |              |              |              |              |
| <b>C.D. for Interaction</b>                                                         | <b>0.017</b> |              |              |              |              |

Amongst the varieties, HG 563 resulted in almost significantly higher AGR at every stage in both the years. This was followed by RGC 1038 and then RGC 1055. The significantly lowest AGR values were noticed in case of RGC 1017 variety of clusterbean at every growth stage.

In case of fertility levels, 75% RDF+VC and 100% RDF resulted in almost equally higher AGR at every stage in both the years. All the values were found significantly superior to the lower fertility levels. The significantly lowest AGR was obtained from N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> treatment at every stage in both the years.

In case of treatment interactions (Tables 4.28 to 4.29), HG 563 grown with 100% RDF recorded the maximum AGR values at every stage in both the years. This was followed by HG 563 grown with 75% RDF+VC. In stages where the treatment interactions were significant, the values of the best treatment interactions were found almost significantly superior to all the remaining interactions. The significantly or non-significantly lowest AGR values were observed in case of RGC 1017 variety grown without NPK fertilizer at every stage in both the years.

## **4.5 Yield attributing parameters**

### **4.5.1. Number of pods/ plant**

The data pertaining to number of pods /plant are presented in Table 4.30 and diagrammatically illustrated through Fig. 4.15. This parameter was influenced significantly due to varieties and fertility levels but not due to their interactions in both the years.

The variety HG 563 being at par with RGC 1038 produced significantly higher number of pods (73.15 to 75.28 /plant) over RGC-1017 and RGC-1055 varieties. Thus, the second best variety was RGC 1038 (71.28 to 73.62 pods/ plant). The significantly lowest pods (62.63 to 65.63/plant) were produced by RGC 1017 in both the years.

Amongst the fertility levels, 75% RDF with vermicompost (VC) performed the best and producing significantly higher number of pods (85.08 to 87.54 /plant) over the other fertility levels in both the years. However, the second best fertility level was 100% RDF and then 50% RDF + VC. The significantly lowest pod number (53.66 to 56.47/plant) was noted in control treatment.

Although the interactions were non-significant in both the years, the best treatment combination was HG-563 grown with 75% RDF + VC (92.23 to 94.83 pods/plant). On the other hand, the minimum pods (47.88 to 51.73/plant) were recorded in case of RGC 1017 grown with fertilizers in both the years.

### **4.5.2 Length of pod**

The data in Table 4.30 and illustrated through Fig. 4.16 reveal that the pod length was influenced significantly by varieties and fertility levels singly both years as well as in pooled data.

The maximum pod length (5.22 to 5.72 cm) was noted from variety HG 563, closely followed by RGC 1038 and then RGC 1055. Almost significantly lowest pod length (4.70 to 5.24 cm) was recorded in variety RGC 1017 in both the years.

**Table 4.30 Yield attributes of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                     | Number of pods/plant |             |              | Length of pod (cm) |             |             | Number of seeds/pod |             |             | 1000-seed weight (g) |             |              |
|----------------------------------------------------------------|----------------------|-------------|--------------|--------------------|-------------|-------------|---------------------|-------------|-------------|----------------------|-------------|--------------|
|                                                                | 2011-12              | 2012-13     | Mean         | 2011-12            | 2012-13     | Mean        | 2011-12             | 2012-13     | Mean        | 2011-12              | 2012-13     | Mean         |
| <b>Varities</b>                                                |                      |             |              |                    |             |             |                     |             |             |                      |             |              |
| RGC-1017                                                       | 62.63                | 65.63       | <b>64.13</b> | 4.70               | 5.24        | <b>4.97</b> | 7.61                | 7.68        | <b>7.65</b> | 30.26                | 30.63       | <b>30.45</b> |
| RGC-1038                                                       | 71.28                | 73.62       | <b>72.45</b> | 5.15               | 5.57        | <b>5.36</b> | 7.94                | 8.01        | <b>7.98</b> | 34.69                | 36.00       | <b>35.35</b> |
| RGC-1055                                                       | 67.21                | 69.57       | <b>68.39</b> | 4.85               | 5.41        | <b>5.13</b> | 7.78                | 7.85        | <b>7.82</b> | 33.18                | 34.00       | <b>33.59</b> |
| HG-563                                                         | 73.15                | 75.28       | <b>74.22</b> | 5.22               | 5.72        | <b>5.47</b> | 8.22                | 8.26        | <b>8.24</b> | 35.11                | 36.44       | <b>35.78</b> |
| <b>SE(m) ±</b>                                                 | <b>1.42</b>          | <b>1.44</b> | <b>1.01</b>  | <b>0.13</b>        | <b>0.17</b> | <b>0.11</b> | <b>0.04</b>         | <b>0.04</b> | <b>0.03</b> | <b>0.21</b>          | <b>0.24</b> | <b>0.16</b>  |
| <b>CD (P=0.05)</b>                                             | <b>4.06</b>          | <b>4.11</b> | <b>2.84</b>  | <b>0.37</b>        | <b>NS</b>   | <b>0.30</b> | <b>0.11</b>         | <b>0.10</b> | <b>0.07</b> | <b>0.61</b>          | <b>0.68</b> | <b>0.45</b>  |
| <b>Fertility level</b>                                         |                      |             |              |                    |             |             |                     |             |             |                      |             |              |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )        | 53.66                | 56.47       | <b>55.06</b> | 4.68               | 5.16        | <b>4.92</b> | 7.43                | 7.70        | <b>7.57</b> | 31.95                | 33.38       | <b>32.66</b> |
| 50% RDF +VC 5t/ha.                                             | 65.59                | 68.18       | <b>66.89</b> | 4.88               | 5.39        | <b>5.13</b> | 7.78                | 7.91        | <b>7.85</b> | 32.95                | 34.06       | <b>33.51</b> |
| 75% RDF +VC 5t/ha.                                             | 85.08                | 87.54       | <b>86.31</b> | 5.30               | 5.75        | <b>5.53</b> | 8.26                | 8.13        | <b>8.20</b> | 34.38                | 35.00       | <b>34.69</b> |
| 100% RDF<br>(N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 69.95                | 71.90       | <b>70.93</b> | 5.07               | 5.65        | <b>5.36</b> | 8.10                | 8.05        | <b>8.08</b> | 33.96                | 34.63       | <b>34.30</b> |
| <b>SE(m) ±</b>                                                 | <b>1.42</b>          | <b>1.44</b> | <b>1.01</b>  | <b>0.13</b>        | <b>0.17</b> | <b>0.11</b> | <b>0.04</b>         | <b>0.04</b> | <b>0.03</b> | <b>0.21</b>          | <b>0.24</b> | <b>0.16</b>  |
| <b>CD (P=0.05)</b>                                             | <b>4.06</b>          | <b>4.11</b> | <b>2.84</b>  | <b>0.37</b>        | <b>0.48</b> | <b>0.30</b> | <b>0.11</b>         | <b>0.10</b> | <b>0.07</b> | <b>0.61</b>          | <b>0.68</b> | <b>0.45</b>  |
| <b>Interaction</b>                                             | <b>NS</b>            | <b>NS</b>   | <b>NS</b>    | <b>NS</b>          | <b>NS</b>   | <b>NS</b>   | <b>0.21</b>         | <b>0.20</b> | <b>0.14</b> | <b>NS</b>            | <b>NS</b>   | <b>NS</b>    |

Fig. 4.15 Number of pods/ plant of Clusterbean as influenced by varieties and fertility levels.

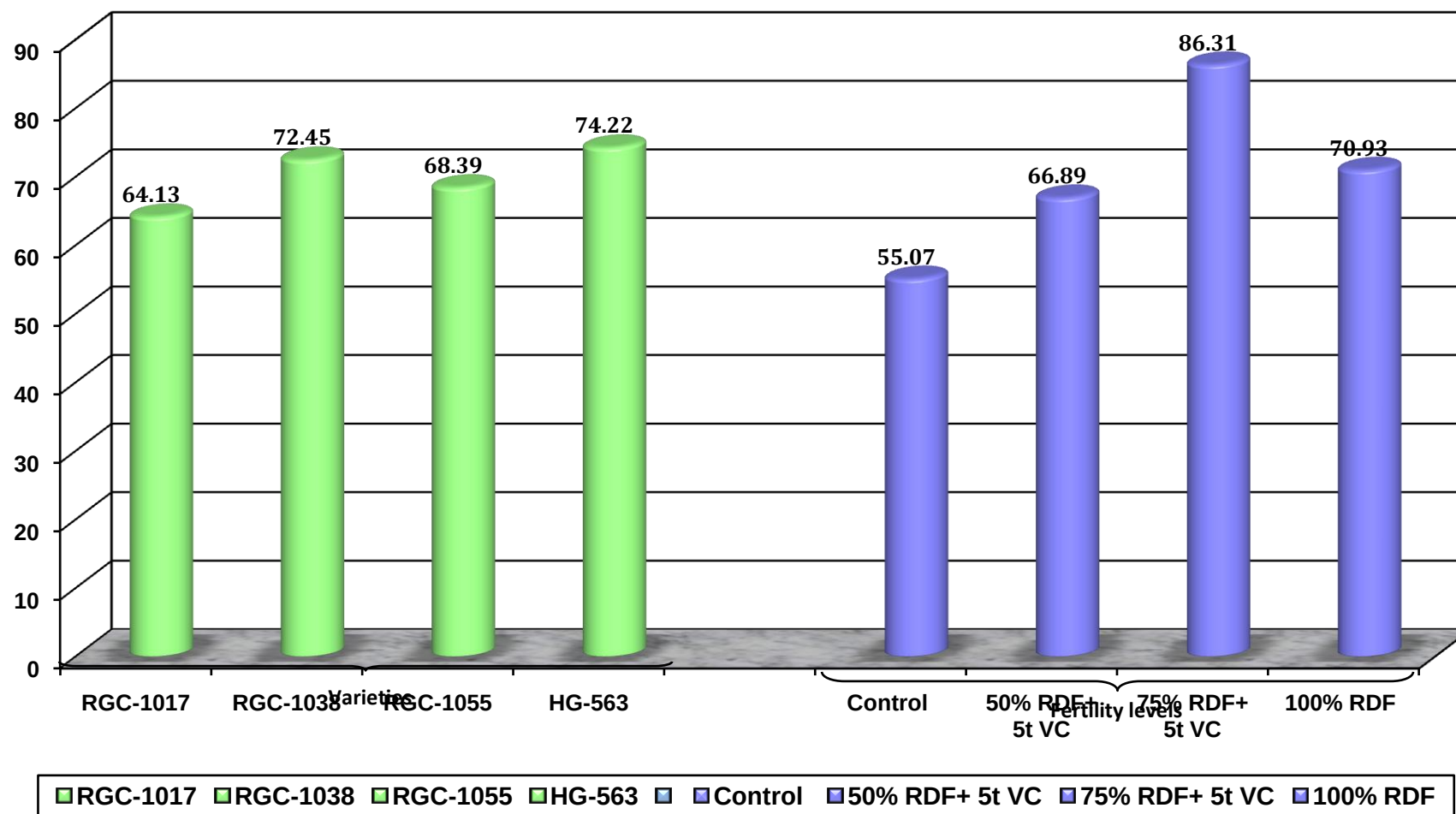


Fig. 4.16 Length of pods (cm) of clusterbean as influenced by varieties and fertility

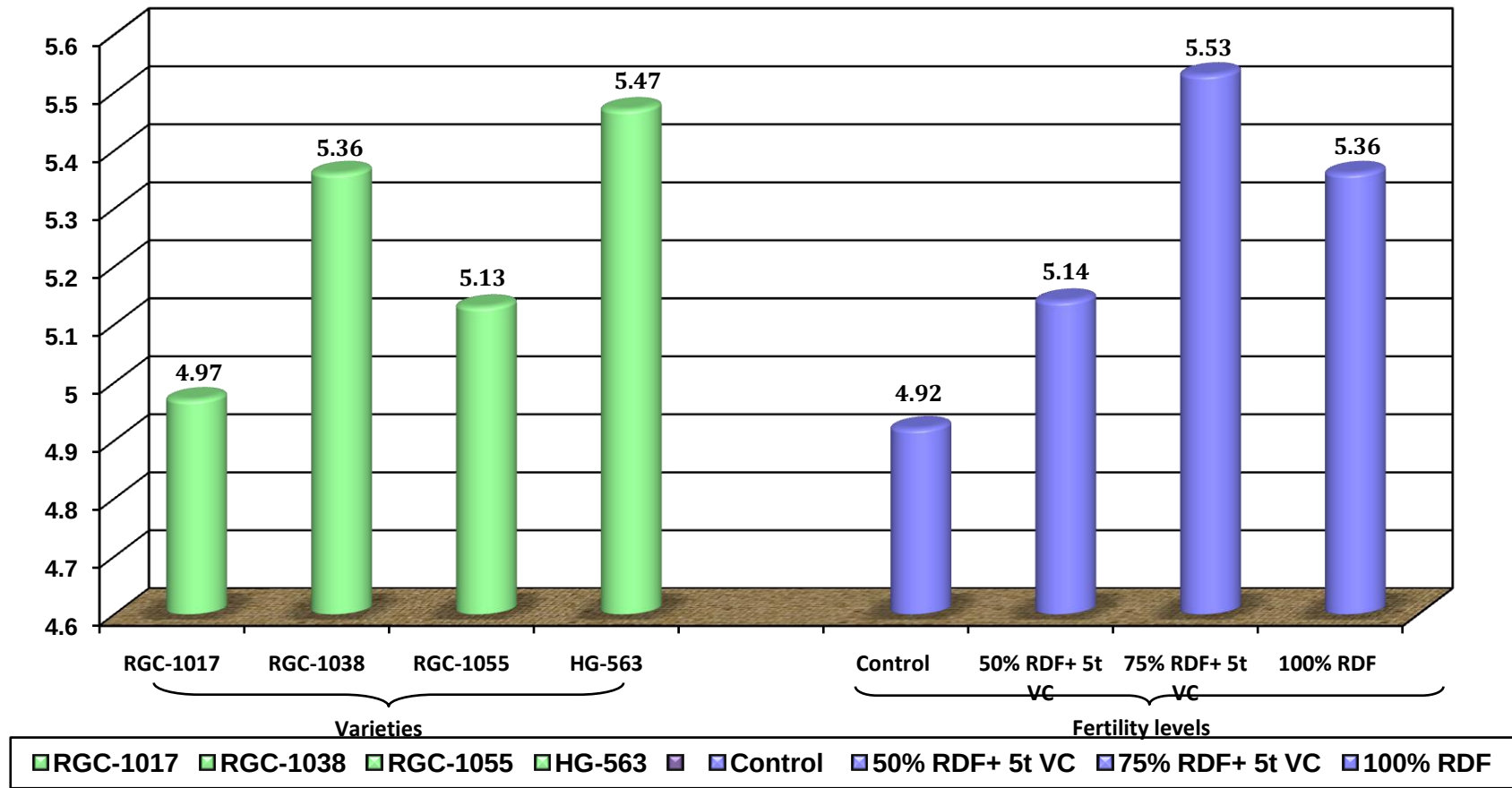


**Fig. 4.17 Number of seeds/pod of clusterbean as influenced by varieties and fertility levels.**

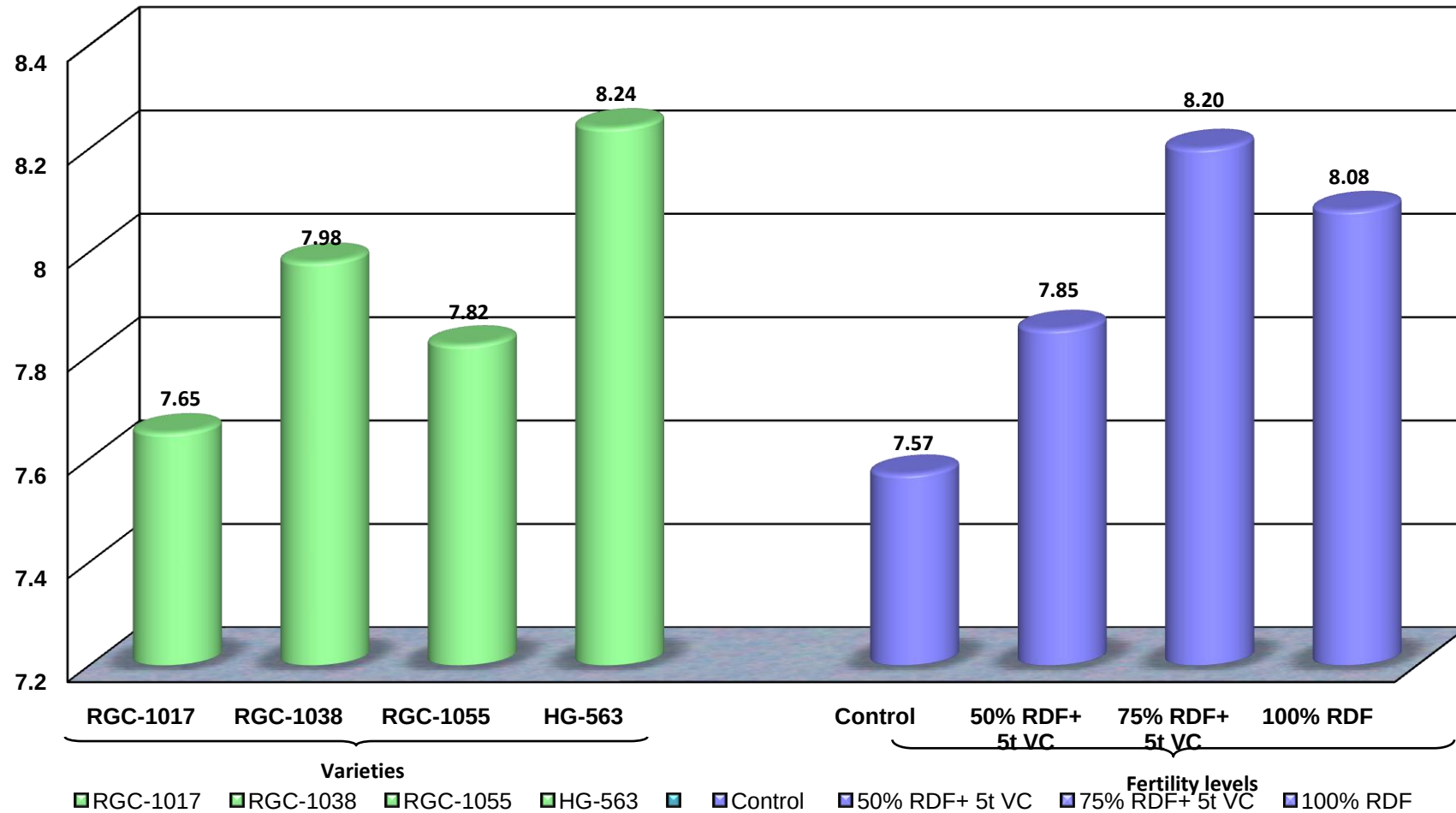
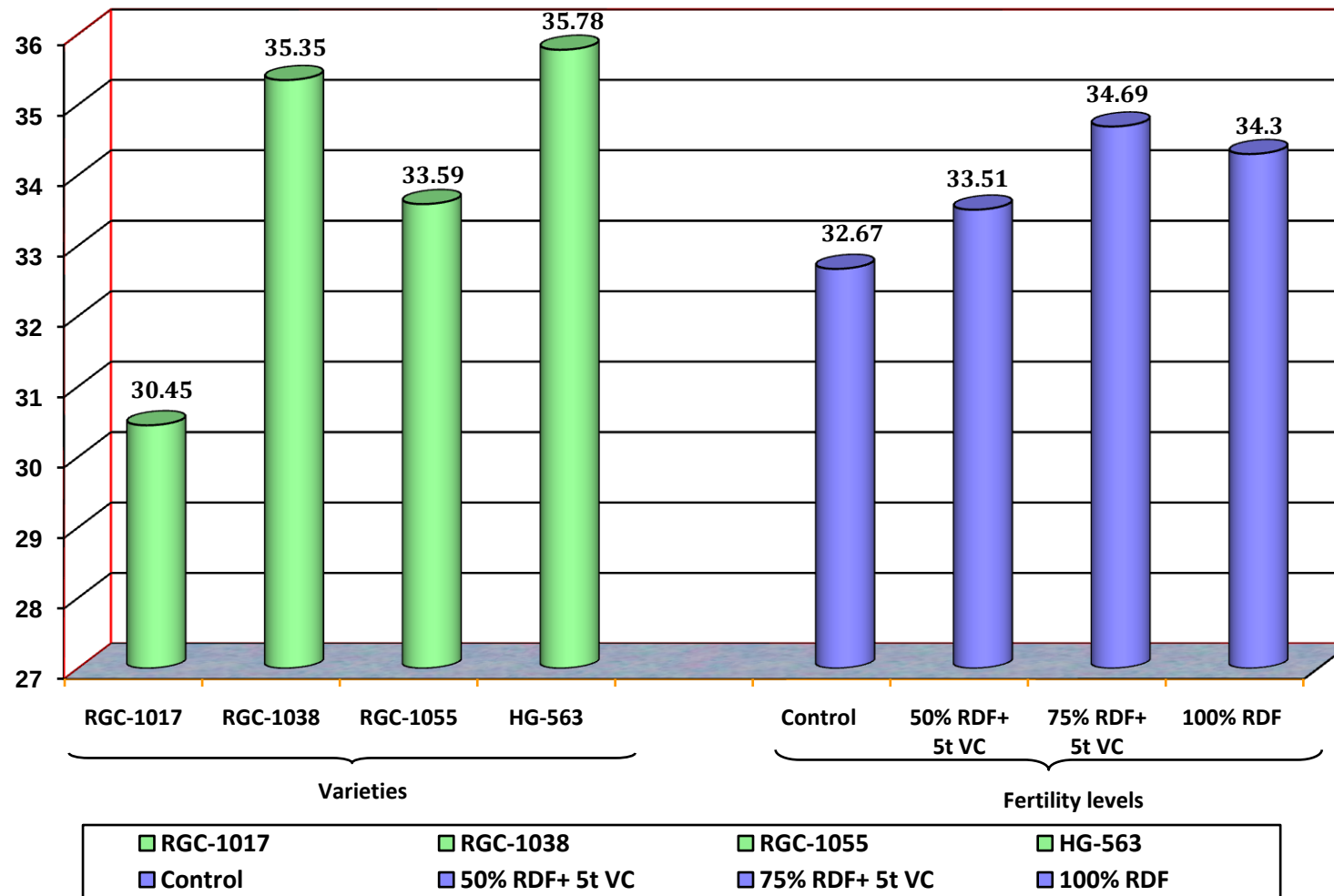


Fig. 4.18 1000-seed weight (g) of clusterbean as influenced by varieties and



The best fertility level was 75% RDF + VC which resulted in highest pod length (5.30 to 5.75 cm) closely followed by 100% RDF and then 50% RDF + VC. The lowest pod length (4.68 to 5.16 cm) was noted in case of control in both the years, 75% RDF + VC was significantly superior to only control which means all the three fertilizer applied treatments were equal in their influence for this parameter.

Both the experimental variables did not interact to each other in both years as well as in pooled analysis. However, HG 563 grown with 75% RDF + VC proved the best (5.50 to 5.98 cm) in both the years. The lowest values were obtained from RGC 1017 grown without fertilizers (4.30 to 5.12 cm).

#### 4.5.3 Number of seeds/ pod

The data pertaining to number of seeds/ pod are presented in Table 4.31 and depicted through Fig. 4.17. This parameter was influenced significantly due to varieties and fertility levels as well as their interactions in both the years.

Amongst the varieties, HG 563 resulted in significantly higher seeds count (8.22 to 8.26 /pod) as compared to the other varieties. However, the second best variety was RGC 1038 and then RGC 1055. The significantly lowest seeds number (7.61 to 7.68 /pod) was noted in variety RGC 1017 in both the years.

The best fertility level was 75% RDF + VC which recorded almost significantly higher number of seeds (8.13 to 8.26 /pod) over the other fertility levels. However, the second best fertility level was 100% RDF only (8.05 to 8.10 seeds/ pod), followed by 50% RDF + VC and the significantly lowest seeds number (7.43 to 7.70 /pod) was noted from the control treatment.

**Table 4.31 Interaction effect on number of seeds per pod of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                                    | Varieties  |          |          |        |             |
|-------------------------------------------------------------------------------------|------------|----------|----------|--------|-------------|
|                                                                                     | RGC-1017   | RGC-1038 | RGC-1055 | HG-563 | Mean        |
|                                                                                     | First Year |          |          |        |             |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 7.45       | 7.40     | 7.35     | 7.50   | <b>7.43</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 7.55       | 7.80     | 7.65     | 8.10   | <b>7.78</b> |

|                                                                                 |                  |                  |             |             |             |             |
|---------------------------------------------------------------------------------|------------------|------------------|-------------|-------------|-------------|-------------|
| 75%<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | RDF              | 7.70             | 8.30        | 8.12        | 8.90        | <b>8.26</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                         |                  | 7.75             | 8.25        | 8.02        | 8.37        | <b>8.10</b> |
| <b>Mean</b>                                                                     |                  | <b>7.61</b>      | <b>7.94</b> | <b>7.78</b> | <b>8.22</b> |             |
| <b>Second Year</b>                                                              |                  |                  |             |             |             |             |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                            |                  | 7.60             | 7.60        | 7.60        | 7.99        | <b>7.70</b> |
| 50%<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | RDF              | 7.65             | 8.05        | 7.75        | 8.20        | <b>7.91</b> |
| 75%<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | RDF              | 7.75             | 8.25        | 8.10        | 8.43        | <b>8.13</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                         |                  | 7.70             | 8.15        | 7.95        | 8.40        | <b>8.05</b> |
| <b>Mean</b>                                                                     |                  | <b>7.68</b>      | <b>8.01</b> | <b>7.85</b> | <b>8.26</b> |             |
| <b>Pooled</b>                                                                   |                  |                  |             |             |             |             |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                            |                  | 7.53             | 7.50        | 7.48        | 7.75        | <b>7.57</b> |
| 50%<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | RDF              | 7.60             | 7.93        | 7.70        | 8.15        | <b>7.85</b> |
| 75%<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | RDF              | 7.73             | 8.28        | 8.11        | 8.67        | <b>8.20</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                         |                  | 7.73             | 8.20        | 7.98        | 8.39        | <b>8.08</b> |
| <b>Mean</b>                                                                     |                  | <b>7.65</b>      | <b>7.98</b> | <b>7.82</b> | <b>8.24</b> |             |
|                                                                                 |                  |                  |             |             |             |             |
|                                                                                 | <b>Varieties</b> | <b>Fertility</b> | <b>V×F</b>  |             |             |             |
| <b>First year SE(m)±</b>                                                        | 0.037            | 0.037            | 0.075       |             |             |             |
| <b>C D (P=0.05)</b>                                                             | 0.107            | 0.107            | 0.213       |             |             |             |
|                                                                                 |                  |                  |             |             |             |             |
| <b>Second year SE(m)±</b>                                                       | 0.035            | 0.035            | 0.069       |             |             |             |
| <b>C D (P=0.05)</b>                                                             | 0.099            | 0.099            | 0.198       |             |             |             |
|                                                                                 |                  |                  |             |             |             |             |
| <b>Pooled SE(m)±</b>                                                            | 0.025            | 0.025            | 0.051       |             |             |             |
| <b>C D (P=0.05)</b>                                                             | 0.071            | 0.071            | 0.143       |             |             |             |

Among the treatment combinations, HG 563 grown with 75% RDF + VC brought about significantly higher value (8.90 seeds / pod) over all other treatment combination in first year. However in the second year, HG 563 grown with 75% RDF + VC or 100% RDF only recorded equal number of seeds (8.40 to 8.43 / pod). On the other hand, all the varieties grown without fertilizers recorded almost significantly lowest number of seeds formation per pod in both the years.

#### 4.5.4 Test weight of 1000-seeds

The test weight of 1000-seeds was recorded treatment wise and the data after statistical analysis are presented in Table 4.30 and illustrated diagrammatically through Fig. 4.18. The perusal of data indicate that this yield attributing parameter was influenced significantly due to varieties and fertility levels but not due to their interactions in both the years.

Among the varieties, HG 563 and RGC 1038 resulted in equally higher test weight (34.69 to 35.11g in first year and 36.0 to 36.44 g in second year), being significantly superior to RGC 1038 and RGC 1017 varieties. The significantly lowest test weight (30.26 to 30.63 g) was obtained from RGC 1017 variety in both the years.

Amongst the fertility levels, 75% RDF + VC and 100% RDF brought about equally higher test weight (33.96 to 34.38 g in first year and 34.63 to 35.0 g in second year), being significantly superior to the remaining fertility levels. The significantly lowest test weight (31.95 to 33.38 g) was noted from the control treatment in both the years.

The treatment interactions, although non-significant in both the years, the maximum test weight was recorded when HG 563 was grown with each of the fertility levels. On the other hand, the minimum test weight was noted when RGC 1017 was grown with each of the fertility levels.

#### **4.5.5 Seed yield per plant**

The seed yield per plant was recorded in each treatment and the values after statistical analysis are highlighted in Table 4.33 and illustrated through Fig. 4.19. The different varieties and fertility levels were found to exert significant impact upon this parameter, however the treatment interactions brought about non-significant influence in both the years.

**Table 4.32 Yield attributes of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                  | Seed yield/plant (g) |             |              | Stover yield/plant (g) |             |              |
|-------------------------------------------------------------|----------------------|-------------|--------------|------------------------|-------------|--------------|
|                                                             | 2011-12              | 2012-13     | Mean         | 2011-12                | 2012-13     | Mean         |
| <b><i>Varities</i></b>                                      |                      |             |              |                        |             |              |
| RGC-1017                                                    | 9.07                 | 8.73        | <b>8.90</b>  | 19.91                  | 19.60       | <b>19.76</b> |
| RGC-1038                                                    | 9.74                 | 9.35        | <b>9.55</b>  | 20.63                  | 19.06       | <b>19.85</b> |
| RGC-1055                                                    | 9.51                 | 8.87        | <b>9.19</b>  | 21.10                  | 19.00       | <b>20.05</b> |
| HG-563                                                      | 10.42                | 10.21       | <b>10.32</b> | 23.67                  | 22.63       | <b>23.15</b> |
| <b>SE(m) ±</b>                                              | <b>0.08</b>          | <b>0.10</b> | <b>0.06</b>  | <b>0.16</b>            | <b>0.16</b> | <b>0.11</b>  |
| <b>CD (P=0.05)</b>                                          | <b>0.22</b>          | <b>0.28</b> | <b>0.17</b>  | <b>0.45</b>            | <b>0.46</b> | <b>0.32</b>  |
| <b><i>Fertility level</i></b>                               |                      |             |              |                        |             |              |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )     | 9.02                 | 8.58        | <b>8.80</b>  | 21.44                  | 20.17       | <b>20.81</b> |
| 50% RDF +VC 5t/ha.                                          | 9.69                 | 9.32        | <b>9.51</b>  | 22.05                  | 20.20       | <b>21.13</b> |
| 75% RDF +VC 5t/ha.                                          | 10.04                | 9.79        | <b>9.92</b>  | 20.62                  | 19.81       | <b>20.22</b> |
| 100% RDF (N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 9.98                 | 9.46        | <b>9.72</b>  | 21.22                  | 20.10       | <b>20.66</b> |
| <b>SE(m) ±</b>                                              | <b>0.08</b>          | <b>0.10</b> | <b>0.06</b>  | <b>0.16</b>            | <b>0.16</b> | <b>0.11</b>  |
| <b>CD (P=0.05)</b>                                          | <b>0.22</b>          | <b>0.28</b> | <b>0.17</b>  | <b>0.45</b>            | <b>NS</b>   | <b>0.32</b>  |
| <b>Interaction</b>                                          | <b>NS</b>            | <b>NS</b>   | <b>0.35</b>  | <b>0.91</b>            | <b>0.92</b> | <b>0.63</b>  |

**Fig. 4.19 Seed & Straw yield/plant (g) of Clusterbean as influenced by varieties and fertility**

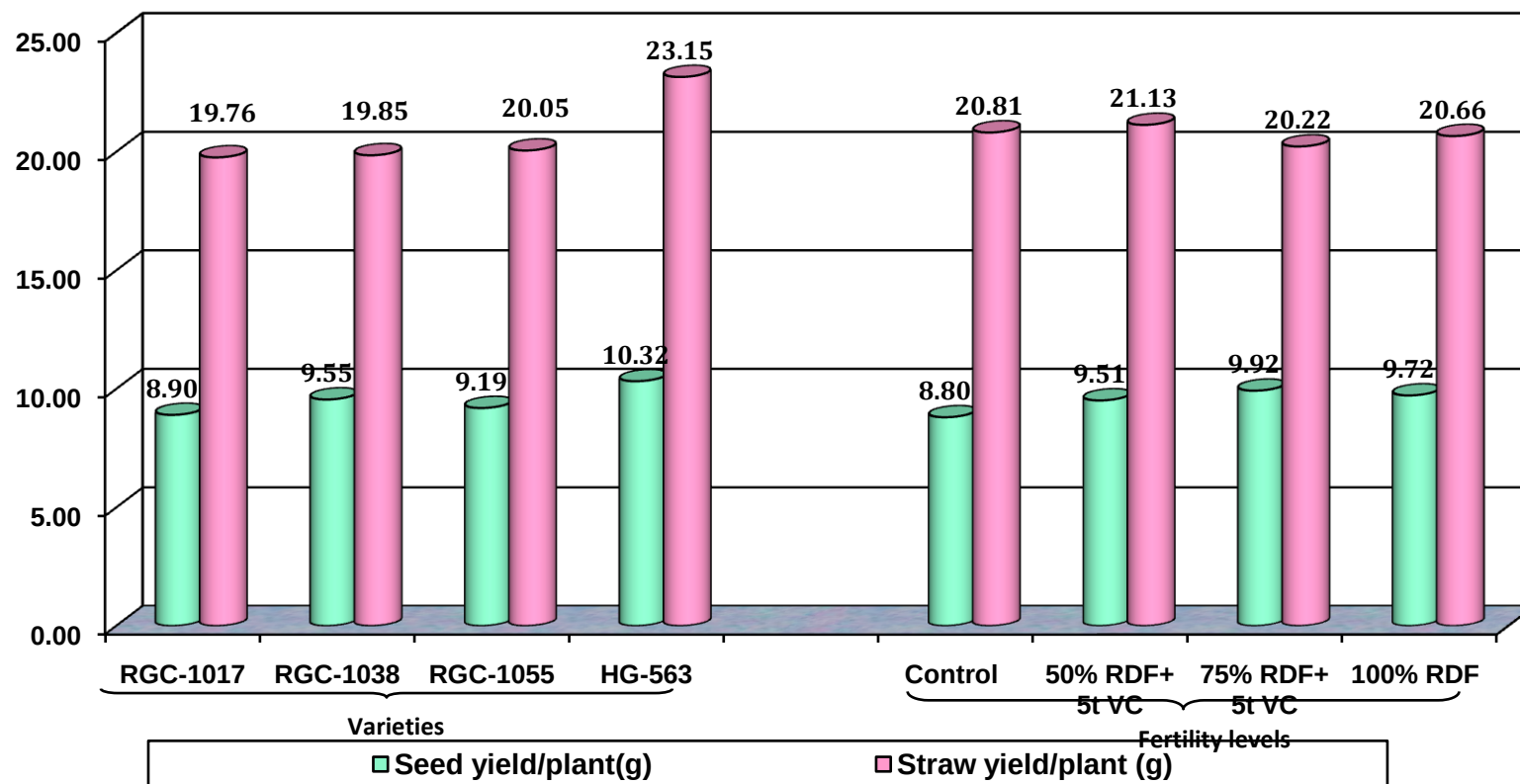


**Table 4.33 Interaction effect on seed yield per plant (g) of clusterbean as influenced by varieties and fertility levels pooled of two years data.**

| Fertility levels                                                               | Varieties    |             |             |              |             |
|--------------------------------------------------------------------------------|--------------|-------------|-------------|--------------|-------------|
|                                                                                | RGC-1017     | RGC-1038    | RGC-1055    | HG-563       | Mean        |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                           | 8.55         | 8.64        | 8.35        | 9.67         | <b>8.80</b> |
| 50% RDF N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost 5 t/ha.  | 8.78         | 9.80        | 9.18        | 10.27        | <b>9.51</b> |
| 75% RDF N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> + Vermicompost 5 t/ha. | 9.18         | 10.10       | 9.70        | 10.70        | <b>9.92</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                        | 9.09         | 9.65        | 9.53        | 10.63        | <b>9.72</b> |
| <b>Mean</b>                                                                    | <b>8.90</b>  | <b>9.55</b> | <b>9.19</b> | <b>10.31</b> |             |
| <b>C.D. for Varieties</b>                                                      | <b>0.173</b> |             |             |              |             |
| <b>C.D. for Fertility</b>                                                      | <b>0.173</b> |             |             |              |             |
| <b>C.D. for Interaction</b>                                                    | <b>0.346</b> |             |             |              |             |

The variety HG 563 resulted in significantly higher seed yield (10.21 to 10.42 g /plant) over all other varieties in both the years. However, the second best variety was RGC 1038 and then RGC 1055. Almost significantly lowest seed yield (8.73 to 9.07 g/plant) was obtained from RGC 1017.

The best fertility level was 75% RDF+VC which resulted in maximum seed yield (9.79 to 10.04 g/plant) in both the years. The second best fertility was 100% RDF (9.46 to 9.98 g/plant). However in first year, both the treatments brought about similar influence upon this parameter. Both these treatments were found significantly superior to control and 50% RDF + VC fertility levels in both the years. Control treatments gave the lowest seed yield/plant.

The interaction effect of varieties and fertility levels, although non-significant in both the years, but HG 563 grown with 75% RDF + VC resulted in maximum seed yield/plant, followed by HG 563 grown with 100% RDF alone. The lowest seed yield/plant was noted in case of RGC 1055 grown without fertilizer application.

#### 4.5.6 Stover yield/ plant

The stover yield per plant was noted in each treatment and the data so obtained were statistically analyzed. The data in Table 4.34 reveal that the various treatments as well as treatment interactions exerted significant influence upon this parameter in both the years except fertility levels in second year.

Variety 'HG-563' produced significantly highest stover yield (22.63 to 23.67g/ plant) as compared to remaining varieties in both the years. The significantly lowest stover yield (19.91 g /plant) was noted in RGC 1017 in first year, but in second year, significantly lowest stover yields (19.0 to 19.06 g/plant) were obtained from RGC 1038 and RGC 1055 varieties.

Application of 5 t/ha VC along with 50% RDF recorded significantly higher stover yield (22.05 g /plant) over the remaining fertility levels in first year, however, in the second year, all the four fertility levels resulted in equal production of stover (19.81 to 20.20 g/plant).

Interaction effect of varieties and fertility levels was found significant. Amongst the treatment interactions, HG 563 performed the best under each fertility level in both the years. Accordingly in first year, the stover yields from HG 563 were the same (23.43 to 23.97 g/plant) under each fertility level in first year, whereas in second year, the stover yields were the same (22.70 to 23.28 g/plant) in all the fertility levels except in case of 75% RDF + VC (21.34 g/plant). On the other hand, the minimum stover yield (18.60 g/plant) was secured with RGC 1017 grown with 75% RDF + VC in first year, whereas in second year, RGC 1038 grown with 100% RDF recorded the lowest stover yield (18.30 g/plant). This was followed by RGC 1038 grown with 50% RDF + VC (18.48 g / plant)

**Table 4.34 Interaction effect on stover yield per plant (g) of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                                    | Varieties  |           |          |        |       |
|-------------------------------------------------------------------------------------|------------|-----------|----------|--------|-------|
|                                                                                     | RGC-1017   | RGC-1038  | RGC-1055 | HG-563 | Mean  |
|                                                                                     | First Year |           |          |        |       |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 21.00      | 20.19     | 20.86    | 23.69  | 21.44 |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 20.58      | 21.56     | 22.08    | 23.97  | 22.05 |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 18.60      | 20.48     | 19.80    | 23.58  | 20.62 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 19.48      | 20.30     | 21.67    | 23.43  | 21.22 |
| Mean                                                                                | 19.91      | 20.63     | 21.10    | 23.67  |       |
| Second Year                                                                         |            |           |          |        |       |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 20.04      | 19.55     | 18.40    | 22.70  | 20.17 |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 19.78      | 18.48     | 19.27    | 23.28  | 20.20 |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 19.00      | 19.90     | 19.00    | 21.34  | 19.81 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 19.58      | 18.30     | 19.32    | 23.21  | 20.10 |
| Mean                                                                                | 19.60      | 19.06     | 19.00    | 22.63  |       |
| Pooled                                                                              |            |           |          |        |       |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 20.52      | 19.87     | 19.63    | 23.20  | 20.80 |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 20.18      | 20.02     | 20.68    | 23.63  | 21.13 |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 18.80      | 20.19     | 19.40    | 22.46  | 20.21 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 19.53      | 19.30     | 20.50    | 23.32  | 20.66 |
| Mean                                                                                | 19.76      | 19.85     | 20.05    | 23.15  |       |
|                                                                                     |            |           |          |        |       |
|                                                                                     | Varieties  | Fertility | V×F      |        |       |
| First year SE(m)±                                                                   | 0.159      | 0.159     | 0.317    |        |       |
| C D (P=0.05)                                                                        | 0.453      | 0.453     | 0.905    |        |       |
|                                                                                     |            |           |          |        |       |
| Second year SE(m)±                                                                  | 0.161      | 0.161     | 0.321    |        |       |
| C D (P=0.05)                                                                        | 0.458      | NS        | 0.917    |        |       |
|                                                                                     |            |           |          |        |       |
| Pooled SE(m)±                                                                       | 0.113      | 0.113     | 0.226    |        |       |
| C D (P=0.05)                                                                        | 0.316      | 0.316     | 0.632    |        |       |

#### **4.5.7 Yield attributes at a glance**

All the yield attributes (mean of two years) summarized in Table 4.30 and 4.34 indicate that HG 563 recorded highest pods (74.21 /plant), pod length (5.47 cm), seeds/pod (8.24), 1000-seed weight (35.77g), seed yield (10.31 g/plant) and stover yield (23.15 g/plant). This was followed by RGC 1038 and the lowest values were recorded in case of RGC-1017 variety. Similarly amongst the fertility levels, 75% RDF (N<sub>15</sub>P<sub>30</sub>K<sub>15</sub>) + VC resulted in maximum yield attributes of clusterbean, closely followed by 100% RDF (N<sub>20</sub>P<sub>40</sub>K<sub>20</sub>). The significantly lowest yield attributes were noted in case of N<sub>0</sub> P<sub>0</sub>K<sub>0</sub> (control).

### **4.6 Productivity parameters**

#### **4.6.1 Seed Yield**

The seed yield was deviated significantly due to varieties and fertility levels but not due to their interactions in both the years (Table 4.35 and 4.36). The results are shown through Fig. 4.20. Among the varieties, HG 563 yielded significantly higher (1944.63 kg/ha) over the other varieties. This was equally followed by RGC 1038 and RGC 1055 (1757.63 to 1720.75 kg/ha). The significantly lowest seed yield (1302.06 kg/ha) was secured from RGC 1017 variety of clusterbean-based on two years mean values.

The best fertility level was 75% RDF + VC which yield up to 1952.06 kg/ha, being significantly superior to the remaining fertility levels. However, the second best fertility level was 100% RDF (N<sub>20</sub>P<sub>40</sub>K<sub>20</sub>) producing 1771.50 kg seed/ha. This was significantly higher to 50% RDF + VC and control treatments. The significantly lowest seed yield (1440.63 kg/ha) was recorded from N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> treatment.

**Table 4.35 Yield attributes of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                     | Seed yield (kg/ha.) |              |                | Stover yield (kg/ha.) |               |                | Harvest index |             |              |
|----------------------------------------------------------------|---------------------|--------------|----------------|-----------------------|---------------|----------------|---------------|-------------|--------------|
|                                                                | 2011-12             | 2012-13      | Mean           | 2011-12               | 2012-13       | Mean           | 2011-12       | 2012-13     | Mean         |
| <b><i>Varieties</i></b>                                        |                     |              |                |                       |               |                |               |             |              |
| RGC-1017                                                       | 1167.50             | 1436.63      | <b>1302.06</b> | 2609.88               | 3123.25       | <b>2866.56</b> | 30.81         | 31.33       | <b>31.07</b> |
| RGC-1038                                                       | 1664.75             | 1850.50      | <b>1757.63</b> | 3623.25               | 4046.75       | <b>3835.00</b> | 32.01         | 30.87       | <b>31.44</b> |
| RGC-1055                                                       | 1582.50             | 1859.00      | <b>1720.75</b> | 3598.50               | 4065.50       | <b>3832.00</b> | 30.50         | 31.32       | <b>30.91</b> |
| HG-563                                                         | 1817.88             | 2071.38      | <b>1944.63</b> | 3973.25               | 4639.75       | <b>4306.50</b> | 31.27         | 30.81       | <b>31.04</b> |
| <b>SE (m) ±</b>                                                | <b>23.65</b>        | <b>22.05</b> | <b>16.32</b>   | <b>40.41</b>          | <b>42.21</b>  | <b>29.22</b>   | <b>0.69</b>   | <b>0.12</b> | <b>0.35</b>  |
| <b>CD (P=0.05)</b>                                             | 67.50               | 64.23        | <b>45.71</b>   | 115.31                | 120.47        | <b>81.81</b>   | <b>NS</b>     | <b>0.34</b> | <b>NS</b>    |
| <b><i>Fertility level</i></b>                                  |                     |              |                |                       |               |                |               |             |              |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )        | 1309.00             | 1572.25      | <b>1440.63</b> | 3201.50               | 3771.00       | <b>3486.25</b> | 29.08         | 29.42       | <b>29.25</b> |
| 50% RDF +VC 5t/ha.                                             | 1435.00             | 1686.75      | <b>1560.88</b> | 3299.88               | 3879.50       | <b>3589.69</b> | 30.33         | 30.30       | <b>30.31</b> |
| 75% RDF +VC 5t/ha.                                             | 1848.38             | 2055.75      | <b>1952.06</b> | 3911.25               | 4222.00       | <b>4066.63</b> | 32.02         | 32.33       | <b>32.18</b> |
| 100% RDF<br>(N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 1640.25             | 1902.75      | <b>1771.50</b> | 3392.25               | 4002.75       | <b>3697.50</b> | 33.15         | 32.27       | <b>32.71</b> |
| <b>SE (m) ±</b>                                                | <b>23.65</b>        | <b>22.05</b> | <b>16.32</b>   | <b>40.41</b>          | <b>42.21</b>  | <b>29.22</b>   | <b>0.69</b>   | <b>0.12</b> | <b>0.35</b>  |
| <b>CD (P=0.05)</b>                                             | 67.50               | 64.23        | <b>45.71</b>   | 115.31                | 120.47        | <b>81.81</b>   | <b>1.95</b>   | <b>0.34</b> | <b>0.97</b>  |
| <b>Interaction</b>                                             | <b>NS</b>           | <b>NS</b>    | <b>91.42</b>   | <b>230.62</b>         | <b>240.92</b> | <b>163.62</b>  | <b>NS</b>     | <b>0.69</b> | <b>NS</b>    |

**Fig. 4.20 Seed and straw yield (kg/ha) of Clusterbean as influenced by varieties and fertility levels.**

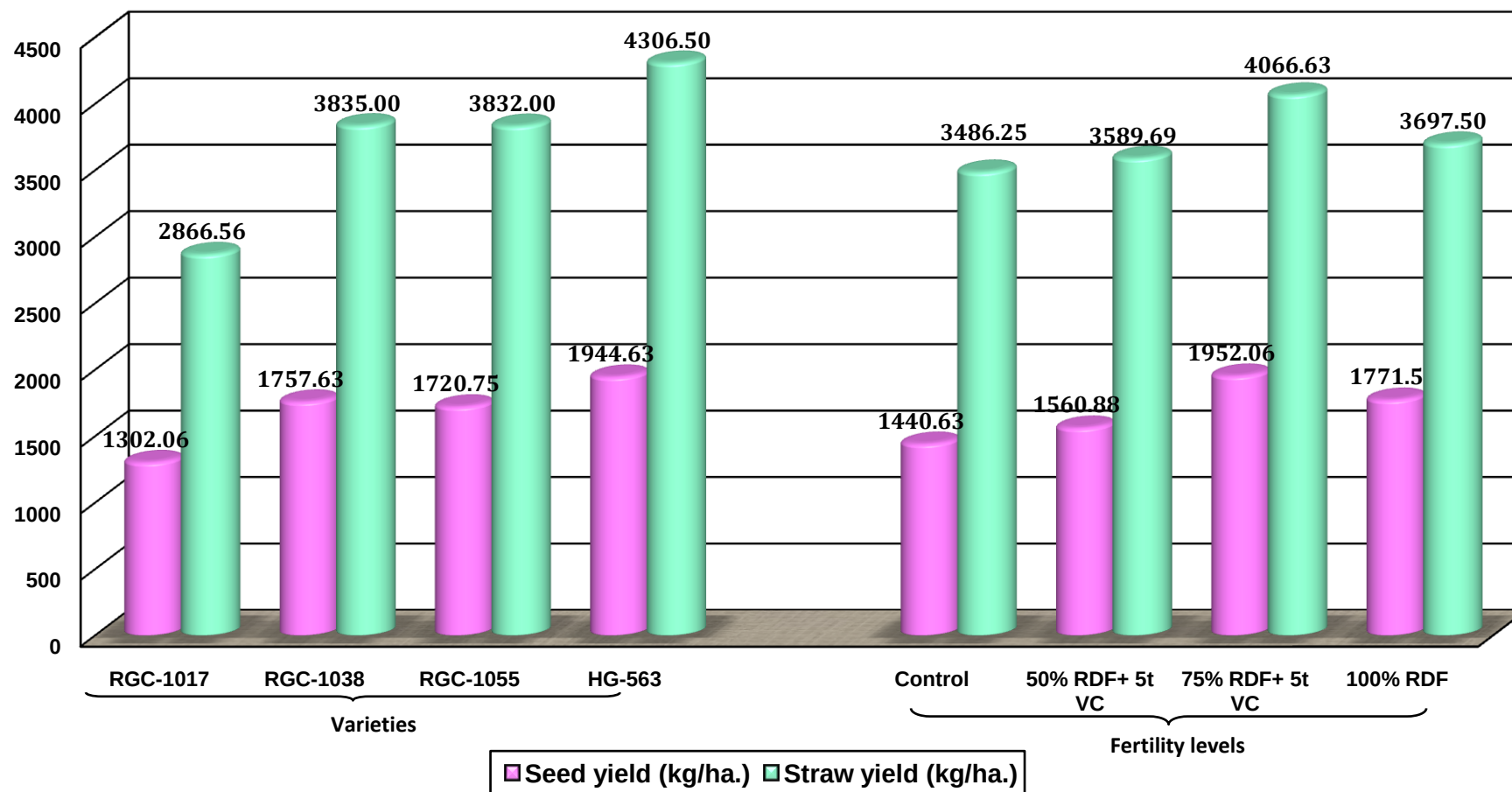


Fig. 4.21 Harvest index(%) of Clusterbean as influenced by varieties and fertility levels.

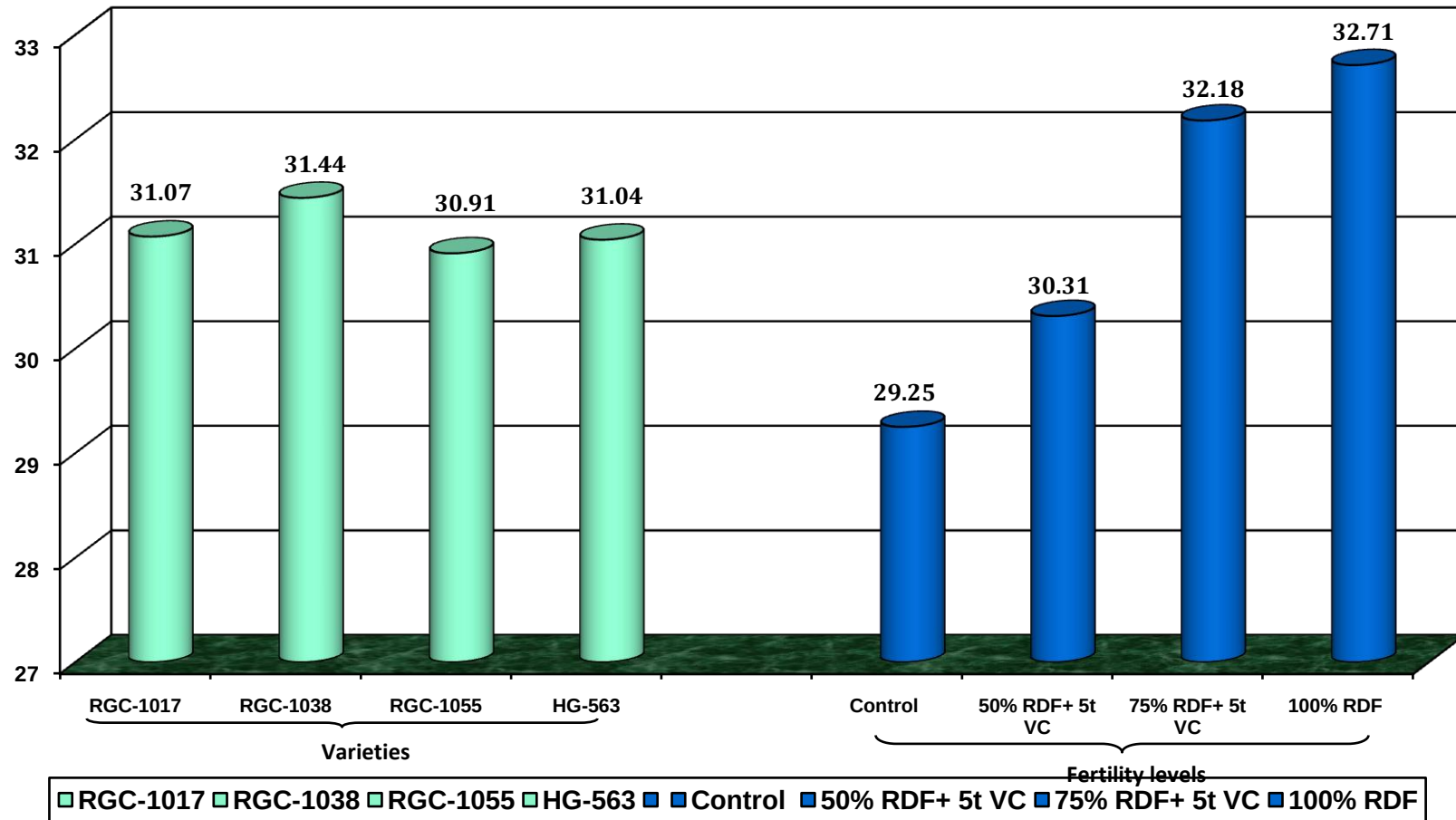


**Table 4.36 Interaction effect on seed yield (kg/ha.) of clusterbean as influenced by varieties and fertility levels pooled of two years data.**

| Fertility levels                                                                    | Varieties      |                |                |                |                |
|-------------------------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|
|                                                                                     | RGC-1017       | RGC-1038       | RGC-1055       | HG-563         | Mean           |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 1052.50        | 1550.50        | 1484.00        | 1675.50        | <b>1440.63</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 1121.00        | 1636.50        | 1676.00        | 1810.00        | <b>1560.88</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 1659.75        | 2001.50        | 1914.50        | 2232.50        | <b>1952.06</b> |
| 100% RDF N <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                            | 1375.00        | 1842.00        | 1808.50        | 2060.50        | <b>1771.50</b> |
| <b>Mean</b>                                                                         | <b>1302.06</b> | <b>1757.63</b> | <b>1720.75</b> | <b>1944.63</b> |                |
| <b>C.D. for Varieties</b>                                                           | <b>45.713</b>  |                |                |                |                |
| <b>C.D. for Fertility</b>                                                           | <b>45.713</b>  |                |                |                |                |
| <b>C.D. for Interaction</b>                                                         | <b>91.425</b>  |                |                |                |                |

Although the treatment interactions were non-significant, HG 563 grown with 75% RDF + VC recorded maximum seed yield (2232.50 kg/ha), followed by HG 563 grown with 100% RDF (2060.50 kg/ha). On the other hand, nearly half seed yield (1052.50 kg/ha) was obtained from variety RGC 1017 grown without NPK fertilizers, All these data are based on the years pooled data.

#### **4.6.2 Stover yield**

The stover yield of clusterbean was influenced significantly due to varieties and fertility levels as well as their interactions in both the years (Table 4.35 and 4.37). The results are exhibited through Fig. 4.20. Amongst the varieties, HG 563 produced significantly higher stover yield (4306.50 kg/ha) over rest of the varieties. However, this was equally followed by RGC-1038 and RGC 1055 (3835.00 to 3832.00 kg/ha). The significantly lowest stover yield (2866.56 kg/ha) was obtained from RGC 1017 variety based on the pooled data.

**Table 4.37 Interaction effect on stover yield (kg/ha.) of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                                    | Varieties  |           |          |         |         |
|-------------------------------------------------------------------------------------|------------|-----------|----------|---------|---------|
|                                                                                     | RGC-1017   | RGC-1038  | RGC-1055 | HG-563  | Mean    |
|                                                                                     | First Year |           |          |         |         |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 2239.00    | 3432.00   | 3271.00  | 3864.00 | 3201.50 |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 2287.50    | 3346.00   | 3691.00  | 3875.00 | 3299.88 |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 3414.00    | 4011.00   | 3916.00  | 4304.00 | 3911.25 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 2499.00    | 3704.00   | 3516.00  | 3850.00 | 3392.25 |
| Mean                                                                                | 2609.88    | 3623.25   | 3598.50  | 3973.25 |         |
| Second Year                                                                         |            |           |          |         |         |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 2813.00    | 4001.00   | 3852.00  | 4418.00 | 3771.00 |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 2868.00    | 3951.00   | 4248.00  | 4451.00 | 3879.50 |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 3536.00    | 4395.00   | 4098.00  | 4859.00 | 4222.00 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 3276.00    | 3840.00   | 4064.00  | 4831.00 | 4002.75 |
| Mean                                                                                | 3123.25    | 4046.75   | 4065.50  | 4639.75 |         |
| Pooled                                                                              |            |           |          |         |         |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 2526.00    | 3716.50   | 3561.50  | 4141.00 | 3486.25 |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 2577.75    | 3648.50   | 3969.50  | 4163.00 | 3589.69 |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 3475.00    | 4203.00   | 4007.00  | 4581.50 | 4066.63 |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 2887.50    | 3772.00   | 3790.00  | 4340.50 | 3697.50 |
| Mean                                                                                | 2866.56    | 3835.00   | 3832.00  | 4306.50 |         |
|                                                                                     |            |           |          |         |         |
|                                                                                     | Varieties  | Fertility | V×F      |         |         |
| First year SE(m)±                                                                   | 40.406     | 40.406    | 80.812   |         |         |
| C D (P=0.05)                                                                        | 115.314    | 115.314   | 230.628  |         |         |
|                                                                                     |            |           |          |         |         |
| Second year SE(m)±                                                                  | 42.212     | 42.212    | 84.425   |         |         |
| C D (P=0.05)                                                                        | 120.470    | 120.470   | 240.939  |         |         |
|                                                                                     |            |           |          |         |         |
| Pooled SE(m)±                                                                       | 29.217     | 29.217    | 58.434   |         |         |
| C D (P=0.05)                                                                        | 81.812     | 81.812    | 163.624  |         |         |

Application of 75% RDF + VC resulted in significantly higher stover yield (4066.63 kg/ha) over all the remaining fertility levels. However, the second best fertility level was 100% RDF (3697.50 kg/ha) and then 50% RDF + VC (3589.69 kg/ha stover). The significantly lowest stover yield (3486.25 kg/ha) was noted from  $N_0P_0K_0$ .

Amongst the treatment combinations, HG 563 grown with 75% RDF + VC resulted in significantly higher stover yield (4581.50 kg/ha) over all the remaining interactions (Table 4.37). However, the second best interaction was HG 563 grown with 100% RDF (4340.50 kg/ha). This was significantly superior to almost all the other interactions. The significantly lowest yields (2526.00 to 2577.75 kg/ha) were recorded in case of RGC-1017 grown without fertilizers or with 50% RDF + VC. All these data are based on the pooled analysis for two years.

#### **4.6.3 Harvest index**

The harvest index of clusterbean was found to deviate upto significant extent due to fertility level in second year; variety and fertility level and their interaction in second year and due to only fertility level in pooled analysis (Table 4.35). The results are also illustrated through Fig. 4.21 Based on pooled analysis; the harvest index was identical in all the varieties under study (30.91 to 31.44%).

Amongst the fertility levels, 75% RDF + VC and 100% RDF recorded equally higher harvest index (32.18 to 32.71 %), being significantly superior to the remaining fertility levels. The significantly lowest harvest index (29.25%) was recorded from  $N_0P_0K_0$  treatment.

On pooled basis, the treatment interactions were found to be non-significant (Table 4.35). However, RGC 1038 grown with 100% RDF recorded maximum harvest index (33.99%), followed by HG 563 grown with 75% RDF + VC (32.80%). The general trend was that when all the varieties grown with higher fertility levels recorded higher harvest index as compared to those when grown with lower fertility levels.



**Plate: 4.1. Experimental Field at Early Stage of Variety HG- 563**



**Plate: 4.2. Experimental Field at Maturity Stage of Variety HG- 563**

**Table 4.38 Interaction effect on harvest index of clusterbean as influenced by varieties and fertility levels in the year 2012.**

| Fertility levels                                                                    | Varieties    |              |              |              |              |
|-------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|
|                                                                                     | RGC-1017     | RGC-1038     | RGC-1055     | HG-563       | Mean         |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 29.41        | 29.46        | 29.41        | 29.41        | <b>29.42</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 30.30        | 30.30        | 30.30        | 30.30        | <b>30.30</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 33.33        | 30.39        | 33.33        | 32.26        | <b>32.33</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 32.26        | 33.33        | 32.25        | 31.25        | <b>32.27</b> |
| <b>Mean</b>                                                                         | <b>31.33</b> | <b>30.87</b> | <b>31.32</b> | <b>30.81</b> |              |
| <b>C.D. for Varieties</b>                                                           | <b>0.344</b> |              |              |              |              |
| <b>C.D. for Fertility</b>                                                           | <b>0.344</b> |              |              |              |              |
| <b>C.D. for Interaction</b>                                                         | <b>0.688</b> |              |              |              |              |

#### 4.7 Economic gain

The economics from the different treatment combinations was worked out on per hectare basis and the values so obtained are depicted in Table 4.39 and also illustrated through Fig. 4.22 and 4.23.

Out of the four clusterbean varieties under study, HG 563 proved to be most economical giving Rs. 1,78,151/ha with highest B:C ratio up to 10.66. This was, however, followed by RGC 1038 and RGC 1055 having no much difference in the economical gain (Rs. 1,55,514 to Rs. 1,59,203/ha with B:C ratio 9.43 to 9.64). The variety RGC 1017 gave the lowest net income (Rs. 1,13,169/ha) with B:C ratio only 7.11 (Table 4.39).

Application of 75% RDF (N<sub>15</sub>P<sub>30</sub>K<sub>15</sub>) with 5 t vermicompost/ ha resulted in maximum net income up to Rs. 1,77,089/ha with B:C ratio 9.78. However, this was followed by 100% RDF (N<sub>20</sub>P<sub>40</sub>K<sub>20</sub>) giving net income up to Rs. 1,60,739/ha with B:C ratio 9.81. When NPK was reduced to 50% along with vermicompost, the economical gain was also reduced to a greater extent i.e. net income up to Rs. 1,38,303/ha with B:C ratio 8.07. The net income was minimum up to Rs. 1,29,906/ha with B:C ratio 9.18 in the control treatment (N<sub>0</sub>P<sub>0</sub>K<sub>0</sub>). All these values are given on pooled basis.

**Table 4.39 Economical gain from clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                  | Net Income (Rs/ha.) |         |               | B:C ratio |         |              |
|-------------------------------------------------------------|---------------------|---------|---------------|-----------|---------|--------------|
|                                                             | 2011-12             | 2012-13 | Mean          | 2011-12   | 2012-13 | Mean         |
| <b><i>Varities</i></b>                                      |                     |         |               |           |         |              |
| RGC-1017                                                    | 99578               | 126759  | <b>113169</b> | 6.36      | 7.85    | <b>7.11</b>  |
| RGC-1038                                                    | 149809              | 168596  | <b>159203</b> | 9.12      | 10.16   | <b>9.64</b>  |
| RGC-1055                                                    | 141572              | 169455  | <b>155514</b> | 8.67      | 10.18   | <b>9.43</b>  |
| HG-563                                                      | 165309              | 190993  | <b>178151</b> | 9.94      | 11.37   | <b>10.66</b> |
| <b>SE (m) ±</b>                                             | -                   | -       | -             | -         | -       | -            |
| <b>CD (P=0.05)</b>                                          | -                   | -       | -             | -         | -       | -            |
| <b><i>Fertility level</i></b>                               |                     |         |               |           |         |              |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )     | 116601              | 143211  | <b>129906</b> | 9.34      | 10.01   | <b>9.18</b>  |
| 50% RDF +VC 5t/ha.                                          | 125570              | 151035  | <b>138303</b> | 7.42      | 8.72    | <b>8.07</b>  |
| 75% RDF +VC 5t/ha.                                          | 166636              | 187541  | <b>177089</b> | 9.26      | 10.30   | <b>9.78</b>  |
| 100% RDF (N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 147461              | 174017  | <b>160739</b> | 9.08      | 10.53   | <b>9.81</b>  |
| <b>CD (P=0.05)</b>                                          | -                   | -       | -             | -         | -       | -            |
| <b>Interaction</b>                                          | -                   | -       | -             | -         | -       | -            |

Fig. 4.22 Net income (Rs./ha.) from Clusterbean as influenced by

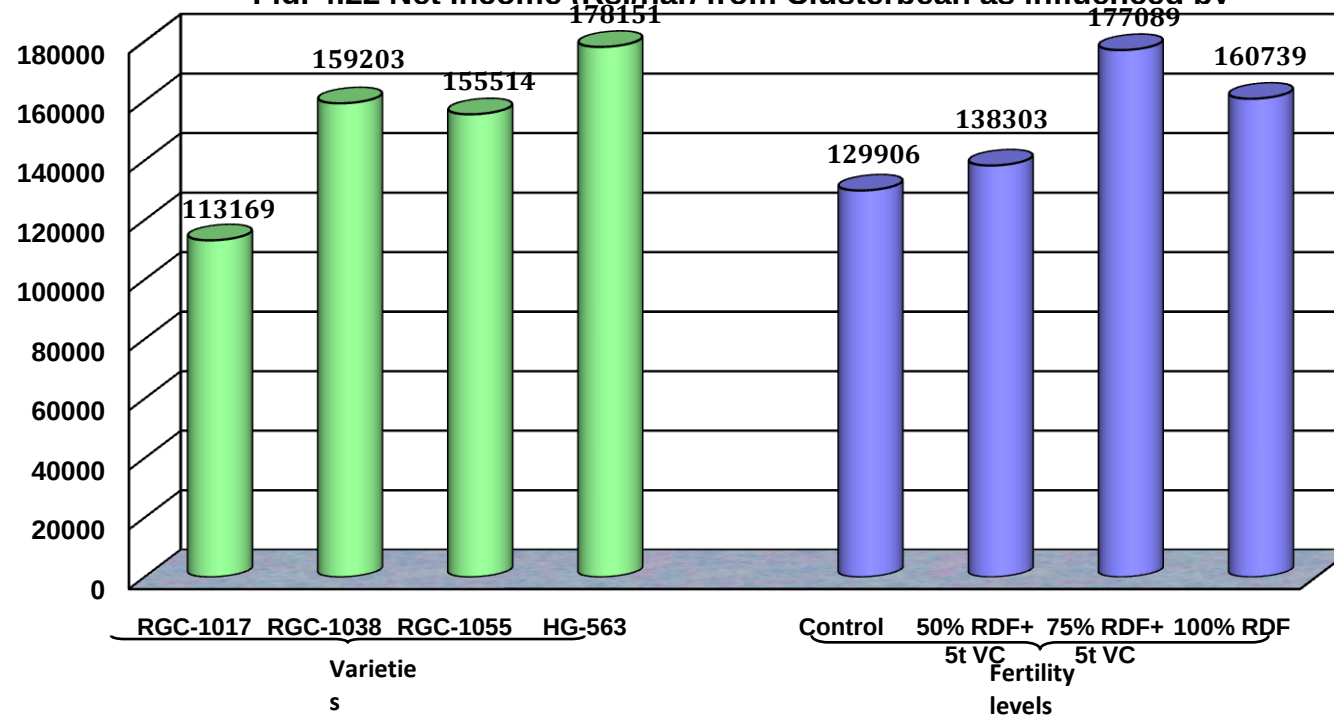
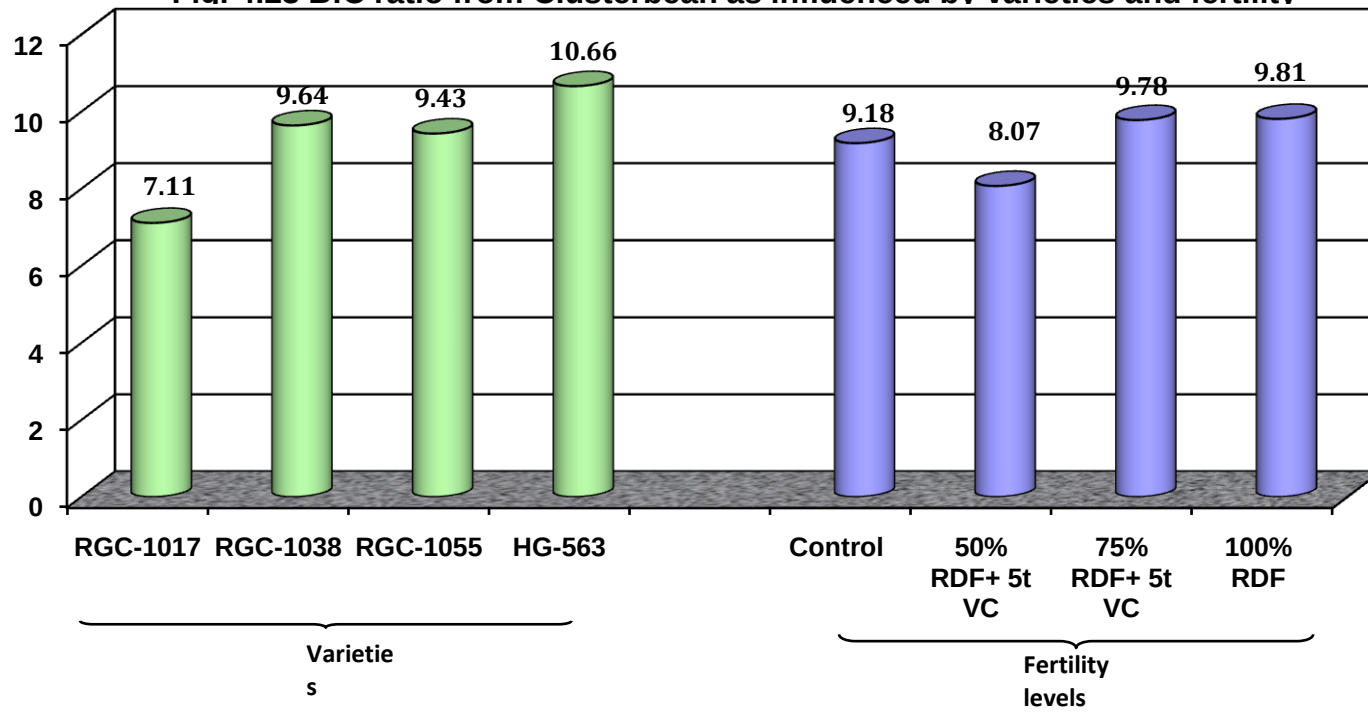


**Fig. 4.23 B:C ratio from Clusterbean as influenced by varieties and fertility**



The effect of treatment interactions on the economical gain has been highlighted in Table 4.39. HG 563 grown with 75% RDF +VC gave maximum net income (Rs. 2,05,421/ha) and B:C ratio 11.19. This was followed by HG 563 grown with 100% RDF (Rs. 1,89,961/ha and B:C ratio 11.41). The third best interaction was RGC 1038 grown with 75% RDF + VC (Rs. 1,82,082/ha and B:C ratio 10.03). In contrast to these values, the minimum net income (Rs. 90,614) and B:C ratio (6.70) were noted in case of RGC 1017 grown without fertilizer. All these values are on two years pooled basis.

#### **4.8 Qualitative parameters**

The data pertaining to qualitative parameters of clusterbean are presented in Tables 4.40 and illustrated through Fig. 4.24 and 4.25.

The different varieties as well as fertility levels exerted significant impact upon gum content and protein content of clusterbean seeds in both the years. The treatment interaction was found to be significantly in case of gum content only in both the years.

Among the varieties, HG 563 registered significantly higher gum content 30.94% (603.16 kg/ha) as well as protein content 32.19% (627.36 kg/ha) over the remaining varieties. This was followed by RGC 1038 and then RGC 1055. The significantly lowest gum content 30.51% (398.13 kg/ha) and protein content 31.21% (407.99 kg/ha) were recorded in case of RGC 1017 variety.

Amongst the fertility levels, 75% RDF + VC resulted in significantly higher gum content 31.59% (617.39 kg/ha) and protein content 32.62% (637.53 kg/ha) as compared to other fertility levels. This was, however, followed by 100% RDF and then 50% RDF + VC. The significantly lowest gum content 30.11% (433.81 kg/ha) and protein content 30.64% (442.55 kg/ha) were recorded in case of no fertilizers ( $N_0P_0K_0$ ). These results are based on two years pooled data.

**Table 4.40 Qualitative attributes of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                     | Gum content % |             |              | Gum yield (kg/ha) |              |               | Protein content % |             |              | Protein yield (kg/ha) |              |               |
|----------------------------------------------------------------|---------------|-------------|--------------|-------------------|--------------|---------------|-------------------|-------------|--------------|-----------------------|--------------|---------------|
|                                                                | 2011-12       | 2012-13     | Mean         | 2011-12           | 2012-13      | Mean          | 2011-12           | 2012-13     | Mean         | 2011-12               | 2012-13      | Mean          |
| <b><i>Varities</i></b>                                         |               |             |              |                   |              |               |                   |             |              |                       |              |               |
| RGC-1017                                                       | 30.49         | 30.52       | <b>30.51</b> | 356.94            | 439.31       | <b>398.13</b> | 31.21             | 31.21       | <b>31.21</b> | 365.94                | 450.04       | <b>407.99</b> |
| RGC-1038                                                       | 30.77         | 30.80       | <b>30.79</b> | 513.64            | 571.11       | <b>542.38</b> | 31.95             | 31.95       | <b>31.95</b> | 532.97                | 592.30       | <b>562.63</b> |
| RGC-1055                                                       | 30.56         | 30.54       | <b>30.55</b> | 484.25            | 568.40       | <b>526.33</b> | 31.47             | 31.47       | <b>31.47</b> | 498.95                | 586.20       | <b>542.57</b> |
| HG-563                                                         | 30.92         | 30.96       | <b>30.94</b> | 563.77            | 642.55       | <b>603.16</b> | 32.15             | 32.23       | <b>32.19</b> | 585.98                | 668.73       | <b>627.36</b> |
| <b>SE (m) ±</b>                                                | <b>0.02</b>   | <b>0.01</b> | <b>0.01</b>  | <b>7.23</b>       | <b>6.95</b>  | <b>5.01</b>   | <b>0.06</b>       | <b>0.06</b> | <b>0.04</b>  | <b>7.46</b>           | <b>7.24</b>  | <b>5.20</b>   |
| <b>CD (P=0.05)</b>                                             | <b>0.07</b>   | <b>0.03</b> | <b>0.04</b>  | <b>20.65</b>      | <b>19.83</b> | <b>14.05</b>  | <b>0.18</b>       | <b>0.18</b> | <b>0.12</b>  | <b>21.30</b>          | <b>20.67</b> | <b>14.56</b>  |
| <b><i>Fertility level</i></b>                                  |               |             |              |                   |              |               |                   |             |              |                       |              |               |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )        | 30.10         | 30.12       | <b>30.11</b> | 394.03            | 473.58       | <b>433.81</b> | 30.63             | 30.65       | <b>30.64</b> | 401.99                | 483.11       | <b>442.55</b> |
| 50% RDF +VC 5t/ha.                                             | 30.41         | 30.46       | <b>30.44</b> | 436.69            | 513.91       | <b>475.30</b> | 31.72             | 31.74       | <b>31.73</b> | 455.78                | 535.95       | <b>495.87</b> |
| 75% RDF +VC 5t/ha.                                             | 31.60         | 31.58       | <b>31.59</b> | 584.86            | 649.93       | <b>617.39</b> | 32.61             | 32.63       | <b>32.62</b> | 603.42                | 671.63       | <b>637.53</b> |
| 100% RDF<br>(N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 30.64         | 30.67       | <b>30.65</b> | 503.03            | 583.96       | <b>543.50</b> | 31.82             | 31.84       | <b>31.83</b> | 522.64                | 606.57       | <b>564.60</b> |
| <b>SE (m) ±</b>                                                | <b>0.02</b>   | <b>0.01</b> | <b>0.01</b>  | <b>7.23</b>       | <b>6.95</b>  | <b>5.01</b>   | <b>0.06</b>       | <b>0.06</b> | <b>0.04</b>  | <b>7.46</b>           | <b>7.24</b>  | <b>5.20</b>   |
| <b>CD (P=0.05)</b>                                             | <b>0.07</b>   | <b>0.03</b> | <b>0.04</b>  | <b>20.65</b>      | <b>19.83</b> | <b>14.05</b>  | <b>0.18</b>       | <b>0.18</b> | <b>0.12</b>  | <b>21.30</b>          | <b>20.67</b> | <b>14.56</b>  |
| <b>Interaction</b>                                             | <b>0.07</b>   | <b>0.07</b> | <b>0.07</b>  | <b>NS</b>         | <b>NS</b>    | <b>28.09</b>  | <b>NS</b>         | <b>NS</b>   | <b>0.25</b>  | <b>NS</b>             | <b>NS</b>    | <b>29.13</b>  |

**Fig. 4.24 Gum and protein content (%) of Clusterbean as influenced by varieties**

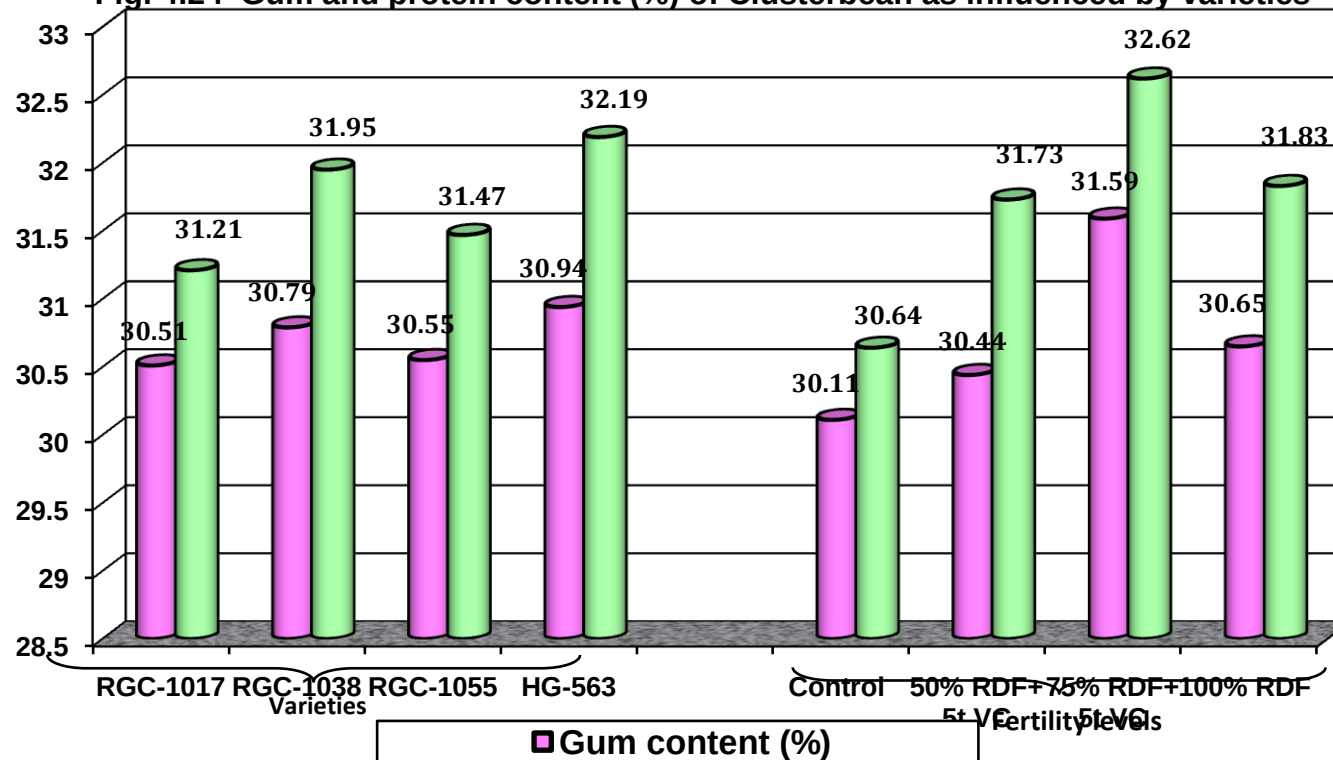


**Fig. 4.25 Gum and Protein yield (kg/ha.) of Clusterbean as influenced by varieties**

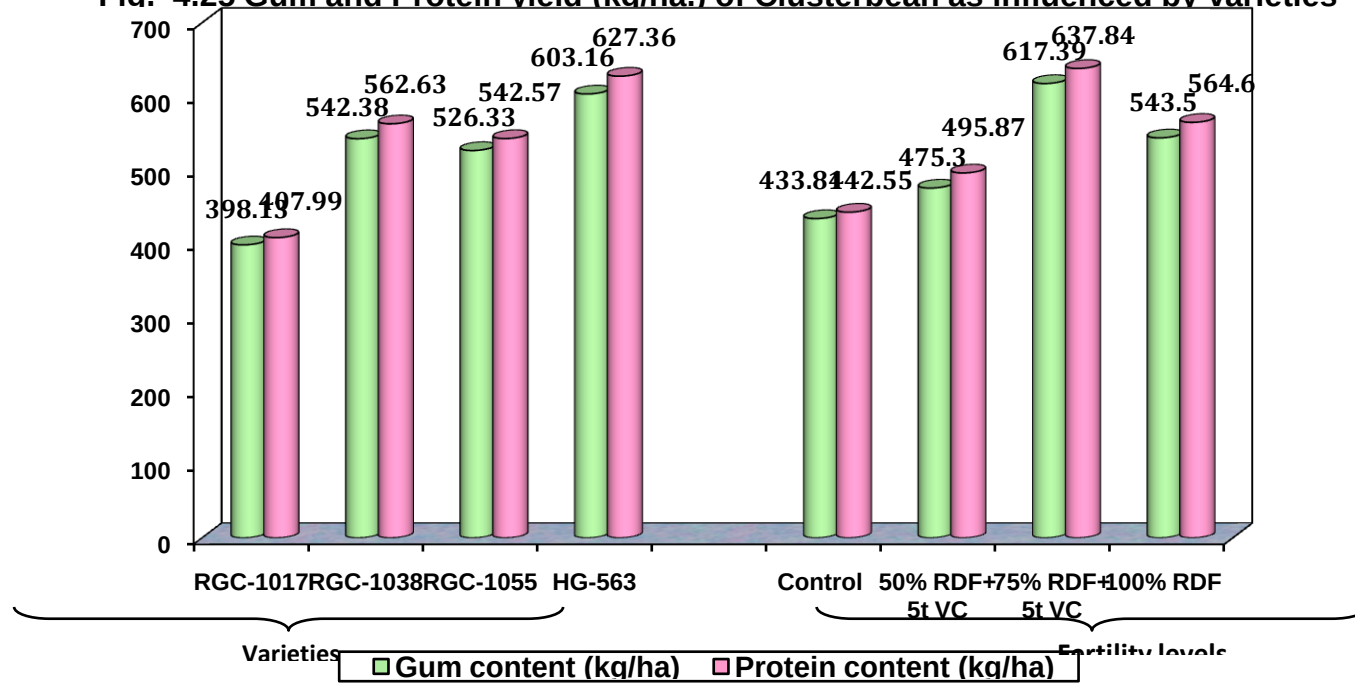


**Table 4.41 Interaction effect on gum content % of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                                    | Varieties    |              |              |              |              |
|-------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|
|                                                                                     | RGC-1017     | RGC-1038     | RGC-1055     | HG-563       | Mean         |
|                                                                                     | First Year   |              |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 30.03        | 30.12        | 30.09        | 30.15        | <b>30.10</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 30.37        | 30.41        | 30.38        | 30.50        | <b>30.41</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 31.15        | 31.91        | 31.32        | 32.03        | <b>31.60</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 30.43        | 30.65        | 30.46        | 31.01        | <b>30.64</b> |
| <b>Mean</b>                                                                         | <b>30.49</b> | <b>30.77</b> | <b>30.56</b> | <b>30.92</b> |              |
| Second Year                                                                         |              |              |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 30.06        | 30.13        | 30.10        | 30.17        | <b>30.12</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 30.38        | 30.47        | 30.41        | 30.58        | <b>30.46</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 31.16        | 31.93        | 31.18        | 32.06        | <b>31.58</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 30.47        | 30.68        | 30.49        | 31.03        | <b>30.67</b> |
| <b>Mean</b>                                                                         | <b>30.52</b> | <b>30.80</b> | <b>30.54</b> | <b>30.96</b> |              |
| Pooled                                                                              |              |              |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 30.04        | 30.13        | 30.09        | 30.16        | <b>30.11</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 30.38        | 30.44        | 30.39        | 30.54        | <b>30.44</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 31.15        | 31.92        | 31.25        | 32.04        | <b>31.59</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 30.45        | 30.67        | 30.47        | 31.02        | <b>30.65</b> |
| <b>Mean</b>                                                                         | <b>30.51</b> | <b>30.79</b> | <b>30.55</b> | <b>30.94</b> |              |
|                                                                                     | Varieties    | Fertility    | V×F          |              |              |
| <b>First year SE(m)±</b>                                                            | 0.023        | 0.023        | 0.046        |              |              |
| <b>C D (P=0.05)</b>                                                                 | 0.065        | 0.065        | 0.072        |              |              |
| <b>Second year SE(m)±</b>                                                           | 0.012        | 0.012        | 0.024        |              |              |
| <b>C D (P=0.05)</b>                                                                 | 0.034        | 0.034        | 0.068        |              |              |
| <b>Pooled SE(m)±</b>                                                                | 0.013        | 0.013        | 0.026        |              |              |
| <b>C D (P=0.05)</b>                                                                 | 0.036        | 0.036        | 0.072        |              |              |

**Table 4.41 (a) Interaction effect on gum yield (kg/ha) of clusterbean as influenced by varieties and fertility levels pooled of two years data.**

| Fertility levels                                                                    | Varieties     |               |               |               |               |
|-------------------------------------------------------------------------------------|---------------|---------------|---------------|---------------|---------------|
|                                                                                     | RGC-1017      | RGC-1038      | RGC-1055      | HG-563        | Mean          |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 316.21        | 467.10        | 446.59        | 505.32        | <b>433.81</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 340.50        | 498.55        | 509.39        | 552.78        | <b>475.30</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 517.07        | 638.94        | 598.18        | 715.38        | <b>617.39</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 418.73        | 564.93        | 551.14        | 639.19        | <b>543.50</b> |
| <b>Mean</b>                                                                         | <b>398.13</b> | <b>542.38</b> | <b>526.33</b> | <b>603.16</b> |               |
| <b>C.D. for Varieties</b>                                                           | <b>14.047</b> |               |               |               |               |
| <b>C.D. for Fertility</b>                                                           | <b>14.047</b> |               |               |               |               |
| <b>C.D. for Interaction</b>                                                         | <b>28.093</b> |               |               |               |               |

**Table 4.42 Interaction effect on protein content % of clusterbean as influenced by varieties and fertility levels pooled of two years data.**

| Fertility levels                                                                    | Varieties    |              |              |              |              |
|-------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|
|                                                                                     | RGC-1017     | RGC-1038     | RGC-1055     | HG-563       | Mean         |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 29.86        | 31.02        | 30.56        | 31.12        | <b>30.64</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 31.34        | 31.93        | 31.43        | 32.22        | <b>31.73</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 32.18        | 32.85        | 32.34        | 33.11        | <b>32.62</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 31.47        | 32.01        | 31.55        | 32.30        | <b>31.83</b> |
| <b>Mean</b>                                                                         | <b>31.21</b> | <b>31.95</b> | <b>31.47</b> | <b>32.19</b> |              |
| <b>C.D. for Varieties</b>                                                           | <b>0.124</b> |              |              |              |              |
| <b>C.D. for Fertility</b>                                                           | <b>0.124</b> |              |              |              |              |
| <b>C.D. for Interaction</b>                                                         | <b>0.247</b> |              |              |              |              |

**Table 4.42 (a) Interaction effect on protein yield (kg/ha) of clusterbean as influenced by varieties and fertility levels pooled of two years data.**

| Fertility levels                                                                    | Varieties     |               |               |               |               |
|-------------------------------------------------------------------------------------|---------------|---------------|---------------|---------------|---------------|
|                                                                                     | RGC-1017      | RGC-1038      | RGC-1055      | HG-563        | Mean          |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 314.12        | 480.92        | 453.84        | 521.33        | <b>442.55</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 351.05        | 522.54        | 526.64        | 583.25        | <b>495.87</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 534.20        | 657.43        | 619.13        | 739.35        | <b>637.53</b> |
| 100% RDF N <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                            | 432.58        | 589.65        | 570.69        | 665.50        | <b>564.60</b> |
| <b>Mean</b>                                                                         | <b>407.99</b> | <b>562.63</b> | <b>542.57</b> | <b>627.36</b> |               |
| <b>C.D. for Varieties</b>                                                           | <b>14.563</b> |               |               |               |               |
| <b>C.D. for Fertility</b>                                                           | <b>14.563</b> |               |               |               |               |
| <b>C.D. for Interaction</b>                                                         | <b>29.126</b> |               |               |               |               |

Both the best treatments when combined together (HG 563 + 75% RDF + VC) enhanced these quality parameters synergistically. Thus the gum and protein contents were found significantly and non-significantly higher i.e. 32.04 (715.38) and 33.11% (739.35 kg/ha), respectively over all the remaining interactions. However, the second best interaction was RGC 1038 grown with 75% RDF + VC 31.92, (638.94) and 32.85%, (657.43 kg/ha) gum and protein, respectively. The third best interaction was RGC 1055 with 75% RDF + VC or HG 563 with 100% RDF. The lowest gum and protein contents i.e. 30.04 (316.21) and 29.86%, (314.12 kg/ha) respectively were obtained from RGC 1017 variety grown without NPK application. In case of protein content although the treatment interactions were non-significant, still the results trend was found the same as in case of gum content.

## **4.9 Uptake of nutrients**

### **4.9.1 Nutrients uptake by whole plant**

The nutrient uptake by whole plant was determined in each treatment with respect to N, P and K and the data so obtained were subjected to statistical analysis for both the years. The data on the separate effect of varieties and fertility levels are shown in Table 4.43 and exhibited through Fig. 4.26. The data related to treatment interactions of N, P and K nutrients are presented in Tables 4.43.

The examination of the mean data in Table 4.43 indicates that the N uptake, in general, was found in the higher range (3.21 to 3.70 g) in all the treatments. This was followed by K uptake (1.99 to 2.28 g/plant) and then the values in the lowest range (0.24 to 0.34 g/plant) were noted in case of P uptake by whole plant in both the years.

The different varieties and fertility levels exerted significant influence only upon N and P uptake by whole plant in both the years. However the treatment interactions were found to be non-significant in each case (Table 4.43).

The variety HG 563 recorded significantly higher N and P uptake by whole plant over the remaining varieties in both the years. On pooled basis, the values were 5.15 and 0.32 g, respectively. This was followed by RGC 1038 and RGC 1055. The lowest uptake values were 4.99 and 0.27 g, respectively in case of RGC 1017 variety.

Application of 75% RDF + VC resulted in significantly higher N and P uptake by whole plant i.e., 5.22 and 0.34 g, respectively over the remaining fertility levels. This was equally followed by 100% RDF and 50% RDF + VC. The significantly lowest N and P uptake by whole plant i.e., 4.90 and 0.24 gm respectively was recorded in case of  $N_0P_0K_0$  treatment.

**Table 4.43 N,P,K uptake by whole plant (g) of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                  | N-uptake (g) |             |             | P-uptake (g) |              |              | K-uptake (g) |              |              |
|-------------------------------------------------------------|--------------|-------------|-------------|--------------|--------------|--------------|--------------|--------------|--------------|
|                                                             | 2011-12      | 2012-13     | Mean        | 2011-12      | 2012-13      | Mean         | 2011-12      | 2012-13      | Mean         |
| <b>Varities</b>                                             |              |             |             |              |              |              |              |              |              |
| RGC-1017                                                    | 4.99         | 4.99        | <b>4.99</b> | 0.26         | 0.28         | <b>0.27</b>  | 2.11         | 2.15         | <b>2.13</b>  |
| RGC-1038                                                    | 5.11         | 5.11        | <b>5.11</b> | 0.27         | 0.30         | <b>0.29</b>  | 2.15         | 2.18         | <b>2.17</b>  |
| RGC-1055                                                    | 5.03         | 5.04        | <b>5.04</b> | 0.27         | 0.31         | <b>0.29</b>  | 2.14         | 2.17         | <b>2.16</b>  |
| HG-563                                                      | 5.14         | 5.16        | <b>5.15</b> | 0.30         | 0.33         | <b>0.32</b>  | 2.18         | 2.22         | <b>2.20</b>  |
| <b>SE (m) ±</b>                                             | <b>0.01</b>  | <b>0.01</b> | <b>0.01</b> | <b>0.003</b> | <b>0.008</b> | <b>0.004</b> | <b>0.112</b> | <b>0.097</b> | <b>0.074</b> |
| <b>CD (P=0.05)</b>                                          | <b>0.03</b>  | <b>0.03</b> | <b>0.02</b> | <b>0.01</b>  | <b>0.02</b>  | <b>0.01</b>  | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    |
| <b>Fertility level</b>                                      |              |             |             |              |              |              |              |              |              |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )     | 4.90         | 4.90        | <b>4.90</b> | 0.23         | 0.25         | <b>0.24</b>  | 1.97         | 2.00         | <b>1.99</b>  |
| 50% RDF +VC 5t/ha.                                          | 5.08         | 5.08        | <b>5.08</b> | 0.27         | 0.30         | <b>0.29</b>  | 2.13         | 2.16         | <b>2.15</b>  |
| 75% RDF +VC 5t/ha.                                          | 5.22         | 5.22        | <b>5.22</b> | 0.32         | 0.35         | <b>0.34</b>  | 2.26         | 2.30         | <b>2.28</b>  |
| 100% RDF (N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 5.09         | 5.10        | <b>5.09</b> | 0.29         | 0.33         | <b>0.31</b>  | 2.23         | 2.26         | <b>2.25</b>  |
| <b>SE (m) ±</b>                                             | <b>0.01</b>  | <b>0.01</b> | <b>0.01</b> | <b>0.003</b> | <b>0.008</b> | <b>0.004</b> | <b>0.112</b> | <b>0.097</b> | <b>0.074</b> |
| <b>CD (P=0.05)</b>                                          | <b>0.03</b>  | <b>0.03</b> | <b>0.02</b> | <b>0.01</b>  | <b>0.02</b>  | <b>0.01</b>  | <b>NS</b>    | <b>NS</b>    | <b>0.21</b>  |
| <b>Interaction</b>                                          | <b>NS</b>    | <b>NS</b>   | <b>0.04</b> | <b>0.02</b>  | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    | <b>NS</b>    |

Fig. 4.26 N,P,K uptake by whole plant (g) of Clusterbean as influenced by varieties

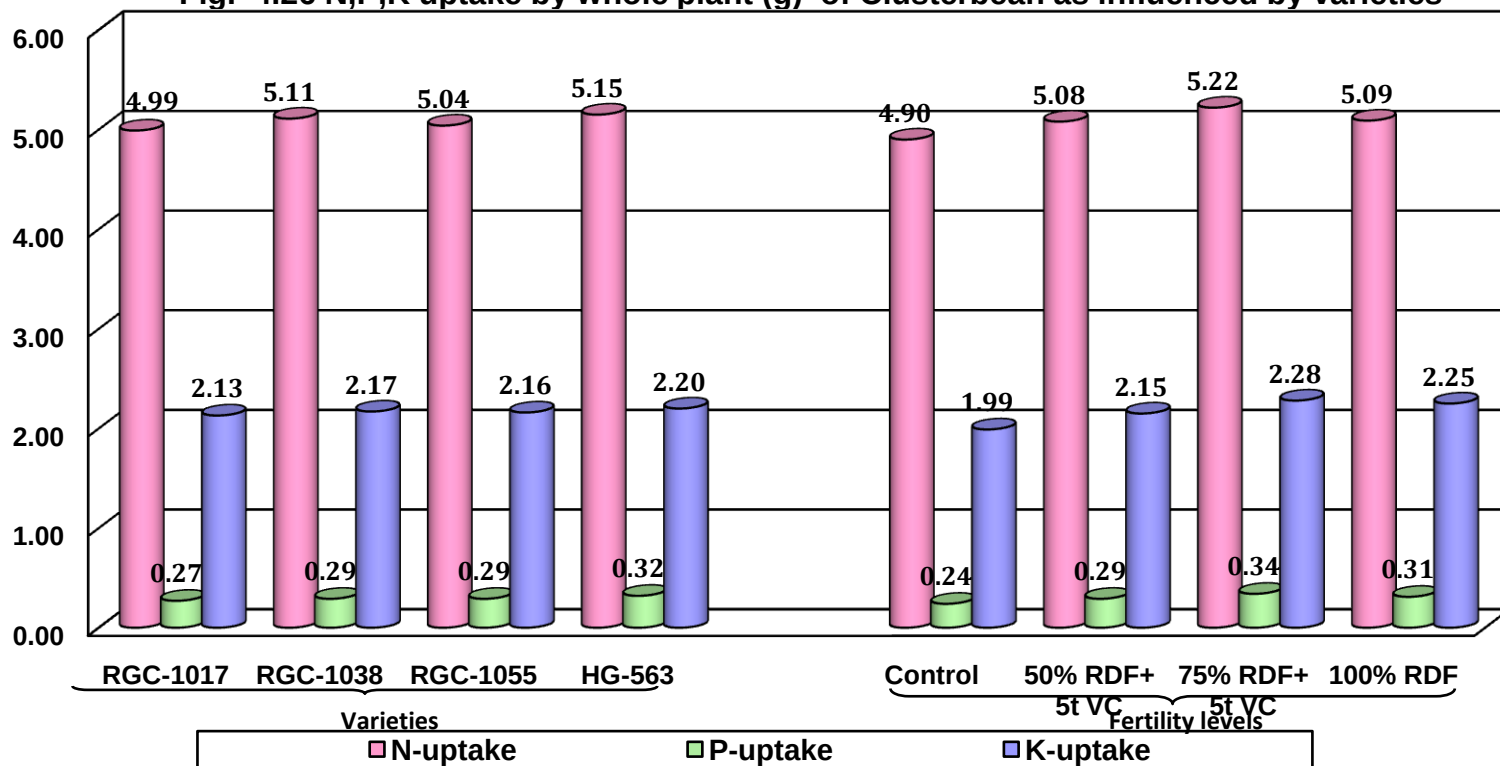


**Table 4.44 Interaction effect on N uptake by whole plant (g) of clusterbean as influenced by varieties and fertility levels and pooled of two years data.**

| Fertility levels                                                                    | Varieties    |             |             |             |             |
|-------------------------------------------------------------------------------------|--------------|-------------|-------------|-------------|-------------|
|                                                                                     | RGC-1017     | RGC-1038    | RGC-1055    | HG-563      | Mean        |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 4.78         | 4.96        | 4.89        | 4.98        | <b>4.90</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 5.01         | 5.11        | 5.03        | 5.16        | <b>5.08</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 5.15         | 5.26        | 5.17        | 5.30        | <b>5.22</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 5.03         | 5.12        | 5.05        | 5.17        | <b>5.09</b> |
| <b>Mean</b>                                                                         | <b>4.99</b>  | <b>5.11</b> | <b>5.04</b> | <b>5.15</b> |             |
| <b>C.D. for Varieties</b>                                                           | <b>0.020</b> |             |             |             |             |
| <b>C.D. for Fertility</b>                                                           | <b>0.020</b> |             |             |             |             |
| <b>C.D. for Interaction</b>                                                         | <b>0.040</b> |             |             |             |             |

**Table 4.45 Interaction effect on P uptake by whole plant (g) of clusterbean as influenced by varieties and fertility levels in the year 2011.**

| Fertility levels                                                                    | Varieties    |             |             |             |             |
|-------------------------------------------------------------------------------------|--------------|-------------|-------------|-------------|-------------|
|                                                                                     | RGC-1017     | RGC-1038    | RGC-1055    | HG-563      | Mean        |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 0.22         | 0.21        | 0.23        | 0.24        | <b>0.23</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 0.24         | 0.26        | 0.27        | 0.29        | <b>0.27</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 0.30         | 0.32        | 0.31        | 0.35        | <b>0.32</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 0.28         | 0.29        | 0.28        | 0.33        | <b>0.29</b> |
| <b>Mean</b>                                                                         | <b>0.26</b>  | <b>0.27</b> | <b>0.27</b> | <b>0.30</b> |             |
| <b>C.D. for Varieties</b>                                                           | <b>0.009</b> |             |             |             |             |
| <b>C.D. for Fertility</b>                                                           | <b>0.009</b> |             |             |             |             |
| <b>C.D. for Interaction</b>                                                         | <b>0.017</b> |             |             |             |             |

Amongst the treatment interactions (Table 4.43), HG 563 grown with 75% RDF + VC recorded non-significantly maximum N, P and K uptake by whole plant i.e. 5.30, 0.37 and 2.32 g, respectively. This is based on two years pooled data. On the other hand, the lowest N, P and K uptake by whole plant was recorded in case of RGC 1017 grown without fertilization i.e. 4.78, 0.23 and 1.94 g, respectively.

Varieties when grown with 75% RDF + VC. The significantly lowest P uptake (0.22g) was noted in case of RGC 1017 grown without any fertilizers. The similar results trend was noticed in second year also where the interactions were non-significant. In case of N and K uptake also the same results trend appeared in both the years however the treatments and their interactions were non-significant.

The overall trend indicate that the NPK uptake by whole plant was found maximum under HG 563 as well as under 75% RDF + VC fertility level. When both these treatments combined the NPK uptake by whole plant was found maximum over the remaining interacting treatments in both the years.

#### **4.9.2 Nutrients uptake kg/ha**

The per ha uptake of N, P and K nutrients was calculated based on per hectare yield under each treatment and the data thus obtained were subjected to statistical analysis for both the years. The data on the separate effect of varieties and fertility levels are shown in Table 4.46 and exhibited through Fig. 4.27. The data pertaining to treatment interactions of N, P and K nutrients are presented in Tables 4.47 to 4.48.

The scrutiny of the mean of two years, data in Table 4.46 reveal that the N uptake /ha, in general, were found in the higher range (208.81 to 322.59 kg/ha) in all the treatments. This was followed by K uptake (89.43 to 138.22 kg/ha) and then the values in the lowest range (11.52 to 20.43 kg/ha) were recorded in case of P uptake by clusterbean per hectare in both the years.

The different varieties and fertility levels deviated these parameters up to significant extent in both the years. The treatment interactions were found to be significant only in case of N uptake/ha in both the years and P uptake/ha in the first year (Table 4.46).

**Table 4.46 N,P,K uptake (kg/ha) of clusterbean as influenced by varieties and fertility levels (treatment factors mean effects)**

| Treatments                                                     | N-uptake (kg/ha) |              |               | P-uptake (kg/ha) |             |              | K-uptake (kg/ha) |              |               |
|----------------------------------------------------------------|------------------|--------------|---------------|------------------|-------------|--------------|------------------|--------------|---------------|
|                                                                | 2011-12          | 2012-13      | Mean          | 2011-12          | 2012-13     | Mean         | 2011-12          | 2012-13      | Mean          |
| <b>Varities</b>                                                |                  |              |               |                  |             |              |                  |              |               |
| RGC-1017                                                       | 189.04           | 228.58       | <b>208.81</b> | 9.98             | 13.06       | <b>11.52</b> | 80.57            | 98.29        | <b>89.43</b>  |
| RGC-1038                                                       | 271.07           | 301.80       | <b>286.43</b> | 14.47            | 17.95       | <b>16.21</b> | 114.29           | 128.85       | <b>121.57</b> |
| RGC-1055                                                       | 261.20           | 295.17       | <b>278.19</b> | 14.25            | 17.97       | <b>16.11</b> | 111.24           | 126.82       | <b>119.03</b> |
| HG-563                                                         | 298.62           | 346.56       | <b>322.59</b> | 17.70            | 22.42       | <b>20.06</b> | 126.93           | 149.50       | <b>138.22</b> |
| <b>SE (m) ±</b>                                                | <b>2.53</b>      | <b>2.54</b>  | <b>1.79</b>   | <b>0.22</b>      | <b>0.48</b> | <b>0.27</b>  | <b>5.55</b>      | <b>5.66</b>  | <b>3.96</b>   |
| <b>CD (P=0.05)</b>                                             | <b>7.21</b>      | <b>7.25</b>  | <b>5.02</b>   | <b>0.62</b>      | <b>1.38</b> | <b>0.74</b>  | <b>15.83</b>     | <b>16.16</b> | <b>11.10</b>  |
| <b>Fertility level</b>                                         |                  |              |               |                  |             |              |                  |              |               |
| Control (N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> )        | 221.07           | 259.74       | <b>240.40</b> | 10.16            | 13.13       | <b>11.65</b> | 88.44            | 105.73       | <b>97.09</b>  |
| 50% RDF +VC 5t/ha.                                             | 240.60           | 282.85       | <b>261.73</b> | 12.72            | 16.71       | <b>14.72</b> | 101.25           | 120.25       | <b>110.75</b> |
| 75% RDF +VC 5t/ha.                                             | 301.46           | 328.40       | <b>314.93</b> | 18.57            | 22.29       | <b>20.43</b> | 130.62           | 144.16       | <b>137.39</b> |
| 100% RDF<br>(N <sub>20</sub> P <sub>40</sub> K <sub>20</sub> ) | 256.79           | 301.13       | <b>278.96</b> | 14.94            | 19.28       | <b>17.11</b> | 112.71           | 133.32       | <b>123.02</b> |
| <b>SE (m) ±</b>                                                | <b>2.53</b>      | <b>2.54</b>  | <b>1.79</b>   | <b>0.22</b>      | <b>0.48</b> | <b>0.27</b>  | <b>5.55</b>      | <b>5.66</b>  | <b>3.96</b>   |
| <b>CD (P=0.05)</b>                                             | <b>7.21</b>      | <b>7.25</b>  | <b>5.02</b>   | <b>0.62</b>      | <b>1.38</b> | <b>0.74</b>  | <b>15.83</b>     | <b>16.16</b> | <b>11.10</b>  |
| <b>Interaction</b>                                             | <b>14.43</b>     | <b>14.50</b> | <b>10.04</b>  | <b>1.23</b>      | <b>NS</b>   | <b>1.48</b>  | <b>NS</b>        | <b>NS</b>    | <b>NS</b>     |

Fig. 4.27 N,P,K uptake (kg/ha) of Clusterbean as influenced by varieties and fertility

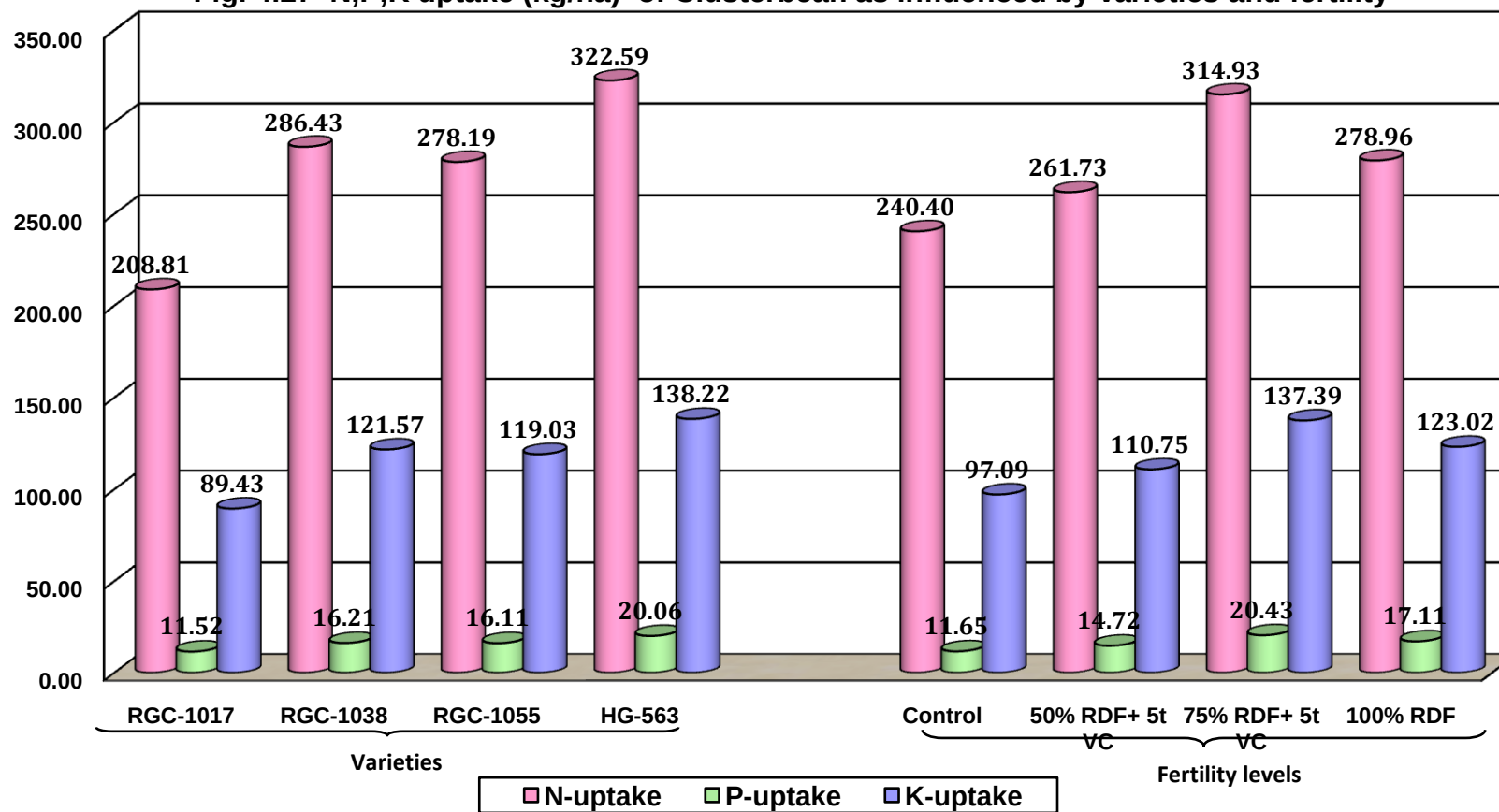


**Table 4.47 Interaction effect on N uptake (kg/ha.) of clusterbean as influenced by varieties and fertility levels.**

| Fertility levels                                                                    | Varieties     |               |               |               |               |
|-------------------------------------------------------------------------------------|---------------|---------------|---------------|---------------|---------------|
|                                                                                     | RGC-1017      | RGC-1038      | RGC-1055      | HG-563        | Mean          |
|                                                                                     | First Year    |               |               |               |               |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 150.19        | 239.99        | 226.71        | 267.39        | <b>221.07</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 164.54        | 250.39        | 261.15        | 286.32        | <b>240.60</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 255.78        | 311.23        | 294.63        | 344.19        | <b>301.46</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 185.63        | 282.65        | 262.31        | 296.58        | <b>256.79</b> |
| <b>Mean</b>                                                                         | <b>189.04</b> | <b>271.07</b> | <b>261.20</b> | <b>298.62</b> |               |
| Second Year                                                                         |               |               |               |               |               |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 190.49        | 281.55        | 254.46        | 312.44        | <b>259.74</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 206.60        | 289.62        | 305.19        | 330.00        | <b>282.85</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 274.30        | 341.06        | 318.14        | 380.10        | <b>328.40</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 242.95        | 294.98        | 302.90        | 363.70        | <b>301.13</b> |
| <b>Mean</b>                                                                         | <b>228.58</b> | <b>301.80</b> | <b>295.17</b> | <b>346.56</b> |               |
| Pooled                                                                              |               |               |               |               |               |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 170.34        | 260.77        | 240.59        | 289.91        | <b>240.40</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 185.57        | 270.01        | 283.17        | 308.16        | <b>261.73</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 265.04        | 326.15        | 306.38        | 362.14        | <b>314.93</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 214.29        | 288.82        | 282.60        | 330.14        | <b>278.96</b> |
| <b>Mean</b>                                                                         | <b>208.81</b> | <b>286.43</b> | <b>278.19</b> | <b>322.59</b> |               |
|                                                                                     | Varieties     | Fertility     | V×F           |               |               |
| <b>First year SE(m)±</b>                                                            | 2.527         | 2.527         | 5.055         |               |               |
| <b>C D (P=0.05)</b>                                                                 | 7.213         | 7.213         | 14.426        |               |               |
| <b>Second year SE(m)±</b>                                                           | 2.541         | 2.541         | 5.082         |               |               |
| <b>C D (P=0.05)</b>                                                                 | 7.252         | 7.252         | 14.504        |               |               |
| <b>Pooled S. Em 1 ±</b>                                                             | 1.792         | 1.792         | 3.584         |               |               |
| <b>C D (P=0.05)</b>                                                                 | 5.018         | 5.018         | 10.036        |               |               |

**Table 4.48 Interaction effect on P uptake (kg/ha.) of clusterbean as influenced by varieties and fertility levels in the year 2011 and pooled of two years data.**

| Fertility levels                                                                    | Varieties    |              |              |              |              |
|-------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|
|                                                                                     | RGC-1017     | RGC-1038     | RGC-1055     | HG-563       | Mean         |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 6.93         | 10.16        | 10.64        | 12.91        | <b>10.16</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 7.87         | 12.73        | 14.15        | 16.12        | <b>12.72</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 14.89        | 18.97        | 17.66        | 22.78        | <b>18.57</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 10.24        | 16.01        | 14.53        | 18.98        | <b>14.94</b> |
| <b>Mean</b>                                                                         | <b>9.98</b>  | <b>14.47</b> | <b>14.25</b> | <b>17.70</b> |              |
| <b>C.D. for Varieties</b>                                                           | <b>0.616</b> |              |              |              |              |
| <b>C.D. for Fertility</b>                                                           | <b>0.616</b> |              |              |              |              |
| <b>C.D. for Interaction</b>                                                         | <b>1.232</b> |              |              |              |              |
| Control N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>                                | 8.25         | 11.59        | 11.82        | 14.91        | <b>11.65</b> |
| 50% RDF<br>N <sub>10</sub> P <sub>20</sub> K <sub>10</sub> +Vermicompost<br>5 t/ha. | 9.53         | 14.58        | 16.15        | 18.60        | <b>14.72</b> |
| 75% RDF<br>N <sub>15</sub> P <sub>30</sub> K <sub>15</sub> +Vermicompost<br>5 t/ha. | 15.97        | 21.17        | 19.59        | 24.99        | <b>20.43</b> |
| 100% RDFN <sub>20</sub> P <sub>40</sub> K <sub>20</sub>                             | 12.34        | 17.50        | 16.86        | 21.74        | <b>17.11</b> |
| <b>Mean</b>                                                                         | <b>11.52</b> | <b>16.21</b> | <b>16.11</b> | <b>20.06</b> |              |
| <b>C.D. for Varieties</b>                                                           | <b>0.742</b> |              |              |              |              |
| <b>C.D. for Fertility</b>                                                           | <b>0.742</b> |              |              |              |              |
| <b>C.D. for Interaction</b>                                                         | <b>1.484</b> |              |              |              |              |

Based on two years mean values, the variety HG 563 recorded almost significantly higher N, P and K uptake i.e. 322.59, 20.06 and 138.22 kg/ha, respectively over the other varieties. This was equally followed by RGC 1038 and RGC 1055 varieties. The significantly lowest N, P and K uptake (208.81, 11.52 and 89.43 kg/ha, respectively) was secured from RGC 1017 variety based on pooled analysis.

Amongst the fertility levels, 75% RDF + VC resulted in almost significantly higher N, P and K uptake i.e. 314.93 kg N, 20.43 kg P and 137.39 kg K/ha based on pooled data. This was, however followed by 100% RDF and then 50% RDF + VC. The significantly lowest N, P and K uptake was 240.40 kg N, 11.65 kg P and 97.09 kg K/ha in case of N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> treatment.

The treatment interactions were found significant only in case of N uptake in both the years and P uptake in first year only (Tables 4.47 to 4.48). Accordingly, HG 563 grown with 75% RDF + VC recorded significantly higher N uptake (362.14 kg/ha) over all the remaining interactions. However, the second best interaction was HG 563 grown with 100% RDF (330.14 kg N/ha). The third best interaction was RGC 1038 grown with 75% RDF + VC (326.15 kg N/ha). The significantly lowest N uptake (170.34 kg/ha) was recorded in case of RGC 1017 grown without NPK fertilization. These data are based on two years mean values. The similar results trend was also noticed in case of P uptake in first year where the interactions were found significant. In case of K uptake, the interactions although non-significant, still the results trend was observed the same as reported in case of N and P uptake/ha.

## **CHAPTER – V**

### **DISCUSSION**

The production or yield is an ultimate result of the plants which depend on the genetic constitution of the plant and environmental factors which consists of different weather components and soil characteristics. Varieties and fertility levels also play an important role in increasing the productivity of crops. Improvement in crop varieties for high yield is not sufficient to increase the productivity of crop. However, balanced fertilization with organic sources, in relation of clusterbean varieties and agro-climatic condition can help considerably to enhance the productivity on sustainable basis.

Keeping this in view, the present investigation was carried out to evaluate the comparative performance of different varieties and fertility levels. Various observations were recorded periodically on growth parameters, yield- attributing characters and yields including qualities. The inferences obtained from these observations were critically described in the previous chapter. Some of the findings have been focused on the most valuable information of basic and applied importance. These findings are being discussed in this chapter with the support of the data, scientific facts and views of other researchers. The edaphic and weather conditions prevailed during the experimental period also exerted their marked influence on the growth and yields of clusterbean besides the effect of treatments tested under investigation. Hence, brief accounts on these parameters are also included in this chapter. The main discussion is centered around the effect of treatments on the various plant characters.

#### **5.1 Effect of weather conditions on crop**

Different weather components like temperature, relative humidity, evaporation, rainfall, rainy days and sunshine hours play an important role which influences the germination, growth, development and ultimately the yield of crop. Therefore, discussion of the experimental results would be incomplete without considering the crop-weather relationship.

The weekly meteorological data on mean maximum and minimum temperature, relative humidity and rainfall during the course of field experimentation (July to November, 2011 and 2012) were recorded from the Meteorological observatory, College of Agriculture Gwalior (M.P.) and are presented in Table 3.1 and 3.2 and depicted in figure 3.1a & 3.1b and 3.2a & 3.2b.

In general, the weather conditions which prevailed during *kharif* 2011 and 2012 were favourable for growth and development of the clusterbean crop. Monsoon commences in the third week of June and terminated in the last week of September. The rainfall during the crop season was 498.8 and 722.5 mm and was received in 23 and 25 rainy days. Minimum and maximum temperature 0.4 to 47 and 1.0 to 47.2°C which were ideal for growth of clusterbean crop. During this period, the average relative humidity was 83.5 to 86.2 percent in the morning and 56.4 to 55.5 percent in evening.

## **5.2 Effect of soil conditions**

The soil of the experimental field was sandy-loam in texture, neutral in reaction (pH 8.0) with medium in organic content and analyzing medium in available N (212.6 kg/ha), P (15.7 kg/ha) and K (286 kg/ha) contents. The topography of experimental field was uniform. Fertility status of experimental site was homogenous. Variation in the growth and yield of crop were mainly due to effect of the treatment tested.

## **5.3 Plant population /m row length**

Uniform plant density is an important requisite for obtaining higher precision when it is not a variable factor as the treatments. The data in Table 4.1 indicate that the plant population per metre row length remained statistically unchanged (non-significant) under the various treatment combinations without giving any definite trend. It obviously reflects the fact from these data that the sowing of clusterbean was done properly, uniformly in each treatment combination using healthy and viable seeds to maintain the better germination, emergence and crop stand per unit area. Thus the crop stand remained almost uniformly sufficient in all the variety×fertilizer combined treatments. There was no harmful effect of the chemical fertilizers applied in the same furrow in which seeds were sown.

## 5.4 Morphological characters

The significant varietal differences of clusterbean were noticed with respect to plant height, number of branches per plant, root length and weight as well as biomass/ plant at most of the plant growth intervals viz., 30, 60, 90 DAS and at maturity stages. Amongst the varieties, HG 563 resulted in higher values of all these characters, followed by RGC 1038. This was apparently prominent in case of root nodulation i.e. root length and its weight and number of root nodules per plant.

The differential behaviour of clusterbean varieties with respect to root-shoot growth characters could be explained solely by the variation in their genetic makeup and adaptability to soil and climatic conditions. The results are in close conformity with the findings of Vyas (2002) who reported that the late genotypes had better vegetative growth in terms of plant height. Anonymous (2001-02) observed that guar varieties HG-365 recorded maximum number of branches/ plant as compared to other varieties. Bhadoria and Kushwah (2005) observed that guar variety GUAG-003 recorded maximum number of branches per plants as compared to the other varieties.

The different fertility levels brought about significant influence upon plant height, branches formation per plant as well as root growth and development with respect to root length, weight and nodules number per plant. This was observed almost at every stage of observations.

The best fertility level was 75% RDF ( $N_{15}P_{30}K_{15}$ ) + vermicompost 5 t/ha which resulted in significantly higher plant height 107.90 cm at maturity, 8.26 branches / plant at 90 DAS, 34.35 cm root length, 0.445 g root weight and 14.75 nodules/plant. This fertility level proved significantly superior to the remaining fertility levels. However the second best fertility level was 100% RDF ( $N_{20}P_{40}K_{20}$ ) with respect to all these characters.

This may be owing to increased supply of multi-nutrients, plant growth regulators and beneficial microflora released from vermicompost in addition to most favourable conditions improved with respect to physico-chemical and biological properties of the soil.

The boosted vegetative growth (height and branches per plant) due to increased multi-nutrients which promoted plant growth by ensuring higher number of greener leaves with increased photosynthesis as a result of increased metabolism of the absorbed plant nutrients, forming longer and stronger roots to absorb sufficient water and nutrients, Profuse root development ensured more absorption of minerals, nutrients and soil moisture from the deeper soil layers. These favorable soil conditions brought about efficient utilization of plant nutrients accompanied by activating plant enzymes. The remarkable increase in root-shoot growth parameters due to 75% NPK + 5t/ha vermicompost supplying additional nutrients may be as a result of acceleration of cell elongation and cell division. Similar findings have been reported by several research workers (Ramachandra Reddy *et al.* 1998; Usha Kumari *et al.* 1999; Pattar *et al.* 1999; Das *et al.* 2002; Vasanthi and Subramanian, 2004; Rajkhowa *et al.* 2003; Barik *et al.* 2008; Kumawat *et al.* 2009, Singh and Ahmad, 2010; Patel *et al.*, 2010; Yadav *et al.* 2011; Sharma and Jain, 2012).

## **5.5 Root nodulation**

Clusterbean, being a legume, fixes atmospheric-N and improves the soil fertility. Phosphorus fertilization in legumes is of great importance, as it encourages the root nodulation, growth and productivity per unit area. Biological nitrogen fixation by symbiotic bacteria in root-nodules of legume plants is quantitatively one of the most important ways in which atmospheric nitrogen enters the biosphere.

Root nodulation studies at 50 days stage indicated that the different clusterbean varieties significantly differed with respect to the formation of root nodules per plant. Amongst the varieties, HG 563 recorded significantly higher number of root nodules (15.5 /plant), however this was followed by RGC 1038 (12.87/plant). The significantly lowest nodules number (8.87 to 9.12 / plant) was noted in case of RGC 1017 and RGC 1055 varieties. This difference in nodules number among the varieties might be by virtue of differential genetic build up which governs the root-shoot development. These results are in accordance with those of Raj *et al.* (2013) and Singh *et al.* (2013a).

Amongst the fertility levels, 75% RDF + VC brought about significantly higher number of root-nodules (14.75/plant) over the remaining fertility levels. However, the second best fertility level was 100% RDF applied alone (12.87

nodules/plant). This may be because of the increased proliferation and effectiveness of *Rhizobia* in the rhizosphere (root zone) and the sufficient supply of multi-nutrients and favourable physico-chemical and biological properties of the soil due to applied vermicompost along with N, P and K . The present results corroborate with those of Rajkhowa *et al.* (2002), Rajkhowa *et al.* (2003), Kumawat *et al.* (2009), Singh *et al.* (2013 a) and Raj (2013).

## **5.6 Biomass production/ plant**

The summarized data in table 6.2 reveal that out of four varieties, HG 563 resulted in significantly higher biomass per plant at every stage of observations except at 30 DAS. However, the second best variety was RGC 1038 and then RGC 1055. The significantly lowest biomass production was noticed in variety RGC 1017. At maturity stage, the biomass production was 47.28, 46.31, 44.23 and 43.29 g/ plant from HG 563, RGC 1038, RGC 1055 and RGC 1017, respectively. Such variation in biomass production may be attributed to genetic variability among the varieties of clusterbean evolved from the different genetic materials.

All the fertility levels gave significant rise in this parameter over control at every stage of observations. Amongst the fertility levels, 75% RDF + VC or 100% RDF resulted in equally higher biomass per plant at every stage. Both these fertility levels proved significantly superior to 50% RDF + VC and control treatments. At maturity stage, the biomass values were 49.35, 48.26, 44.86 and 38.75 g/ plant from 75% RDF + VC, 100% RDF, 50% RDF and control treatments, respectively. The increased biomass production per plant may be due to significant increases in the vegetative growth parameters under both these best fertility levels. Singh *et al.* (2002) also found that dry matter accumulation in plant increased with increase in fertility levels up to 125% RDF at all the stages.

According to Sattar and Gaur (1987), this could be ascribed to greater nutrient uptake and their translocation favouring the rate of photosynthesis and accumulation of photosynthates. Vermicompost application along with NPK is also known to promote plant growth and development through production of growth promoting substances, control of plant pathogens and proliferation of beneficial organisms in the rhizosphere. Applied vermicompost with the native soil microorganisms might have enhanced the population of *Rhizobium* and phospho-

bacteria in the rhizosphere which might be due to release of higher quantities of root-exudates as soluble carbohydrates and sugars into rhizosphere (Gaur and Alagwadi, 1988) as a result of improved photosynthates. This, in turn, would have resulted in enhanced proliferation of the native phospho-bacteria of the soil.

## **5.7 Growth analysis parameters**

Growth analysis technique has made substantial contribution to the current understanding of the physiological basis of yield variation in different crops.

Efforts to relate crop yields to canopy architecture began in the early 20<sup>th</sup> century with the development of “growth analysis” by British plant physiologists. They recorded total plant dry weight (W) and leaf area (L) in the growing season.

In fact leaf is the factory for the conversion of solar energy into the chemical energy for the growth and development of plants. Leaf area or photosynthetic area fairly gives a good idea of the photosynthetic capacity of the plant. The LAI, LAR, LAD, NAR, CGR, RGR and AGR are the important growth parameters influencing yield which are dependent not only on the genotype but also on the environmental and fertility management practices.

In the present study, the leaf area thereby leaf area index (LAI), leaf area ratio (LAR), leaf area duration (LAD), net assimilation rate (NAR), crop growth rate (CGR) relative growth rate (RGR) and absolute growth rate (AGR) increased upto 90 DAS and decreased thereafter due to senescence and aging of leaves as well as complicated physiological functions in the plant.

The varieties, as well as application of plant nutrients in general showed a profound effect over these growth analysis parameters and significant differences were noticed among the varieties and fertility level treatments almost at all the growth stages. Amongst the varieties, HG 563, and amongst the fertility levels, 100% RDF (N<sub>20</sub>P<sub>40</sub>K<sub>20</sub>) recorded almost significantly higher growth analysis parameters at most of the stages of observations.

The varietal differences amongst these growth analysis parameters attributed to the variability in the genetic inheritance among the varieties. This has been supported by Talwar *et al.* (2004).

The significant differences among the growth analysis parameters as result of applied fertility levels may be owing to differences in the supply of plant nutrients. This had resulted in increase or decrease of photosynthetic activity, varied translocation and utilization of photosynthates, leading to plant growth.

Fertility levels caused a marked variation in growth parameters of clusterbean at most of the crop growth stages. The growth analysis parameters, viz., LAI, LAR, LAD, NAR, CGR, RGR, AGR had a direct relationship with the fertility levels. Therefore the maximum values of these growth parameters were recorded with the 100% recommended fertilizer dose. (20: 40 : 20 NPK kg/ha). The overall improvement in the growth of clusterbean at higher level of fertility could be ascribed to their pivotal role in several physiological and biochemical processes, viz., root development, photosynthesis, energy transfer reaction and symbiotic biological N-fixation process. These observations are in line with the findings of Rathore *et al.* (2007) who reported that N and P<sub>2</sub>O<sub>5</sub> combination had significant favourable effect on plant growth of clusterbean. Patra (1991) reported that N and P combination had significant favourable effect on plant height in horse gram. Arya and Singh (1996) also reported that major plant nutrients mainly nitrogen and phosphorus had a positive effect on plant height in horse gram. Yadav *et al.* (1991) observed increase in number of branches/ plant by using recommended dose of fertilizer (20 kg N + 40 kg P<sub>2</sub>O<sub>5</sub> kg/ha) in clusterbean. Similar results in respect of the effect of N, P and K in single form or in combination on legume crops were also reported by Shubhra *et al.* (2003), Bhadoria and Kushwah (2005), Burman *et al.* (2009b) and Muhammad *et al.* (2009).

Relative growth rate (RGR) represents the increase in dry matter per unit of dry matter already present per unit time. The average daily increment of stand biomass is an important characteristic and is called either the rate of dry matter production or crop growth rate i.e. CGR (Watson, 1952). It is a widely used character for estimating production efficiency of the crop stand and enables to make comparisons between the aspects of study. Net assimilation rate (NAR), synonymously called as “unit leaf rate”, expresses the rate of dry weight increase at any instant on a leaf area basis with leaf representing an estimate of the size of the assimilatory surface area. The maximum NAR values were recorded in HG 563 variety and 100% NPK level. Watson (1952) suggested that NAR does not measure real photosynthesis but represents net result of photosynthetic gain over respiratory

loss and it gives no direct indications of respiratory losses. Further the NAR was maximum at early stages and decreased with an advancement in crop growth and development. Since leaf area is taken in account while computing NAR, the leaf area steadily increased with crop growth and maximum in 100% fertilizer treated plots, thereby causing a mutual shading of leaves in the canopy leading to lower NAR values at later stages.

Another parameter which is determined by the leaf area index of two consecutive growth stages is leaf area duration (LAD). The LAD was significantly higher in both the treatments i.e. in case of HG 563 variety and 100% RDF (NPK). Similar finding were observed by (Evans, 1975; Sinclair and Dewit 1976; Thandapani, 1985 and Goswami, 2000).

Leaf area fairly gives a good idea of the photosynthetic capacity of the plant. In the present study, the leaf area and leaf area index (LAI) increased up to 90 DAS and decreased thereafter due to senescence and ageing of leaves. In general, the varieties as well as application of NPK with or without vermicompost showed a profound effect over these parameters and significant differences were noticed among the varieties and fertility level treatments at all the growth stages. However, HG 563 and 100% RDF recorded significantly higher leaf area and LAI as compared to the remaining respective treatments at all the growth stages. These results are confirmed with the findings of (Gopal Singh *et al.* 1985 and Basuchandhani, 1987).

## **5.8 Yield attributing characters**

The factors which are directly responsible for ultimate grain production viz., number of pods / plant, length of pod, seeds/ pod, 1000-seed weight and seed weight/ plant were augmented almost significantly due to HG 563 variety over the other three clusterbean varieties. The maximum pods were 74.21/plant, pod length 5.47 cm, number of seeds 8.24/pod, 1000-seed weight 35.77g and seed weight 10.31 g/plant as well as stover weight 23.15 g/ plant (Table 6.2). The higher yield attributes in HG 563 may be owing to maximum increase in growth parameters (height and branches), root nodulation and biomass/plant as well as growth analysis parameters. The present findings on varietal differences are in consonance with those of other research workers (Anonymous 2001-02, Bhudhiraja *et al.*, 1998, Singh and Khan, 2002; Garg *et al.*, 2002; Rajput, 2002; D'almeida and Tikka, 2003;

Chaudhary *et al.*, 2005; Singh *et al.* 2005; Bhadoria and Kushwah, 2005; Sheoran and Rana, 2007; Kalyani *et al.*, 2011 and Singh *et al.*, 2013a).

The combined application of 75% RDF (N<sub>15</sub>P<sub>30</sub>K<sub>15</sub>)+ vermicompost (5 t/ha) resulted in almost significantly higher yield attributing parameters over other fertility treatments. The maximum pods were 86.31/plant, pod length 5.52 cm, number of seeds 8.19/pod, 1000-seed weight 34.69 g and seed weight 9.91 g/plant. The second best fertility levels was 100% RDF (N<sub>20</sub>P<sub>40</sub>K<sub>20</sub>) only. The higher yield attributes from these fertility levels may be due to increased growth and physiological (growth analysis) parameters as well as biomass /plant as a result of increased supply of all the essential plant nutrients as well as increased physico-chemical and biological properties of the soil. All these favourable situations might have resulted in greater accumulation of carbohydrates, proteins and their translocation from source to the sink (reproductive organs) which, in turn, increased the higher number of pods as well as other yield attributing parameters (Table 6.2).

These results pertaining to the best performance of 75% RDF + vermicompost on clusterbean are in close agreement with those numerous workers (Vasanthi and Subramanian, 2004; Barik *et al.*, 2008; Singh and Ahmad, 2010; Patel *et al.*, 2010; Rathore *et al.*, 2007a & b ; Rajkhowa *et al.*, 2003; Patel *et al.*, 2003; Singh, 2002; Kumar and Pal, 2010; Kumawat *et al.*, 2009; Sharma and Jain, 2012; Singh *et al.*, 2013a).

It is further mentioned that the improvement in yield components might have resulted from favourable influence of fertilizers on the growth attributes and efficient and greater partitioning of metabolites and adequate translocation of photosynthates and nutrients to developing reproductive structures. These results confirm the findings of Patra (1991), Yadav *et al.*, (1991), Choudhary *et al.*, (2003), Meena and Naagar (2004), Bhadoria and Kushwah (2005), Rathore *et al.*, (2007), Burman *et al.*, (2009) and Muhammad *et al.*, (2009).

## **5.9 Productivity parameters**

Each plant passes through the vegetative as well as reproductive phases of growth to complete its life cycle. Yield can be considered to be the final expression of the physiological and metabolic activities of plants and is governed by various

factors. These yield-attributing factors have direct bearing on plant productivity and for increasing the yield that means the number of pods/ plant, pod length, number of seeds/ pod, 1000-seed weight, seed yield/ plant, etc. play an important role.

The seed and stover yield (1944.63 and 4306.50 kg/ha) were found significantly higher in case of HG 563 variety of clusterbean. This may be due to higher yield attributing parameters in HG 563 variety. This was followed by RGC 1038 and RGC 1055 varieties which gave equal performance with respect to productivity parameters. The variety RGC 1017 produced the lowest seed (1302.06 kg/ha) and the stover (2866.56 kg/ha). There was no change in the harvest index except in second year. The seed yield is the resultant of coordinated interplay of growth and development characters. Thus the productivity parameters are based on the cumulative effect of the genetic ability and production efficiency of the varieties, their fertility management and the agro-climatic conditions where these varieties are grown. The wide variations in productivity parameters among the clusterbean varieties have also been observed by many researchers (Anonymous, 2001-02; Garg *et al.*, 2002; Vyas, 2002; Rajput, 2002; Garg *et al.*, 2003; D'almeida and Tikka, 2003; Chaudhary *et al.*, 2005; Singh *et al.*, 2005; Bhadoria and Kushwaha, 2005; Sheoran and Rana, 2007; Kalyani *et al.*, 2011 and Singh *et al.*, 2013a).

The combined influence of 75% RDF + vermicompost brought about significantly higher seed and stover yields (1952.06 and 4066.63 kg/ha, respectively) and proved to be significantly superior to the remaining fertility levels. Moreover, the best variety HG 563 grown with these fertility levels resulted in further enhancement in the productivity parameters synergistically. The trend of increases in seed and stover yields obtained due to these treatments was exactly in accordance with the similar increases in the yield-attributing characters *viz.*, pods/plant, pod length, seeds/pod, 1000-seed weight and grain yield/plant as well as increased vegetative growth. The increases in yield-attributing characters and consequently the seed yield of clusterbean and other pulses as a result of integrated nutrient management have also been reported by many research workers (Annual Report, 2002; Rajkhowa *et al.*, 2003; Vasanthi and Subramanian, 2004; Suthar, 2005; Meena *et al.*, 2008; Shah and Namdeo, 2009; Barik *et al.*, 2008; Singh and Ahmad, 2010; Kumar and Pal, 2010; Chaurasia *et al.*, 2009a; Patel *et al.*, 2010; Tiwari *et al.*, 2012 a; Sharma and Jain, 2012).

Since yield is the resultant of additive and complementary effect of plant growth and yield attributing parameters and the yield attributing characters had better expression at higher fertility level due to adequate quantity and balanced proportion of plant nutrient supplied during the crop growth period which ultimately led towards an increase in seed and stover yields. The beneficial effect of N, P and K in single as well as in combination with organics on legume crops were also reported by Yadav *et al.*, (1991), Shekhawat *et al.*, (2002), Singh and Khan (2002), Bhadoria and Kushwah (2005), Patel *et al.*, (2005), Rathore *et al.*, (2007) and Muhammad *et al.*, (2009) and Singh *et al.* (2013a).

The increase in stover yield due to various treatments may be mainly due to increases in the vegetative growth characters (plant height and branches/ plant) particularly pods/ plant as a result of such treatments. Under the higher supply of plant nutrients, clusterbean plants synthesized more photosynthates and the storage organ (seed) was better developed. The harvest index was also found to be significantly higher with the increased fertility levels. When higher fertility level was applied, the harvest index was further augmented. The higher harvest index under these treatments might be owing to the proportionately higher seed production per hectare over its stover.

#### **5.10 Economical gain**

The maximum net income per hectare after deduction of cost of cultivation is the ultimate goal of any farm owner or grain producer. Amongst the clusterbean varieties, HG 563 brought about the maximum net income (Rs. 1,78,151/ha) with B:C ratio 10.66. This was equally followed by RGC 1055 and then RGC 1038. The lowest net income (Rs. 1,13,169/ha and B:C ratio 7.11) were obtained from RGC 1017 variety. The net economical gain was secured in accordance with the per hectare yield of the varieties and thereby gross income (Table 4.67).

Amongst the fertility treatments, 75% RDF + VC resulted in maximum net income upto Rs. 1,77,089 /ha with B:C ratio 9.78. This was followed by 100% RDF (Rs. 1,60,739/ha with B:C ratio 9.81).

The overall picture, based on two years mean values, reflects the fact that 75% RDF + VC gave the extra net income by Rs. 47,183/ha as compared to the control where NPK was not applied. Moreover, 75% NPK + Vermicompost (5t/ha) would be advantageous in the long run because of the multifarious role of vermicompost for sustainable crop production and strengthening the soil fertility and health under eco-friendly environment. HG 563 grown with 75% RDF + VC further augmented net income upto Rs. 2,05,421/ha with B:C ratio up to 11.19.

### **5.11 Qualitative parameters**

Clusterbean seed is also used as concentrate for animal and for extraction of gum. Seeds contain 28 to 33% gum and has its use in almost all types of industries. The by product from gum extraction possesses a high value protein feed for cattle as it contains about 40% protein.

Amongst the clusterbean varieties, HG 563 recorded significantly higher, percentage of gum 30.94% (603.16 kg/ha) as well as protein 32.19% (627.36 kg/ha). This was followed by RGC 1038 variety and then RGC 1055.

The lowest gum and protein contents 30.51 and 31.21%, (398.13 and 432.58 kg/ha) were obtained from RGC 1017 variety. The significant variations in gum and protein contents in different varieties of clusterbean might be owing to differences in their genetic inheritance which is ultimately also responsible to such qualitative variations. Similar results have also been reported by Singh *et al.* (2013a) in case of lentil.

The different fertility levels having vermicompost also resulted in significant changes in the qualitative parameters. Accordingly 75% RDF + VC fertility level recorded significantly higher gum and protein percentages 31.59 & 32.62 %, (617.39 and 637.53 kg/ha) over the remaining fertility levels. This was followed by 100% RDF fertility level. The lowest qualitative parameters 30.11 and 30.64%, (433.81 and 442.55 kg/ha) were obtained from the control treatment ( $N_0P_0K_0$ ). The increase qualitative parameters may be attributed to significant role of organic and inorganic applied nutrients in regulating the photosynthesis, root enlargement and better microbial activities under favourable soil conditions (Prasad and Sanoria, 1981) which are responsible for enhanced protein and gum synthesis. The present

results corroborate with those of Meena and Nagar (2004), Ayub *et al.* (2010) and Ibrahim, *et al.* (2011), Singh *et al.* (2013 a) and Marko *et al.* (2013).

### **5.12 Uptake of nutrients by clusterbean.**

The summarized data in Table 6.5 indicate that the uptake of N, P and K per plant and per hectare by clusterbean varieties was found to differ significantly except in case of N and K uptake per plant. Thus amongst the varieties, HG 563 recorded significantly higher uptake of nutrients. The maximum of P uptake per plant was 0.32 g and N, P and K uptake per hectare was 214.4 kg N, 20.06 kg P and 138.22 kg K/ha. The maximum increase in the nutrients uptake by HG 563 variety may be owing to increased root shoot growth parameters and dry matter production and increased seed and stover yields. In this variety which was on account of better genetic attainment for these traits over other varieties. The second best variety was RGC 1038 and then RGC 1055. The significantly lowest nutrients uptake was recorded in RGC 1017 variety. The varietal differences on uptake of nutrients have also been reported by Singh *et al.* (2013 b).

Amongst the fertility treatments, 75% RDF + VC enhanced the N, P and K uptake i.e. 221.32, 20.43 and 137.39 kg/ha, respectively. This uptake was almost equal to that of 100 RDF alone. Both these treatments were found significantly superior to 50% RDF + VC and the control treatments. The higher uptake of N, P and K under both these treatments may be owing to increased total biomass (seed + stover) yields and N, P and K contents in seed and stover at this fertility level. The present results corroborate with the findings of several research workers (Meena and Nagar, 2004; Chaurasia *et al.*, 2009b; Tiwari *et al.*, 2012 b and Pandey *et al.*, 2012b; Singh *et al.*, 2013b and Marko *et al.*, 2013).

According to Yadav *et al.* (1991), the highest level of P resulted in the maximum uptake of N, P and K due to close inter-relationship between N and P metabolism in plant cell.

This makes one to think upon the fact that the combined input of eco-friendly organic source on nutrients (vermicompost 5t/ha) to the best variety of clusterbean (HG 563) is a must to ensure the maximum out put (profit) on a sustainable basis under maximum pollution free soil environment and economy in

the costly chemical fertilizers. Moreover due to fertility variations in different soil types, the response of clusterbean to direct fertilization is highly inconsistent, location specific and even site specific. Therefore it is important that the fertilization to clusterbean with N, P and K with organic nutrients must be made after having soil tests and the crop and the variety to be grown on that piece of land.

Under the present day of heavy soil pollution and serious awakening towards organic farming or integrated nutrient management, vermicompost would go a long way in bringing out the efficient and economical utilization of chemical fertilizers as well as in maintaining the soil health and soil fertility balance for sustainable productivity of clusterbean or other crops in this region.

## CHAPTER – VI

### SUMMARY AND CONCLUSION

The long-term use of chemical fertilizers is known to degrade the physico-chemical and biological properties of the soil. The organic sources of nutrients are gaining global importance in crop production and are required to be integrated with chemical fertilizers. The conjoint use of vermicompost with inorganic fertilizers enhances utilization of nutrients by the soil microbial process. Vermi compost is rich in macro-and micronutrients besides having plant growth promoting substances, humus forming microbes and nitrogen fixers (Bano *et al.*, 1987). The development of high-yielding genotypes of clusterbean has opened new era in its cultivation. The yield potential of such genotypes is governed by different production factors involving organic sources of nutrients with reduced chemical fertilizer application. The yield potential of different clusterbean varieties may differ under different agro-climatic conditions because of their inherent capacity. With this background the present investigation entitled “Effect of varieties and nutrients management on productivity, profitability and nutrient uptake of clusterbean” was carried out with the following objectives:

- To find out the suitable variety of clusterbean in respect of growth parameters, yield attributes and yield.
- To find out the suitable fertility level for clusterbean.
- To assess the uptake of nutrients by clusterbean varieties.
- To calculate the economics of different treatments.

The experiment was conducted during two *kharif* season 2011 and 2012 at the College of Agriculture Research Farm, Gwalior (M.P.). The soil of the experimental field was sandy loam having pH 8.0, organic carbon 4.56 g/kg, electrical conductivity 0.12 dS/m, available N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O 212.6, 15.7 and 286 kg/ha, respectively. The total rainfall received during 2011 and 2012 was 852.2 and 785.3 mm, respectively. The treatments comprised of four varieties (RCG-1017, RGC-1038, RGC-1055 and HG-563) and four fertility levels (control, 50% RDF + VC 5t/ha, 75% RDF +VC 5t/ha and 100% RDF, N<sub>20</sub>P<sub>40</sub>K<sub>20</sub>). Thus 16

treatment combinations were laid out in randomized-block design (factorial) keeping four replications. The crop varieties were sown on 25 July 2011 and 14 July, 2012 keeping a seed rate of 20 kg/ha and planting distance of 45×10 cm.

The crop was grown as per recommended package of practices in both the years. The varieties were harvested on 22.11.11 to 26.11.2011 and 15.11.12 to 21.11.2012. The periodical observations were recorded on growth parameters, growth analysis parameters, quantitative and qualitative parameters, nutrient uptake studies and economical gain as per prescribed procedures and formulae as detailed in materials and methods chapter.

The salient achievements of work and the main conclusion drawn from these studies are summarized as below:

- The significant varietal differences of clusterbean were noticed in growth parameters at 30, 60, 90 DAS and maturity stages. HG 563 recorded maximum plant height, branches/plant, length and weight of root as well as biomass/plant at every stage. This was followed by RGC 1038. The lowest values were obtained from RGC 1017 variety.
- The fertility levels exerted significant influence upon all the growth parameters at every stage. The best fertility level was 75% RDF ( $N_{15}P_{30}K_{15}$ ) + vermicompost 5t/ha which resulted in significantly higher plant height (107.90 cm), branches (8.26 /plant), root length (34.35cm), root weight (0.445 g) and root nodules (14.75/plant). This fertility level was significantly superior to the remaining fertility levels. However, the second best fertility level was 100% RDF ( $N_{20}P_{40}K_{20}$ ) with respect to all these characters. The treatment interactions were non-significant except in case of root-nodulation.
- Amongst the varieties, HG 563 recorded significantly higher number of root nodules (15.5 /plant), followed by RGC 1038 (12.87/plant). The lowest nodules number (8.87 to 9.12/plant) was noted in case of RGC 1017 and RGC 1055 varieties.
- Application of 75% RDF +VC recorded significantly higher nodules number (14.75/plant) as compared to the remaining fertility levels. However, the second best fertility level was 100% RDF alone (12.87 nodules/ plant). The best

treatment interaction was HG 563 grown with 75% RDF + VC; the value was significantly higher to those of remaining interactions.

- Out of four varieties of clusterbean, HG 563 resulted in significantly higher biomass per plant at every stage except at 30 DAS. However, the second best variety was RGC 1038 and then RGC 1055. The significantly lowest biomass production was found in variety RGC 1017. At maturity stage, the biomass was 47.28, 46.31, 44.23 and 43.29 g/plant from HG 563, RGC 1038, RGC 1055 and RGC 1017, respectively.
- All the fertility levels gave significantly rise in this parameter over control at every stage. The fertility level 75% RDF + VC or 100% RDF produced equally higher biomass/ plant at every stage. Both the fertility levels proved significantly superior to 50% RDF + VC and control treatments. At maturity stage, the biomass values were 49.35, 48.26, 44.86 and 38.75 g/plant from 75% RDF + VC, 100% RDF, 50% RDF + VC and control treatments, respectively. The treatment interactions were found non-significant for this parameter.
- The LAI, LAR, LAD, NAR, CGR, RGR and AGR increased up to 90 DAS and then decreased due to senescence and aging of leaves. The varieties and fertility levels exerted significant impact upon these parameters at every stage of observation. Amongst the varieties, HG 563 and amongst the fertility levels, 100% RDF ( $N_{20}P_{40}K_{20}$ ) recorded almost significantly higher growth analysis parameters at most of the stages. Amongst the varieties, the second best was RGC 1038, and amongst the fertility levels, the second best was 75% RDF + VC to augment these parameters. The lowest values were recorded in case of RGC 1017 variety, and  $N_0P_0K_0$  (Control) fertility level at all the stages.
- The number of pods (74.21/plant), pod length (5.47 cm), number of seeds (8.24/pod), 1000-seed weight (35.77g) and seed weight (10.31/plant) were augmented almost significantly in case of HG 563 variety over the other three clusterbean varieties. The second best variety was RGC 1038 and then RGC-1055. The lowest values of these parameters were recorded in case of RGC 1017 variety.
- The combined application of 75% RDF + VC resulted in almost significantly higher yield-attributing parameters over other fertility levels. The maximum pods

per plant (86.31/plant), pod length (5.52 cm), number of seeds per pod (8.19/pod), 1000-seed weight (34.69 g) and seed weight per plant (9.91 g/plant) were observed under above fertility level. The second best fertility level was 100% RDF ( $N_{20}P_{40}K_{20}$ ). The lowest yield attributes were obtained from the control treatment. The treatment interactions were almost non-significant in each case.

- The variety of clusterbean HG 563 recorded significantly higher grain yield (1944.63 kg/ha), stover yield (4306.50 kg/ha) but not the harvest index (31.04%). The second best variety was RGC 1038 and then RGC 1055. The significantly lowest values of these parameters were noted in case of RGC 1017 variety.
- The combined influence of 75% RDF + VC brought about significantly higher grain and stover yields but not harvest index and proved significantly superior to the remaining fertility levels. Moreover, HG 563 grown with both these fertility levels resulted in further enhancement in the productivity parameters synergistically (2060.50 to 2232.50 kg/ha seed yields and 4340.50 to 4581.50 kg/ha stover yields).
- Amongst the clusterbean varieties, HG 563 gave the maximum net income up to Rs. 178151/ha with B:C ratio 10.66. The second economically best variety was RGC 1038 and then RGC 1055. The lowest net income (113169/ha) and B:C ratio (7.11) were obtained from RGC 1017 variety. Amongst the fertility levels, 75% RDF + VC resulted in maximum net income up to Rs. 177089/ha with B:C ratio 9.78. This was followed by 100% RDF (Rs. 160739/ha) with B:C ratio 9.81. The control treatment ( $N_0P_0K_0$ ) gave the lowest net income (Rs. 129906/ha) and B:C ratio only 9.18. HG 563 grown with 75% RDF + VC further raised the net income (Rs. 205421/ha).
- Amongst the clusterbean varieties, HG 563 recorded significantly higher percentage of gum 30.94% (603.16 kg/ha) as well as protein 32.19% (627.36 kg/ha). This was followed by RGC 1038 variety and then RGC 1055. The lowest gum and protein contents 30.51 and 31.21%, (398.13 and 432.58 kg/ha) were obtained from RGC 1017 variety.
- The different fertility levels having vermicompost also resulted in significant changes in the qualitative parameters. Accordingly 75% RDF + VC recorded significantly higher gum and protein percentages, 31.59 (617.39) and 32.62%

(637,53 kg/ha), respectively over the remaining fertility levels. This was followed by 100% RDF fertility level. The lowest qualitative parameters 30.11 (433.81) and 30.64% (442.55 kg/ha), respectively) were obtained from the control ( $N_0P_0K_0$ ) treatment. HG 563 grown with 75% RDF + VC further enhanced the gum up to 32.04% (715.38 kg/ha) and protein up to 33.11% (739.35 kg/ha) based on pooled data.

- Amongst the varieties, HG 563 recorded significantly higher uptake of nutrient. The maximum P uptake per plant was 0.32g and N, P and K per hectare was 214.4 kg N, 20.06 kg P and 138.22 kg K/ha. This was equally followed by RGC 1038 and RGC 1055. The lowest nutrient uptake was observed in case of RGC 1017 variety.
- Amongst the fertility treatment, 75% RDF + VC enhanced the N, P and K uptake i.e. 221.32, 20.43 and 137.39 kg/ha, respectively. This uptake was almost equal to that of 100% RDF alone. Both these treatments were found significantly superior to 50% RDF + VC and the control treatments. The treatment interactions were found to be non-significant with respect to uptake of nutrients per plant or per hectare.

### **Conclusion**

- Based on two years mean data, it is alluded that amongst the clusterbean varieties, HG 563 recorded maximum growth and physiological parameters, yield and yield attributes, net income and quality parameters, N, P and K uptake per hectare. Thus HG 563 produced maximum 1944.63 kg/ha grain with net income up to Rs. 178151/ha as well as highest protein 32.19% (627.36 kg/ha) and gum up to 30.94% (603.16 kg/ha) in grain.
- Amongst the fertility treatments, 75% RDF ( $N_{15}P_{30}K_{15}$ ) with 5t/ha vermicompost raised all the above parameters upto maximum extent. The net income was highest Rs. 177089/ha with B:C ratio 9.78. The treatment interactions were non-significant for grain yield. For the sake of recommendation to the clusterbean growers in this region, HG 563 may be recommended with 75% NPK + 5t vermicompost /ha. For maintaining good soil health and sustainable crop productivity, vermicompost would be most beneficial in the long run. The net income would reduce only slightly.

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**APPENDIX- I a: Mean sum of squares for plant population during first year**

| Source of Variation | d.f. | Plant population / m row length at |          |
|---------------------|------|------------------------------------|----------|
|                     |      | 15 DAS                             | Maturity |
| Rep                 | 3    | 0.341                              | 0.398    |
| V                   | 3    | 0.041                              | 0.044    |
| F                   | 3    | 0.124                              | 0.159    |
| V*F                 | 9    | 0.086                              | 0.098    |
| Error               | 45   | 0.446                              | 0.336    |
| Total               | 63   | 0.355                              | 0.283    |

**APPENDIX- I b: Mean sum of squares for plant population during second year**

| Source of Variation | d.f. | Plant population / m row length at |          |
|---------------------|------|------------------------------------|----------|
|                     |      | 15 DAS                             | Maturity |
| Rep                 | 3    | 1.641                              | 1.003    |
| V                   | 3    | 0.019                              | 0.020    |
| F                   | 3    | 0.098                              | 0.173    |
| V*F                 | 9    | 0.102                              | 0.063    |
| Error               | 45   | 0.336                              | 0.284    |
| Total               | 63   | 0.338                              | 0.269    |

**APPENDIX- I c: Mean sum of squares for plant population pooled**

| Source of Variation | d.f.      | Plant population / m row length at |              |
|---------------------|-----------|------------------------------------|--------------|
|                     |           | 15 DAS                             | Maturity     |
| Year                | 1         | 0.197                              | 0.021        |
| Rep with year       | 6         | 0.991                              | 0.701        |
| <b><u>Treat</u></b> | <b>15</b> | <b>0.113</b>                       | <b>0.105</b> |
| V                   | 3         | 0.058                              | 0.038        |
| F                   | 3         | 0.187                              | 0.176        |
| V*F                 | 9         | 0.107                              | 0.103        |
| <b><u>Y*T</u></b>   | <b>15</b> | <b>0.056</b>                       | <b>0.071</b> |
| Y*V                 | 3         | 0.003                              | 0.027        |
| Y*F                 | 3         | 0.035                              | 0.155        |
| Y*V*F               | 9         | 0.081                              | 0.058        |
| Pooled Error        | 90        | 0.391                              | 0.310        |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- II a: Mean sum of squares for plant height during first year**

| Source of Variation | d.f. | Plant height (cm) at |            |            |            |
|---------------------|------|----------------------|------------|------------|------------|
|                     |      | 30 DAS               | 60 DAS     | 90 DAS     | Maturity   |
| Rep                 | 3    | 22.937               | 98.157     | 126.155    | 117.210    |
| V                   | 3    | 9.176 **             | 438.449**  | 417.848**  | 394.743**  |
| F                   | 3    | 56.367 **            | 1171.922** | 1256.090** | 1282.799** |
| V*F                 | 9    | 5.224 **             | 30.335**   | 25.572**   | 22.670**   |
| Error               | 45   | 5.483                | 14.819     | 14.021     | 13.641     |
| Total               | 63   | 8.876                | 96.277     | 99.387     | 98.447     |

**APPENDIX- II b: Mean sum of squares for plant height during second year**

| Source of Variation | d.f. | Plant height (cm) at |           |           |           |
|---------------------|------|----------------------|-----------|-----------|-----------|
|                     |      | 30 DAS               | 60 DAS    | 90 DAS    | Maturity  |
| Rep                 | 3    | 15.987               | 40.878    | 40.198    | 46.947    |
| V                   | 3    | 9.867**              | 214.836** | 224.515** | 221.870** |
| F                   | 3    | 53.005**             | 450.266** | 457.895** | 487.818** |
| V*F                 | 9    | 3.830**              | 9.751**   | 10.505**  | 11.889**  |
| Error               | 45   | 4.228                | 55.210    | 57.984    | 65.032    |
| Total               | 63   | 7.322                | 74.447    | 77.328    | 84.180    |

**APPENDIX- II c: Mean sum of squares for plant height pooled**

| Source of Variation | d.f.      | Plant height (cm) at |                |                |                |
|---------------------|-----------|----------------------|----------------|----------------|----------------|
|                     |           | 30 DAS               | 60 DAS         | 90 DAS         | Maturity       |
| <b>Year</b>         | 1         | 127.600              | 2913.700       | 2641.736       | 4197.570       |
| Rep with year       | 6         | 19.462               | 69.518         | 83.177         | 82.079         |
| <b><u>Treat</u></b> | <b>15</b> | <b>31.042</b>        | <b>434.301</b> | <b>446.952</b> | <b>453.925</b> |
| V                   | 3         | 19.035**             | 574.744**      | 566.683**      | 547.170**      |
| F                   | 3         | 109.345**            | 1533.363**     | 1610.007**     | 1668.167**     |
| V*F                 | 9         | 8.943**              | 21.132**       | 19.356**       | 18.096**       |
| <b><u>Y*T</u></b>   | <b>15</b> | <b>0.074</b>         | <b>44.845</b>  | <b>45.964</b>  | <b>44.256</b>  |
| Y*V                 | 3         | 0.008                | 78.541**       | 75.680**       | 69.443**       |
| Y*F                 | 3         | 0.027                | 88.825**       | 103.979**      | 102.450**      |
| Y*V*F               | 9         | 0.111                | 18.954**       | 16.720**       | 16.463**       |
| Pooled Error        | 90        | 4.855                | 35.015         | 36.002         | 39.336         |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- III a: Mean sum of squares for number of branches / plant during first year**

| Source of Variation | d.f. | Branches / plant at |          |          |          |
|---------------------|------|---------------------|----------|----------|----------|
|                     |      | 30 DAS              | 60 DAS   | 90 DAS   | Maturity |
| Rep                 | 3    | 1.157               | 3.644    | 1.342    | 1.342    |
| V                   | 3    | 2.218               | 7.169**  | 0.027    | 0.027    |
| F                   | 3    | 3.672*              | 12.942** | 20.667** | 20.667** |
| V*F                 | 9    | 0.064               | 0.280    | 0.186    | 0.186    |
| Error               | 45   | 0.117               | 0.433    | 0.436    | 0.436    |
| Total               | 63   | 0.428               | 1.481    | 1.387    | 1.387    |

**APPENDIX- III b: Mean sum of squares for number of branches /plant during second year**

| Source of Variation | d.f. | Branches / plant at |          |          |          |
|---------------------|------|---------------------|----------|----------|----------|
|                     |      | 30 DAS              | 60 DAS   | 90 DAS   | Maturity |
| Rep                 | 3    | 0.127               | 0.303    | 1.891    | 1.891    |
| V                   | 3    | 1.630               | 7.136**  | 4.615**  | 4.615**  |
| F                   | 3    | 3.740*              | 13.563** | 14.125** | 14.125** |
| V*F                 | 9    | 0.042               | 0.123    | 0.733    | 0.733    |
| Error               | 45   | 0.059               | 0.172    | 0.425    | 0.425    |
| Total               | 63   | 0.310               | 1.140    | 1.391    | 1.391    |

**APPENDIX- III c: Mean sum of squares for number of branches / plant pooled**

| Source of Variation | d.f.      | Branches / plant at |              |              |              |
|---------------------|-----------|---------------------|--------------|--------------|--------------|
|                     |           | 30 DAS              | 60 DAS       | 90 DAS       | Maturity     |
| <b>Year</b>         | 1         | 0.033               | 0.095        | 0.618        | 0.618        |
| Rep with year       | 6         | 0.642               | 1.974        | 1.616        | 1.616        |
| <b><u>Treat</u></b> | <b>15</b> | <b>2.292</b>        | <b>8.352</b> | <b>7.346</b> | <b>7.346</b> |
| V                   | 3         | 3.799*              | 14.221**     | 2.052        | 2.052        |
| F                   | 3         | 7.385**             | 26.485**     | 33.762**     | 33.762**     |
| V*F                 | 9         | 0.091               | 0.351        | 0.304        | 0.304        |
| <b><u>Y*T</u></b>   | <b>15</b> | <b>0.024</b>        | <b>0.052</b> | <b>1.092</b> | <b>1.092</b> |
| Y*V                 | 3         | 0.049               | 0.084        | 2.590        | 2.590        |
| Y*F                 | 3         | 0.027               | 0.021        | 1.030        | 1.030        |
| Y*V*F               | 9         | 0.015               | 0.052        | 0.614        | 0.614        |
| Pooled Error        | 90        | 0.088               | 0.303        | 0.430        | 0.430        |

\* Significant at p=0.05

\*\* Significant at p=0.01

#### APPENDIX- IV a: Mean sum of squares for AGR during first year

| Source of Variation | d.f. | AGR (g/day) at |           |           |             |
|---------------------|------|----------------|-----------|-----------|-------------|
|                     |      | 0-30 DAS       | 30-60 DAS | 60-90 DAS | 90-Maturity |
| Rep                 | 3    | 0.0003         | 0.0173    | 0.0013    | 0.0008      |
| V                   | 3    | 0.0006         | 0.0022    | 0.0177    | 0.0095      |
| F                   | 3    | 0.0003         | 0.0015    | 0.0170    | 0.0128      |
| V*F                 | 9    | 1.625E-05      | 5.6889**  | 0.0012    | 0.0003      |
| Error               | 45   | 2.9347         | 0.0005    | 0.0003    | 0.0002      |
| Total               | 63   | 8.5361         | 0.0014    | 0.0021    | 0.0013      |
| Pooled Error        | 90   | 0.0003         | 0.0173    | 0.0013    | 0.0008      |

#### APPENDIX- IV b: Mean sum of squares for AGR during second year

| Source of Variation | d.f. | AGR (g/day) at |           |           |             |
|---------------------|------|----------------|-----------|-----------|-------------|
|                     |      | 0-30 DAS       | 30-60 DAS | 60-90 DAS | 90-Maturity |
| Rep                 | 3    | 0.0005         | 0.0022    | 0.0015    | 0.0005      |
| V                   | 3    | 0.0004         | 0.0012    | 0.0177    | 0.0092      |
| F                   | 3    | 0.0002         | 0.0007    | 0.0171    | 0.0123      |
| V*F                 | 9    | 6.3403**       | 5.5833    | 0.0012    | 0.0002      |
| Error               | 45   | 0.0001         | 2.3481    | 2.07E-05  | 0.0004      |
| Total               | 63   | 0.0001         | 0.0002    | 0.0019    | 0.0014      |

#### APPENDIX- IV c: Mean sum of squares for AGR pooled

| Source of Variation | d.f.      | AGR (g/day) at |               |                 |                 |
|---------------------|-----------|----------------|---------------|-----------------|-----------------|
|                     |           | 0-30 DAS       | 30-60 DAS     | 60-90 DAS       | 90-Maturity     |
| Year                | 1         | 0.0005         | 5.5125        | 0.0005          | 0.0005          |
| Rep with year       | 6         | 0.0004         | 0.0097        | 0.0014          | 0.0006          |
| <b><u>Treat</u></b> | <b>15</b> | <b>0.0003</b>  | <b>0.0010</b> | <b>0.0154</b>   | <b>0.0091</b>   |
| V                   | 3         | 0.0009         | 0.0031        | 0.0355          | 0.0188          |
| F                   | 3         | 0.0005         | 0.0021        | 0.0341          | 0.0251          |
| V*F                 | 9         | 1.6420         | 2.3236 *      | 0.0025          | 0.0006          |
| <b><u>Y*T</u></b>   | <b>15</b> | <b>1.0747</b>  | <b>8.8458</b> | <b>1.25E-07</b> | <b>1.55E-06</b> |
| Y*V                 | 3         | 2.6364         | 0.0002        | 1.25E-07        | 1.125E-06       |
| Y*F                 | 3         | 8.8645 **      | 9.7125 **     | 1.25E-07        | 2.7083          |
| Y*V*F               | 9         | 6.1701 **      | 3.9236 **     | 1.25E-07        | 1.3055          |
| Pooled Error        | 90        | 6.6784         | 0.0003        | 0.0001          | 0.0002          |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- V a: Mean sum of squares for CGR during first year**

| Source of Variation | d.f. | CGR (g/dm <sup>2</sup> /day) at |           |           |             |
|---------------------|------|---------------------------------|-----------|-----------|-------------|
|                     |      | 0-30 DAS                        | 30-60 DAS | 60-90 DAS | 90-Maturity |
| Rep                 | 3    | 12.236                          | 42.623    | 52.463    | 157.213     |
| V                   | 3    | 0.338                           | 0.348     | 5.906**   | 5.766**     |
| F                   | 3    | 0.260                           | 0.237     | 8.119**   | 31.004**    |
| V*F                 | 9    | 0.005                           | 0.002     | 0.295     | 0.194       |
| Error               | 45   | 3.017                           | 14.265    | 14.344    | 10.005      |
| Total               | 63   | 2.767                           | 12.247    | 13.454    | 16.412      |

**APPENDIX- V b: Mean sum of squares for CGR during second year**

| Source of Variation | d.f. | CGR (g/dm <sup>2</sup> /day) at |           |           |             |
|---------------------|------|---------------------------------|-----------|-----------|-------------|
|                     |      | 0-30 DAS                        | 30-60 DAS | 60-90 DAS | 90-Maturity |
| Rep                 | 3    | 6.106                           | 31.539    | 111.592   | 70.684      |
| V                   | 3    | 0.394                           | 0.357     | 6.155**   | 7.474**     |
| F                   | 3    | 0.162                           | 0.243     | 9.803**   | 28.924**    |
| V*F                 | 9    | 0.019                           | 0.002     | 0.320     | 0.496       |
| Error               | 45   | 1.434                           | 21.113    | 14.251    | 9.677       |
| Total               | 63   | 1.344                           | 16.611    | 16.299    | 12.083      |

**APPENDIX- V c: Mean sum of squares for CGR pooled**

| Source of Variation | d.f.      | CGR (g/dm <sup>2</sup> /day) at |              |              |               |
|---------------------|-----------|---------------------------------|--------------|--------------|---------------|
|                     |           | 0-30 DAS                        | 30-60 DAS    | 60-90 DAS    | 90-Maturity   |
| <b>Year</b>         | 1         | 0.103                           | 0.101        | 5.780        | 1.280         |
| Rep with year       | 6         | 9.171                           | 37.081       | 82.028       | 113.948       |
| <b><u>Treat</u></b> | <b>15</b> | <b>0.237</b>                    | <b>0.239</b> | <b>6.354</b> | <b>14.950</b> |
| V                   | 3         | 0.724                           | 0.705        | 12.051**     | 13.151**      |
| F                   | 3         | 0.414                           | 0.480        | 17.880**     | 59.845**      |
| V*F                 | 9         | 0.016                           | 0.004        | 0.613        | 0.585         |
| <b><u>Y*T</u></b>   | <b>15</b> | <b>0.008</b>                    | <b>5E-05</b> | <b>0.012</b> | <b>0.098</b>  |
| Y*V                 | 3         | 0.008                           | 5E-05**      | 0.010        | 0.090         |
| Y*F                 | 3         | 0.008                           | 1.67E-05     | 0.043        | 0.083         |
| Y*V*F               | 9         | 0.008                           | 6.11E-05**   | 0.002        | 0.106         |
| Pooled Error        | 90        | 2.225                           | 17.689       | 14.298       | 9.841         |

\* Significant at p=0.05

\*\* Significant at p=0.01

# **APPENDIX- VI a: Mean sum of squares for RGR during first year**

| Source of Variation | d.f. | RGR (g/g/day) at |          |         |          |
|---------------------|------|------------------|----------|---------|----------|
|                     |      | 30 DAS           | 60 DAS   | 90 DAS  | Maturity |
| Rep                 | 3    | 4.4739           | 3.5156   | 2.1822  | 2.1406   |
| V                   | 3    | 0.0002           | 0.0003   | 0.0002  | 3.9468** |
| F                   | 3    | 0.0001           | 0.0003   | 0.0003  | 1.9823   |
| V*F                 | 9    | 3.5572**         | 4.3906** | 2.7656* | 3.4890** |
| Error               | 45   | 5.6295           | 3.9045   | 6.3267  | 5.4406   |
| Total               | 63   | 2.0008           | 3.3168   | 2.7833  | 1.2216   |

# **APPENDIX- VI b: Mean sum of squares for RGR during second year**

| Source of Variation | d.f. | RGR (g/g/day) at |           |            |             |
|---------------------|------|------------------|-----------|------------|-------------|
|                     |      | 30 DAS           | 60 DAS    | 90 DAS     | Maturity    |
| Rep                 | 3    | 5.887E-05        | 0.0011    | 0.0007     | 5.615E-06   |
| V                   | 3    | 0.0002           | 0.0003    | 0.0002     | 4.949E-06** |
| F                   | 3    | 9.633E-05**      | 0.0003    | 0.0003     | 1.982E-05   |
| V*F                 | 9    | 1E-06            | 6E-06**   | 3.67E-06** | 5.069E-07** |
| Error               | 45   | 2.465E-05        | 2.411E-06 | 1.08E-06   | 8.778E-09   |
| Total               | 63   | 3.259E-05        | 8.527E-05 | 5.64E-05   | 1.525E-06   |

# **APPENDIX- VI c: Mean sum of squares for RGR pooled**

| Source of Variation | d.f.      | RGR (g/g/day) at |               |               |               |
|---------------------|-----------|------------------|---------------|---------------|---------------|
|                     |           | 30 DAS           | 60 DAS        | 90 DAS        | Maturity      |
| Year                | 1         | 0.0001           | 0.0001        | 0.0001        | 2.7103        |
| Rep with year       | 6         | 3.1674           | 0.0005        | 0.0003        | 2.8182        |
| <b>Treat</b>        | <b>15</b> | <b>0.0001</b>    | <b>0.0002</b> | <b>0.0001</b> | <b>1.0168</b> |
| V                   | 3         | 0.0003           | 0.0006        | 0.0003        | 8.8457 **     |
| F                   | 3         | 0.0002           | 0.0006        | 0.0005        | 3.9567 *      |
| V*F                 | 9         | 3.8480**         | 9.7786 **     | 6.1467 **     | 8.1035 **     |
| <b>Y*T</b>          | <b>15</b> | <b>9.6614</b>    | <b>5.7864</b> | <b>3.4947</b> | <b>5.1703</b> |
| Y*V                 | 3         | 1.9244           | 7.9947 **     | 4.8697 **     | 5.0286 **     |
| Y*F                 | 3         | 7.7864 **        | 2.5781        | 4.0364 **     | 7.1744 **     |
| Y*V*F               | 9         | 7.0920**         | 6.1197 **     | 2.8559 **     | 4.5494 **     |
| Pooled Error        | 90        | 1.5141           | 3.1578        | 3.7036        | 3.1592        |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- VII a: Mean sum of squares for LAI during first year**

| Source of Variation | d.f. | LAI      |           |           |             |
|---------------------|------|----------|-----------|-----------|-------------|
|                     |      | 0-30 DAS | 30-60 DAS | 60-90 DAS | 90-Maturity |
| Rep                 | 3    | 0.0014   | 0.0006    | 0.0122    | 0.0033      |
| V                   | 3    | 0.0007   | 0.2334    | 0.2941    | 0.0082      |
| F                   | 3    | 0.0027   | 0.1241    | 0.3785    | 0.0188      |
| V*F                 | 9    | 0.0004   | 0.0054    | 0.0078    | 0.0004      |
| Error               | 45   | 0.0005   | 0.0007    | 0.0006    | 0.0007      |
| Total               | 63   | 0.0006   | 0.0183    | 0.0342    | 0.0020      |

**APPENDIX- VII b: Mean sum of squares for LAI during second year**

| Source of Variation | d.f. | LAI      |           |           |             |
|---------------------|------|----------|-----------|-----------|-------------|
|                     |      | 0-30 DAS | 30-60 DAS | 60-90 DAS | 90-Maturity |
| Rep                 | 3    | 0.0006   | 0.0014    | 0.0053    | 0.0037      |
| V                   | 3    | 0.0034   | 0.2435    | 0.3136    | 0.0060      |
| F                   | 3    | 0.0032   | 0.1434    | 0.4066    | 0.0225      |
| V*F                 | 9    | 0.0009   | 0.0068    | 0.0076    | 0.0005      |
| Error               | 45   | 0.0003   | 0.0007    | 0.0011    | 0.0006      |
| Total               | 63   | 0.0007   | 0.0199    | 0.0364    | 0.0020      |

**APPENDIX- VII c: Mean sum of squares for LAI pooled**

| Source of Variation | d.f.      | LAI           |               |               |               |
|---------------------|-----------|---------------|---------------|---------------|---------------|
|                     |           | 0-30 DAS      | 30-60 DAS     | 60-90 DAS     | 90-Maturity   |
| <b>Year</b>         | <b>1</b>  | <b>0.0001</b> | <b>0.0144</b> | <b>0.0341</b> | <b>0.0098</b> |
| Rep with year       | 6         | 0.0009        | 0.0010        | 0.0087        | 0.0035        |
| <b>Treat</b>        | <b>15</b> | <b>0.0022</b> | <b>0.1560</b> | <b>0.2877</b> | <b>0.0116</b> |
| V                   | 3         | 0.0036        | 0.4768        | 0.6075        | 0.0142        |
| F                   | 3         | 0.0058        | 0.2671        | 0.7848        | 0.0413        |
| V*F                 | 9         | 0.0005        | 0.0120        | 0.0154        | 0.0008        |
| <b>Y*T</b>          | <b>15</b> | <b>0.0006</b> | <b>0.0001</b> | <b>0.0001</b> | <b>6.6667</b> |
| Y*V                 | 3         | 0.0005        | 8.3333 **     | 0.0002        | 1E-04         |
| Y*F                 | 3         | 8.8281**      | 0.00035       | 0.0003        | 0.0001        |
| Y*V*F               | 9         | 0.0008        | 0.00016       | 8.967E-05**   | 4.4444**      |
| Pooled Error        | 90        | 0.0004        | 0.0006        | 0.0009        | 0.0007        |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX –VIII a: Mean sum of squares for LAR during first year**

| Source of Variation | d.f. | LAR (dm <sup>2</sup> /g) at |           |           |             |
|---------------------|------|-----------------------------|-----------|-----------|-------------|
|                     |      | 0-30 DAS                    | 30-60 DAS | 60-90 DAS | 90-Maturity |
| Rep                 | 3    | 0.0092                      | 0.0021    | 0.0440    | 0.1323      |
| V                   | 3    | 0.5428                      | 0.2980    | 0.3989    | 0.1911      |
| F                   | 3    | 0.4104                      | 0.7266    | 2.7073    | 0.7214      |
| V*F                 | 9    | 0.0070                      | 0.0023    | 0.0162    | 0.0042      |
| Error               | 45   | 0.0019                      | 0.0073    | 0.0013    | 0.0039      |
| Total               | 63   | 0.0482                      | 0.0544    | 0.1533    | 0.0531      |

**APPENDIX –VIII b: Mean sum of squares for LAR during second year**

| Source of Variation | d.f. | LAR (dm <sup>2</sup> /g) at |           |           |             |
|---------------------|------|-----------------------------|-----------|-----------|-------------|
|                     |      | 0-30 DAS                    | 30-60 DAS | 60-90 DAS | 90-Maturity |
| Rep                 | 3    | 0.0231                      | 0.0034    | 0.0383    | 0.2324      |
| V                   | 3    | 0.5193                      | 0.3304    | 0.3913    | 0.1850      |
| F                   | 3    | 0.4157                      | 0.8062    | 2.8608*   | 0.7634      |
| V*F                 | 9    | 0.0045                      | 0.0033    | 0.0135    | 0.0055      |
| Error               | 45   | 0.0077                      | 0.0052    | 0.0043    | 0.0003      |
| Total               | 63   | 0.0518                      | 0.0585    | 0.1617    | 0.0572      |

**APPENDIX –VIII c: Mean sum of squares for LAR pooled**

| Source of Variation | d.f.      | LAR (dm <sup>2</sup> /g) at |               |               |               |
|---------------------|-----------|-----------------------------|---------------|---------------|---------------|
|                     |           | 0-30 DAS                    | 30-60 DAS     | 60-90 DAS     | 90-Maturity   |
| Year                | 1         | 0.0670                      | 0.0924        | 0.0882        | 0.0990        |
| Rep with year       | 6         | 0.0161                      | 0.0027        | 0.0412        | 0.1824        |
| <b>Treat</b>        | <b>15</b> | <b>0.3837</b>               | <b>0.4346</b> | <b>1.2888</b> | <b>0.3779</b> |
| V                   | 3         | 1.0608                      | 0.6258        | 0.7895        | 0.3761        |
| F                   | 3         | 0.8256                      | 1.5318        | 5.5665**      | 1.4846        |
| V*F                 | 9         | 0.0107                      | 0.0051        | 0.0292        | 0.0096        |
| <b>Y*T</b>          | <b>15</b> | <b>0.0009</b>               | <b>0.0011</b> | <b>0.0007</b> | <b>0.0001</b> |
| Y*V                 | 3         | 0.0013                      | 0.0026        | 0.0007        | 4.5833**      |
| Y*F                 | 3         | 0.0005                      | 0.0011        | 0.0016        | 0.0003        |
| Y*V*F               | 9         | 0.0008                      | 0.0005        | 0.0005        | 0.0001        |
| Pooled Error        | 90        | 0.0048                      | 0.0062        | 0.0028        | 0.0021        |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- IX a: Mean sum of squares for LAD during first year**

| Source of Variation | d.f. | LAD (days) at |            |             |
|---------------------|------|---------------|------------|-------------|
|                     |      | 30-60 DAS     | 60-90 DAS  | 90-Maturity |
| Rep                 | 3    | 0.1304        | 11.2648    | 60.2096     |
| V                   | 3    | 18.9059**     | 110.1229** | 46.8827**   |
| F                   | 3    | 72.2449**     | 238.1307** | 150.3992**  |
| V*F                 | 9    | 0.6702        | 4.3330**   | 0.2591      |
| Error               | 45   | 0.0056        | 0.6011     | 7.8476      |
| Total               | 63   | 4.4465        | 18.1683    | 17.9040     |

**APPENDIX- IX b: Mean sum of squares for LAD during second year**

| Source of Variation | d.f. | LAD (days) at |            |             |
|---------------------|------|---------------|------------|-------------|
|                     |      | 30-60 DAS     | 60-90 DAS  | 90-Maturity |
| Rep                 | 3    | 1.3948        | 14.6033    | 133.8140    |
| V                   | 3    | 18.9879**     | 116.0040** | 46.1049**   |
| F                   | 3    | 72.3887**     | 239.5564** | 149.6879**  |
| V*F                 | 9    | 0.6059        | 4.5517**   | 0.2280      |
| Error               | 45   | 0.1713        | 11.7690    | 1.1070      |
| Total               | 63   | 4.6266        | 26.6835    | 16.5189     |

**APPENDIX- IX c: Mean sum of squares for LAD pooled**

| Source of Variation | d.f.      | LAD (days) at  |                 |                |
|---------------------|-----------|----------------|-----------------|----------------|
|                     |           | 30-60 DAS      | 60-90 DAS       | 90-Maturity    |
| <b>Year</b>         | <b>1</b>  | 0.4560         | 1.7367          | 1.1973         |
| Rep with year       | 6         | 0.7626         | 12.9340         | 97.0118        |
| <b>Treat</b>        | <b>15</b> | <b>37.2642</b> | <b>145.9278</b> | <b>78.8951</b> |
| V                   | 3         | 37.8903**      | 225.9026**      | 92.9687**      |
| F                   | 3         | 144.6335**     | 477.5968**      | 300.0774**     |
| V*F                 | 9         | 1.2658         | 8.7132**        | 0.4765         |
| <b>Y*T</b>          | <b>15</b> | <b>0.0069</b>  | <b>0.1658</b>   | <b>0.0121</b>  |
| Y*V                 | 3         | 0.0035         | 0.2242          | 0.0189         |
| Y*F                 | 3         | 0.0001         | 0.0902          | 0.0095         |
| Y*V*F               | 9         | 0.0103         | 0.1716          | 0.0106         |
| Pooled Error        | 90        | 0.0884         | 6.1850          | 4.4773         |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- X a: Mean sum of squares for NAR during first year**

| Source of Variation | d.f. | NAR (g/dm <sup>2</sup> /day) at |           |             |
|---------------------|------|---------------------------------|-----------|-------------|
|                     |      | 30-60 DAS                       | 60-90 DAS | 90-Maturity |
| Rep                 | 3    | 0.0021                          | 0.0007    | 0.0012      |
| V                   | 3    | 0.0006                          | 8.2916**  | 0.0103      |
| F                   | 3    | 0.0013                          | 0.0001    | 0.0115      |
| V*F                 | 9    | 2.3444*                         | 2.6944*   | 6.0694**    |
| Error               | 45   | 0.0004                          | 2.1944    | 3.6841      |
| Total               | 63   | 0.0005                          | 6.3900    | 0.0011      |

**APPENDIX- X b: Mean sum of squares for NAR during second year**

| Source of Variation | d.f. | NAR (g/dm <sup>2</sup> /day) at |           |             |
|---------------------|------|---------------------------------|-----------|-------------|
|                     |      | 30-60 DAS                       | 60-90 DAS | 90-Maturity |
| Rep                 | 3    | 0.0115                          | 0.0013    | 0.0020      |
| V                   | 3    | 0.0007                          | 9.3140**  | 0.0110      |
| F                   | 3    | 0.0014                          | 0.0001    | 0.0113      |
| V*F                 | 9    | 2.3474*                         | 3.0572**  | 0.0001      |
| Error               | 45   | 0.0002                          | 3.9562    | 1.55E-06    |
| Total               | 63   | 0.0008                          | 0.0001    | 0.0011      |

**APPENDIX- X c: Mean sum of squares for NAR pooled**

| Source of Variation | d.f.      | NAR (g/dm <sup>2</sup> /day) at |               |               |
|---------------------|-----------|---------------------------------|---------------|---------------|
|                     |           | 30-60 DAS                       | 60-90 DAS     | 90-Maturity   |
| Year                | 1         | 0.0003                          | 0.0001        | 0.0008        |
| Rep with year       | 6         | 0.0068                          | 0.0010        | 0.0016        |
| <b>Treat</b>        | <b>15</b> | <b>0.0008</b>                   | <b>8.9891</b> | <b>0.0089</b> |
| V                   | 3         | 0.0013                          | 0.0001        | 0.0213        |
| F                   | 3         | 0.0028                          | 0.0002        | 0.0229        |
| V*F                 | 9         | 4.3556**                        | 4.0078**      | 0.0001        |
| <b>Y*T</b>          | <b>15</b> | <b>3.0786</b>                   | <b>1.4828</b> | <b>1.1058</b> |
| Y*V                 | 3         | 3.2369**                        | 1.1745        | 1.7458        |
| Y*F                 | 3         | 2.0703                          | 1.0078        | 1.0458        |
| Y*V*F               | 9         | 3.3619**                        | 1.7439        | 9.125E-06**   |
| Pooled Error        | 90        | 0.0003                          | 3.0754        | 1.9195        |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- XI a: Mean sum of squares for biomass / plant (g) during first year**

| Source of Variation | d.f. | Biomass / plant (g) at |          |           |            |
|---------------------|------|------------------------|----------|-----------|------------|
|                     |      | 30 DAS                 | 60 DAS   | 90 DAS    | Maturity   |
| Rep                 | 3    | 0.2500                 | 0.8534   | 2.3378    | 52.2327    |
| V                   | 3    | 0.0545                 | 9.1142** | 57.9268** | 51.8296**  |
| F                   | 3    | 1.8239                 | 2.8047   | 86.6927** | 364.1381** |
| V*F                 | 9    | 0.0024                 | 0.2521   | 1.0752    | 1.3493     |
| Error               | 45   | 0.1918                 | 0.6672   | 6.2865    | 5.2819     |
| Total               | 63   | 0.2387                 | 1.1208   | 11.6419   | 26.2608    |

**APPENDIX- XI b: Mean sum of squares for biomass / plant (g) during second year**

| Source of Variation | d.f. | Biomass / plant (g) at |          |            |            |
|---------------------|------|------------------------|----------|------------|------------|
|                     |      | 30 DAS                 | 60 DAS   | 90 DAS     | Maturity   |
| Rep                 | 3    | 0.1576                 | 0.8780   | 3.5359     | 7.5616     |
| V                   | 3    | 0.0613                 | 9.1904** | 52.7516**  | 52.0489**  |
| F                   | 3    | 1.8117                 | 2.8529*  | 107.8270** | 364.6074** |
| V*F                 | 9    | 0.0035                 | 0.2566   | 1.5427     | 1.3408     |
| Error               | 45   | 0.1825                 | 0.5008   | 4.0549     | 9.9970     |
| Total               | 63   | 0.2276                 | 1.0096   | 10.9317    | 27.5331    |

**APPENDIX- XI c: Mean sum of squares for biomass / plant (g) pooled**

| Source of Variation | d.f.      | Biomass / plant (g) at |               |                |                 |
|---------------------|-----------|------------------------|---------------|----------------|-----------------|
|                     |           | 30 DAS                 | 60 DAS        | 90 DAS         | Maturity        |
| <b>Year</b>         | <b>1</b>  | 0.0315                 | 0.0717        | 0.0630         | 0.1519          |
| Rep with year       | 6         | 0.2038                 | 0.8657        | 2.9368         | 29.8971         |
| <b>Treat</b>        | <b>15</b> | <b>0.7537</b>          | <b>5.0968</b> | <b>62.4275</b> | <b>168.1388</b> |
| V                   | 3         | 0.1156                 | 18.3040**     | 110.5824       | 103.8784**      |
| F                   | 3         | 3.6354*                | 5.6571**      | 193.8718       | 728.7454**      |
| V*F                 | 9         | 0.0059                 | 0.5076        | 2.5611*        | 2.6900**        |
| <b>Y*T</b>          | <b>15</b> | <b>0.0002</b>          | <b>0.0009</b> | <b>0.1829</b>  | <b>0.0001</b>   |
| Y*V                 | 3         | 0.0003                 | 0.0006        | 0.0960         | 0.0001          |
| Y*F                 | 3         | 0.0003                 | 0.0004        | 0.6478         | 0.0001          |
| Y*V*F               | 9         | 0.0001                 | 0.0011        | 0.0569         | 0.0001          |
| Pooled Error        | 90        | 0.1872                 | 0.5840        | 5.1707         | 7.6394          |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- XII a: Mean sum of squares for yield attributing characters during first year**

| Source of Variation | d.f. | Pods/plant  | Pod length(cm) | Seeds/pod |
|---------------------|------|-------------|----------------|-----------|
| Rep                 | 3    | 28.8404     | 0.2194         | 0.0429    |
| V                   | 3    | 349.0071**  | 0.9792         | 1.0548    |
| F                   | 3    | 2697.8190** | 1.1479         | 2.1610    |
| V*F                 | 9    | 27.8505**   | 0.0559         | 0.1614    |
| Error               | 45   | 32.4520     | 0.2749         | 0.0222    |
| Total               | 63   | 173.6190    | 0.3161         | 0.1941    |

**APPENDIX- XII b: Mean sum of squares for yield attributing characters during second year**

| Source of Variation | d.f. | Pods/plant  | Pod length(cm) | Seeds/pod |
|---------------------|------|-------------|----------------|-----------|
| Rep                 | 3    | 30.3632     | 0.3549         | 0.0348    |
| V                   | 3    | 299.2408**  | 0.6853         | 0.9739    |
| F                   | 3    | 2632.7850** | 1.1481         | 0.5781    |
| V*F                 | 9    | 26.3418**   | 0.1020         | 0.0425    |
| Error               | 45   | 33.1343     | 0.4462         | 0.0191    |
| Total               | 63   | 168.4967    | 0.4375         | 0.0953    |

**APPENDIX- XII c: Mean sum of squares for yield attributing characters pooled**

| Source of Variation | d.f.      | Pods/plant       | Pod length(cm) | Seeds/pod     |
|---------------------|-----------|------------------|----------------|---------------|
| Year                | 1         | 192.6930         | 8.1103         | 0.1170        |
| Rep with year       | 6         | 29.6018          | 0.2871         | 0.0389        |
| <b>Treat</b>        | <b>15</b> | <b>1227.6310</b> | <b>0.8224</b>  | <b>0.9901</b> |
| V                   | 3         | 647.1296 **      | 1.6334         | 2.0267        |
| F                   | 3         | 5329.5440 **     | 2.2728         | 2.4836        |
| V*F                 | 9         | 53.8264 **       | 0.0686         | 0.1467        |
| <b>Y*T</b>          | <b>15</b> | <b>0.6551</b>    | <b>0.0644</b>  | <b>0.0859</b> |
| Y*V                 | 3         | 1.11830          | 0.0311         | 0.0021        |
| Y*F                 | 3         | 1.0594           | 0.0232         | 0.2556        |
| Y*V*F               | 9         | 0.3660           | 0.0893         | 0.0572        |
| Pooled Error        | 90        | 32.7932          | 0.3606         | 0.0207        |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- XIII a: Mean sum of squares for yield attributing characters during first year**

| Source of Variation | d.f. | 1000-seed weight. (g) | Seed yield/plant (g) | Straw yield/plant (g) |
|---------------------|------|-----------------------|----------------------|-----------------------|
| Rep                 | 3    | 0.0754                | 0.0597               | 0.9542                |
| V                   | 3    | 77.0772**             | 5.0567               | 42.6995               |
| F                   | 3    | 18.8756**             | 3.4773               | 5.5962                |
| V*F                 | 9    | 0.4539                | 0.1504               | 1.6541                |
| Error               | 45   | 0.7308                | 0.0918               | 0.4023                |
| Total               | 63   | 5.1596                | 0.4963               | 2.8689                |

**APPENDIX- XIII b: Mean sum of squares for yield attributing characters during second year**

| Source of Variation | d.f. | 1000-seed weight. (g) | Seed yield/plant (g) | Straw yield/plant (g) |
|---------------------|------|-----------------------|----------------------|-----------------------|
| Rep                 | 3    | 0.4638                | 0.4067               | 0.0946                |
| V                   | 3    | 112.2414**            | 7.2360               | 47.8010               |
| F                   | 3    | 8.0205**              | 4.2199               | 0.5157                |
| V*F                 | 9    | 0.6548                | 0.2957               | 2.2321                |
| Error               | 45   | 0.9082                | 0.1517               | 0.4126                |
| Total               | 63   | 6.4911                | 0.7155               | 2.9189                |

**APPENDIX- XIII c: Mean sum of squares for yield attributing characters pooled**

| Source of Variation | d.f.      | 1000-seed weight. (g) | Seed yield/plant (g) | Straw yield/plant (g) |
|---------------------|-----------|-----------------------|----------------------|-----------------------|
| <b>Year</b>         | <b>1</b>  | <b>29.2708</b>        | <b>5.0007</b>        | <b>50.5892</b>        |
| Rep with year       | 6         | 0.2696                | 0.2332               | 0.5244                |
| <b>Treat</b>        | <b>15</b> | <b>43.1286</b>        | <b>4.1095</b>        | <b>19.3473</b>        |
| V                   | 3         | 187.6335 **           | 12.0185 **           | 85.8124 **            |
| F                   | 3         | 25.7235 **            | 7.5920 **            | 4.5927 **             |
| V*F                 | 9         | 0.7620                | 0.3124               | 2.1104 *              |
| <b>Y*T</b>          | <b>15</b> | <b>0.7796</b>         | <b>0.1561</b>        | <b>2.3069</b>         |
| Y*V                 | 3         | 1.6851                | 0.2741               | 4.6881 **             |
| Y*F                 | 3         | 1.1726                | 0.1052               | 1.5192                |
| Y*V*F               | 9         | 0.3467                | 0.1337               | 1.7758                |
| Pooled Error        | 90        | 0.8195                | 0.1218               | 0.4075                |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- XIV a: Mean sum of squares for quality characters during first year**

| Source of Variation | d.f. | Protein content in seed (%) | Protein yield (kg/ha) |
|---------------------|------|-----------------------------|-----------------------|
| Rep                 | 3    | 0.0701                      | 394.9180              |
| V                   | 3    | 2.9657*                     | 140737.7390**         |
| F                   | 3    | 10.5630**                   | 121092.0580**         |
| V*F                 | 9    | 0.0828                      | 1652.1493**           |
| Error               | 45   | 0.0604                      | 891.5568              |
| Total               | 63   | 0.7026                      | 13359.7388            |

**APPENDIX- XIV b: Mean sum of squares for quality characters during second year**

| Source of Variation | d.f. | Protein content in seed (%) | Protein yield (kg/ha) |
|---------------------|------|-----------------------------|-----------------------|
| Rep                 | 3    | 0.0369                      | 533.4739              |
| V                   | 3    | 3.3769*                     | 132395.9000**         |
| F                   | 3    | 10.6568**                   | 108273.5000**         |
| V*F                 | 9    | 0.0713                      | 1416.7054**           |
| Error               | 45   | 0.0641                      | 839.5947              |
| Total               | 63   | 0.7260                      | 12287.9480            |

**APPENDIX- XIV c: Mean sum of squares for quality characters pooled**

| Source of Variation | d.f.      | Protein content in seed (%) | Protein yield (kg/ha) |
|---------------------|-----------|-----------------------------|-----------------------|
| <b>Year</b>         | 1         | 0.0180                      | 196484.3000           |
| Rep with year       | 6         | 0.0535                      | 464.1960              |
| <b>Treat</b>        | <b>15</b> | <b>5.6017</b>               | <b>101592.8683</b>    |
| V                   | 3         | 6.3310 **                   | 271817.4488           |
| F                   | 3         | 21.2196 **                  | 228978.7873           |
| V*F                 | 9         | 0.1526                      | 2389.3680             |
| <b>Y*T</b>          | <b>15</b> | <b>0.0032</b>               | <b>748.2843</b>       |
| Y*V                 | 3         | 0.0115                      | 1316.1880             |
| Y*F                 | 3         | 0.0001                      | 386.7740              |
| Y*V*F               | 9         | 0.0015                      | 679.4863              |
| Pooled Error        | 90        | 0.062295                    | 865.5758              |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- XV a: Mean sum of squares for quality characters during first year**

| Source of Variation | d.f. | Gum content in seed (%) | Gum yield (kg/ha) |
|---------------------|------|-------------------------|-------------------|
| Rep                 | 3    | 0.0149                  | 351.6486          |
| V                   | 3    | 0.6124                  | 124325.9311**     |
| F                   | 3    | 6.7337**                | 110897.8286**     |
| V*F                 | 9    | 0.1502                  | 1606.8638**       |
| Error               | 45   | 0.0083                  | 837.7167          |
| Total               | 63   | 0.3779                  | 12045.7976        |

**APPENDIX- XV b: Mean sum of squares for quality characters during second year**

| Source of Variation | d.f. | Gum content in seed (%) | Gum yield (kg/ha) |
|---------------------|------|-------------------------|-------------------|
| Rep                 | 3    | 0.0143                  | 520.1356          |
| V                   | 3    | 0.7211                  | 114602.3632**     |
| F                   | 3    | 6.2908**                | 96882.5091**      |
| V*F                 | 9    | 0.1694                  | 1411.6341**       |
| Error               | 45   | 0.0022                  | 772.8126          |
| Total               | 63   | 0.3603                  | 10849.1476        |

**APPENDIX- XV c: Mean sum of squares for quality characters pooled**

| Source of Variation | d.f.      | Gum content in seed (%) | Gum yield (kg/ha) |
|---------------------|-----------|-------------------------|-------------------|
| <b>Year</b>         | <b>1</b>  | 183348.6107             | 0.0122            |
| Rep with year       | 6         | 435.8921                | 0.0145            |
| <b>Treat</b>        | <b>15</b> | <b>90448.5865</b>       | <b>3.0589</b>     |
| V                   | 3         | 237707.3847**           | 1.3288            |
| F                   | 3         | 207359.7905**           | 13.0185**         |
| V*F                 | 9         | 2391.9192**             | 0.3158            |
| <b>Y*T</b>          | <b>15</b> | <b>704.2386</b>         | <b>0.0044</b>     |
| Y*V                 | 3         | 1220.9096**             | 0.0047            |
| Y*F                 | 3         | 420.5473**              | 0.0060            |
| Y*V*F               | 9         | 626.5787**              | 0.0038            |
| Pooled Error        | 90        | 805.2647                | 0.0052            |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- XVI a: Mean sum of squares for yield and HI during first year**

| Source of Variation | d.f. | Seed yield (kg/ha) | Straw yield (kg/ha) | Harvest index (%) |
|---------------------|------|--------------------|---------------------|-------------------|
| Rep                 | 3    | 4848.02            | 45212.69            | 1127.7950         |
| V                   | 3    | 1237445.23**       | 5502199.70**        | 6.9270**          |
| F                   | 3    | 897133.90**        | 1601975.70**        | 51.7601**         |
| V*F                 | 9    | 15871.34**         | 150585.28**         | 2.9150**          |
| Error               | 45   | 8950.91            | 26122.24            | 7.4983            |
| Total               | 63   | 110538.32          | 380617.98           | 62.2715           |

**APPENDIX- XVI b: Mean sum of squares for yield and HI during second year**

| Source of Variation | d.f. | Seed yield (kg/ha) | Straw yield (kg/ha) | Harvest index (%) |
|---------------------|------|--------------------|---------------------|-------------------|
| Rep                 | 3    | 4645.04            | 89027.17            | 1445.0550         |
| V                   | 3    | 1128749.00**       | 6296298.00**        | 1.2723            |
| F                   | 3    | 749785.00**        | 599264.90**         | 33.7814**         |
| V*F                 | 9    | 15164.72**         | 146814.50**         | 3.1025**          |
| Error               | 45   | 8105.62            | 28510.32            | 0.2322            |
| Total               | 63   | 97631.32           | 373937.50           | 71.0905           |

**APPENDIX- XVI c: Mean sum of squares for yield and HI pooled**

| Source of Variation | d.f.      | Seed yield (kg/ha) | Straw yield (kg/ha) | Harvest index (%) |
|---------------------|-----------|--------------------|---------------------|-------------------|
| Year                | 1         | 1939957.53         | 8572905.28          | 0.1303            |
| Rep with year       | 6         | 4746.53            | 67119.93            | 1286.425          |
| <b>Treat</b>        | <b>15</b> | <b>813230.23</b>   | <b>2879098.03</b>   | <b>19.0462</b>    |
| V                   | 3         | 2352458.03**       | 11708886.03**       | 1.6736            |
| F                   | 3         | 1641333.37**       | 2046685.87**        | 82.9859**         |
| V*F                 | 9         | 24119.92**         | 213306.09**         | 3.5239**          |
| <b>Y*T</b>          | <b>15</b> | <b>8014.07</b>     | <b>99289.42</b>     | <b>3.3124</b>     |
| Y*V                 | 3         | 13736.37**         | 89611.28**          | 6.5257**          |
| Y*F                 | 3         | 5585.53**          | 154554.78**         | 2.5556**          |
| Y*V*F               | 9         | 6916.14**          | 84093.67**          | 2.4935*           |
| Pooled Error        | 90        | 8528.27            | 27316.28            | 3.8652            |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- XVII a: Mean sum of squares for root study during first year**

| Source of Variation | d.f. | Root Length (cm) | Root weight (g) | Root nodules/plant |
|---------------------|------|------------------|-----------------|--------------------|
| Rep                 | 3    | 95.6721          | 4.2792          | 4.7083             |
| V                   | 3    | 148.5692**       | 0.1118          | 208.3333**         |
| F                   | 3    | 461.0025**       | 0.2378          | 189.6667**         |
| V*F                 | 9    | 26.7803**        | 0.0064          | 15.6666**          |
| Error               | 45   | 11.4143          | 1.8881          | 3.4194             |
| Total               | 63   | 45.5619          | 0.0175          | 23.8571            |

**APPENDIX- XVII b: Mean sum of squares for root study during second year**

| Source of Variation | d.f. | Root Length (cm) | Root weight (g) | Root nodules/plant |
|---------------------|------|------------------|-----------------|--------------------|
| Rep                 | 3    | 168.5370         | 0.0001          | 5.1250             |
| V                   | 3    | 126.4467**       | 0.1117          | 138.9167**         |
| F                   | 3    | 472.6467**       | 0.2455          | 178.9167**         |
| V*F                 | 9    | 27.8266**        | 0.0059          | 14.9166**          |
| Error               | 45   | 7.8590           | 1.001E-05       | 3.1250             |
| Total               | 63   | 46.1426          | 0.0178          | 19.7421            |

**APPENDIX- XVII c: Mean sum of squares for root study pooled**

| Source of Variation | d.f.      | Root Length (cm) | Root weight (g) | Root nodules/plant |
|---------------------|-----------|------------------|-----------------|--------------------|
| Year                | 1         | 13.7812          | 0.0033          | 0.1250             |
| Rep with year       | 6         | 132.1045         | 8.73E-05        | 4.9166             |
| <b>Treat</b>        | <b>15</b> | <b>274.2466</b>  | <b>0.1487</b>   | <b>152.3250</b>    |
| V                   | 3         | 273.9546**       | 0.2235          | 324.1250**         |
| F                   | 3         | 933.5646**       | 0.4833          | 362.1250**         |
| V*F                 | 9         | 54.5712**        | 0.0123          | 25.1250**          |
| <b>Y*T</b>          | <b>15</b> | <b>0.2505</b>    | <b>3.53E-05</b> | <b>9.1916</b>      |
| Y*V                 | 3         | 1.0612           | 6.2E-05**       | 23.1250**          |
| Y*F                 | 3         | 0.0845           | 5.9E-05**       | 6.4583**           |
| Y*V*F               | 9         | 0.0356           | 1.86E-05        | 5.4583**           |
| Pooled Error        | 90        | 9.6366           | 1.44E-05        | 3.2722             |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- XVIII a: Mean sum of squares for chemical studies during first year**

| Source of Variation | d.f. | Nutrient uptake whole plant (g) |          |          |
|---------------------|------|---------------------------------|----------|----------|
|                     |      | N-uptake                        | P-uptake | K-uptake |
| Rep                 | 3    | 0.0018                          | 0.0007   | 0.1618   |
| V                   | 3    | 0.0759                          | 0.0054   | 0.0132   |
| F                   | 3    | 0.2704                          | 0.0265   | 0.2818   |
| V*F                 | 9    | 0.0021                          | 0.0004   | 0.0003   |
| Error               | 45   | 0.0015                          | 0.0001   | 0.2009   |
| Total               | 63   | 0.0179                          | 0.0017   | 0.1653   |

**APPENDIX- XVIII b: Mean sum of squares for chemical studies during second year**

| Source of Variation | d.f. | Nutrient uptake whole plant (g) |          |          |
|---------------------|------|---------------------------------|----------|----------|
|                     |      | N-uptake                        | P-uptake | K-uptake |
| Rep                 | 3    | 0.0009                          | 0.0016   | 0.1806   |
| V                   | 3    | 0.0864                          | 0.0067   | 0.0156   |
| F                   | 3    | 0.2728                          | 0.0320   | 0.2722   |
| V*F                 | 9    | 0.0018                          | 0.0004   | 0.0007   |
| Error               | 45   | 0.0016                          | 0.0011   | 0.1508   |
| Total               | 63   | 0.0185                          | 0.0028   | 0.1301   |

**APPENDIX- XVIII c: Mean sum of squares for chemical studies pooled**

| Source of Variation | d.f.      | Nutrient uptake whole plant (g) |               |               |
|---------------------|-----------|---------------------------------|---------------|---------------|
|                     |           | N-uptake                        | P-uptake      | K-uptake      |
| Year                | 1         | 0.0004                          | 0.0276        | 0.0338        |
| Rep with year       | 6         | 0.0013                          | 0.0011        | 0.1712        |
| <b>Treat</b>        | <b>15</b> | <b>0.1434</b>                   | <b>0.0145</b> | <b>0.1169</b> |
| V                   | 3         | 0.1620                          | 0.0120        | 0.0287        |
| F                   | 3         | 0.5432                          | 0.0584        | 0.5538        |
| V*F                 | 9         | 0.0039                          | 0.0006        | 0.0006        |
| <b>Y*T</b>          | <b>15</b> | <b>8.35E-05</b>                 | <b>0.0001</b> | <b>0.0002</b> |
| Y*V                 | 3         | 0.0002                          | 0.0001        | 0.0001        |
| Y*F                 | 3         | 4.05E-06*                       | 0.0001        | 0.0003        |
| Y*V*F               | 9         | 3.88E-05**                      | 0.0001        | 0.0003        |
| Pooled Error        | 90        | 0.0015                          | 0.0006        | 0.1758        |

\* Significant at p=0.05

\*\* Significant at p=0.01

**APPENDIX- XIX a: Mean sum of squares for chemical studies during first year**

| Source of Variation | d.f. | Nutrient uptake (kg/ha) |            |             |
|---------------------|------|-------------------------|------------|-------------|
|                     |      | N-uptake                | P-uptake   | K-uptake    |
| Rep                 | 3    | 158.4719                | 1.0187     | 539.7137    |
| V                   | 3    | 34935.8800**            | 160.2332** | 6187.1750** |
| F                   | 3    | 18772.8300**            | 203.5492** | 5130.6410** |
| V*F                 | 9    | 511.7644**              | 3.1711**   | 99.5158**   |
| Error               | 45   | 102.2049                | 0.7448     | 491.9804    |
| Total               | 63   | 2711.2170               | 18.3565    | 930.2754    |

**APPENDIX- XIX b: Mean sum of squares for chemical studies during second year**

| Source of Variation | d.f. | Nutrient uptake (kg/ha) |            |             |
|---------------------|------|-------------------------|------------|-------------|
|                     |      | N-uptake                | P-uptake   | K-uptake    |
| Rep                 | 3    | 431.0244                | 3.6649     | 7088.0500   |
| V                   | 3    | 37867.7200**            | 233.6473** | 4411.3940** |
| F                   | 3    | 13486.5000**            | 241.5156** | 129.1432**  |
| V*F                 | 9    | 650.6911**              | 3.2946**   | 513.0424**  |
| Error               | 45   | 103.3190                | 3.7498     | 943.7271    |
| Total               | 63   | 2632.7190               | 25.9505    | 7088.0500   |

**APPENDIX- XIX c: Mean sum of squares for chemical studies pooled**

| Source of Variation | d.f.      | Nutrient uptake (kg/ha) |                 |                  |
|---------------------|-----------|-------------------------|-----------------|------------------|
|                     |           | N-uptake                | P-uptake        | K-uptake         |
| Year                | 1         | 4632.000                | 451.0585        | 9922.0410        |
| Rep with year       | 6         | 294.7481                | 2.3418          | 387.7367         |
| <b>Treat</b>        | <b>15</b> | <b>21335.7900</b>       | <b>169.8268</b> | <b>4628.8370</b> |
| V                   | 3         | 72349.86**              | 389.9774**      | 13173.7900**     |
| F                   | 3         | 31776.78**              | 442.3803**      | 9468.4250**      |
| V*F                 | 9         | 850.7686**              | 5.5920**        | 167.3232**       |
| <b>Y*T</b>          | <b>15</b> | <b>374.2713</b>         | <b>1.8417</b>   | <b>71.8106</b>   |
| Y*V                 | 3         | 453.7419**              | 3.9032*         | 101.4358**       |
| Y*F                 | 3         | 482.5543**              | 2.6844          | 73.6098**        |
| Y*V*F               | 9         | 311.6868**              | 0.8736          | 61.3358**        |
| Pooled Error        | 90        | 102.7619                | 2.2473          | 502.5114         |

\* Significant at p=0.05

\*\* Significant at p=0.01

**Appendix-XX a:** Details of calculation of economics from different treatment combinations.

| Treatment combination                   | Grain yield(kg/ha) | Income grain yield (Rs/ha) (1) | Stover yield (kg/ha) | Income Stover yield (Rs/ha) (2) | Gross Income (Rs/ha) (1+2) | Fixed cost (Rs./ha) | Treatment cost | Total Cost (Rs./ha) | Net income (Rs./ha) (1+2) - (3+4) | B:C ratio |
|-----------------------------------------|--------------------|--------------------------------|----------------------|---------------------------------|----------------------------|---------------------|----------------|---------------------|-----------------------------------|-----------|
| <b>RGC 1017</b>                         | –                  | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>1</sub> F <sub>0</sub> (0 % RDF) | 933                | 93300                          | 2239                 | 1120                            | 94420                      | 15900               | –              | 15900               | 78520                             | 5.94      |
| V <sub>1</sub> F <sub>1</sub> (0 % RDF) | 995                | 99500                          | 2288                 | 1144                            | 100644                     | 15900               | 3680           | 19580               | 81064                             | 5.14      |
| V <sub>1</sub> F <sub>2</sub> (0 % RDF) | 1552               | 155200                         | 3414                 | 1707                            | 156907                     | 15900               | 4270           | 20170               | 136737                            | 7.78      |
| V <sub>1</sub> F <sub>3</sub> (0 % RDF) | 1190               | 119000                         | 2499                 | 1250                            | 120250                     | 15900               | 2360           | 18260               | 101990                            | 6.59      |
| <b>RGC-1038</b>                         | –                  | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>2</sub> F <sub>0</sub> (0 % RDF) | 1430               | 143000                         | 3432                 | 1716                            | 144176                     | 15900               | –              | 15900               | 128816                            | 9.10      |
| V <sub>2</sub> F <sub>1</sub> (0 % RDF) | 1555               | 155500                         | 3346                 | 1673                            | 157173                     | 15900               | 3680           | 19580               | 137593                            | 8.03      |
| V <sub>2</sub> F <sub>2</sub> (0 % RDF) | 1910               | 191000                         | 4011                 | 2006                            | 193006                     | 15900               | 4270           | 20170               | 172836                            | 9.57      |
| V <sub>2</sub> F <sub>3</sub> (0 % RDF) | 1764               | 176400                         | 3704                 | 1852                            | 178252                     | 15900               | 2360           | 18260               | 159992                            | 9.76      |
| <b>RGC – 1055</b>                       | –                  | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>3</sub> F <sub>0</sub> (0 % RDF) | 1363               | 136300                         | 3271                 | 1636                            | 137936                     | 15900               | –              | 15900               | 122036                            | 8.68      |
| V <sub>3</sub> F <sub>1</sub> (0 % RDF) | 1505               | 150500                         | 3691                 | 1846                            | 152346                     | 15900               | 3680           | 19580               | 132766                            | 7.78      |
| V <sub>3</sub> F <sub>2</sub> (0 % RDF) | 1780               | 178000                         | 3916                 | 1958                            | 179958                     | 15900               | 4270           | 20170               | 159788                            | 8.92      |
| V <sub>3</sub> F <sub>3</sub> (0 % RDF) | 1682               | 168200                         | 3516                 | 1758                            | 169958                     | 15900               | 2360           | 18260               | 151698                            | 9.31      |
| <b>HG – 563</b>                         | –                  | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>4</sub> F <sub>0</sub> (0 % RDF) | 1510               | 151000                         | 3864                 | 1932                            | 152932                     | 15900               | –              | 15900               | 137032                            | 9.62      |
| V <sub>4</sub> F <sub>1</sub> (0 % RDF) | 1685               | 168500                         | 3875                 | 1938                            | 170438                     | 15900               | 3680           | 19580               | 150858                            | 8.71      |
| V <sub>4</sub> F <sub>2</sub> (0 % RDF) | 2152               | 215200                         | 4304                 | 2152                            | 217352                     | 15900               | 4270           | 20170               | 197182                            | 10.78     |
| V <sub>4</sub> F <sub>3</sub> (0 % RDF) | 1925               | 192500                         | 3850                 | 1925                            | 194425                     | 15900               | 2360           | 18260               | 176165                            | 10.65     |

Sale rate of seed 10,000 Rs/ q

Total fixed cost Rs. 15900

Sale rate of straw 50 Rs/ q

Cost of 5 tonne VC Rs. 2500

Cost of fertilizer Rs. 2360 (100 % RDF)

**Appendix-XX b:** Details of calculation of economics from different treatment combinations.

II yrs

| Treatment combination                   | Grain yield (kg/ha) | Income grain yield (Rs/ha) (1) | Stover yield (kg/ha) | Income Stover yield (Rs/ha) (2) | Gross Income (Rs/ha) (1+2) | Fixed cost (Rs./ha) | Treatment cost | Total Cost (Rs./ha) | Net income (Rs./ha) (1+2) - (3+4) | B:C ratio |
|-----------------------------------------|---------------------|--------------------------------|----------------------|---------------------------------|----------------------------|---------------------|----------------|---------------------|-----------------------------------|-----------|
| <b>RGC 1017</b>                         | –                   | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>1</sub> F <sub>0</sub> (0 % RDF) | 1172                | 117200                         | 2813                 | 1407                            | 118607                     | 15900               | –              | 15900               | 102707                            | 7.46      |
| V <sub>1</sub> F <sub>1</sub> (0 % RDF) | 1247                | 124700                         | 2868                 | 1434                            | 126134                     | 15900               | 3680           | 19580               | 106554                            | 6.44      |
| V <sub>1</sub> F <sub>2</sub> (0 % RDF) | 1768                | 176800                         | 3536                 | 1768                            | 178568                     | 15900               | 4270           | 20170               | 158398                            | 8.85      |
| V <sub>1</sub> F <sub>3</sub> (0 % RDF) | 1560                | 156000                         | 3276                 | 1638                            | 157638                     | 15900               | 2360           | 18260               | 139378                            | 8.63      |
| <b>RGC-1038</b>                         | –                   | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>2</sub> F <sub>0</sub> (0 % RDF) | 1671                | 167100                         | 4001                 | 2001                            | 169101                     | 15900               | –              | 15900               | 153201                            | 10.64     |
| V <sub>2</sub> F <sub>1</sub> (0 % RDF) | 1718                | 171800                         | 3951                 | 1976                            | 173776                     | 15900               | 3680           | 19580               | 154196                            | 8.88      |
| V <sub>2</sub> F <sub>2</sub> (0 % RDF) | 2093                | 209300                         | 4395                 | 2198                            | 211498                     | 15900               | 4270           | 20170               | 191328                            | 10.49     |
| V <sub>2</sub> F <sub>3</sub> (0 % RDF) | 1920                | 192000                         | 3840                 | 1920                            | 193920                     | 15900               | 2360           | 18260               | 175660                            | 10.62     |
| <b>RGC – 1055</b>                       | –                   | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>3</sub> F <sub>0</sub> (0 % RDF) | 1605                | 160500                         | 3852                 | 1926                            | 162426                     | 15900               | –              | 15900               | 146526                            | 10.22     |
| V <sub>3</sub> F <sub>1</sub> (0 % RDF) | 1847                | 184700                         | 4248                 | 2124                            | 186824                     | 15900               | 3680           | 19580               | 167244                            | 9.54      |
| V <sub>3</sub> F <sub>2</sub> (0 % RDF) | 2049                | 204900                         | 4098                 | 2049                            | 206949                     | 15900               | 4270           | 20170               | 186779                            | 10.26     |
| V <sub>3</sub> F <sub>3</sub> (0 % RDF) | 1935                | 193500                         | 4064                 | 2032                            | 195532                     | 15900               | 2360           | 18260               | 177272                            | 10.71     |
| <b>HG – 563</b>                         | –                   | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>4</sub> F <sub>0</sub> (0 % RDF) | 1841                | 184100                         | 4418                 | 2209                            | 186309                     | 15900               | –              | 15900               | 170409                            | 11.72     |
| V <sub>4</sub> F <sub>1</sub> (0 % RDF) | 1935                | 193500                         | 4451                 | 2226                            | 195726                     | 15900               | 3680           | 19580               | 176146                            | 10.00     |
| V <sub>4</sub> F <sub>2</sub> (0 % RDF) | 2314                | 231400                         | 4859                 | 2430                            | 233830                     | 15900               | 4270           | 20170               | 213660                            | 11.59     |
| V <sub>4</sub> F <sub>3</sub> (0 % RDF) | 2196                | 219600                         | 4831                 | 2416                            | 222016                     | 15900               | 2360           | 18260               | 203756                            | 12.16     |

**Cost of 5 tonne VC Rs. 2500**

**Cost of fertilizer Rs. 2360 (100 % RDF)**

**Total fixed cost Rs. 15900**

**Sale rate of seed 10,000 Rs/ q**

**Sale rate of straw 50 Rs/ q**

**Appendix-XX c:** Details of calculation of economics from different treatment combinations.

**pooled**

| Treatment combination                   | Grain yield(kg/ha) | Income grain yield (Rs/ha) (1) | Stover yield (kg/ha) | Income Stover yield (Rs/ha) (2) | Gross Income (Rs/ha) (1+2) | Fixed cost (Rs./ha) | Treatment cost | Total Cost (Rs./ha) | Net income (Rs./ha) (1+2) - (3+4) | B:C ratio |
|-----------------------------------------|--------------------|--------------------------------|----------------------|---------------------------------|----------------------------|---------------------|----------------|---------------------|-----------------------------------|-----------|
| <b>RGC 1017</b>                         | –                  | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>1</sub> F <sub>0</sub> (0 % RDF) | 1053               | 105300                         | 2526                 | 1263                            | 106563                     | 15900               | –              | 15900               | 90663                             | 6.70      |
| V <sub>1</sub> F <sub>1</sub> (0 % RDF) | 1121               | 112100                         | 2578                 | 1289                            | 113389                     | 15900               | 3680           | 19580               | 93809                             | 5.79      |
| V <sub>1</sub> F <sub>2</sub> (0 % RDF) | 1660               | 166000                         | 3475                 | 1738                            | 167738                     | 15900               | 4270           | 20170               | 147568                            | 8.32      |
| V <sub>1</sub> F <sub>3</sub> (0 % RDF) | 1375               | 137500                         | 2888                 | 1444                            | 138944                     | 15900               | 2360           | 18260               | 120684                            | 7.61      |
| <b>RGC-1038</b>                         | –                  | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>2</sub> F <sub>0</sub> (0 % RDF) | 1551               | 155100                         | 3717                 | 1859                            | 156959                     | 15900               | –              | 15900               | 141059                            | 9.87      |
| V <sub>2</sub> F <sub>1</sub> (0 % RDF) | 1637               | 163700                         | 3649                 | 1825                            | 165525                     | 15900               | 3680           | 19580               | 145945                            | 8.45      |
| V <sub>2</sub> F <sub>2</sub> (0 % RDF) | 2002               | 200200                         | 4203                 | 2102                            | 202302                     | 15900               | 4270           | 20170               | 182132                            | 10.03     |
| V <sub>2</sub> F <sub>3</sub> (0 % RDF) | 1842               | 184200                         | 3772                 | 1886                            | 186086                     | 15900               | 2360           | 18260               | 167826                            | 10.19     |
| <b>RGC – 1055</b>                       | –                  | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>3</sub> F <sub>0</sub> (0 % RDF) | 1484               | 148400                         | 3562                 | 1781                            | 150181                     | 15900               | –              | 15900               | 134281                            | 9.45      |
| V <sub>3</sub> F <sub>1</sub> (0 % RDF) | 1676               | 167600                         | 3970                 | 1985                            | 169585                     | 15900               | 3680           | 19580               | 150005                            | 8.66      |
| V <sub>3</sub> F <sub>2</sub> (0 % RDF) | 1915               | 191500                         | 4007                 | 2003.5                          | 193503.5                   | 15900               | 4270           | 20170               | 173333.5                          | 9.59      |
| V <sub>3</sub> F <sub>3</sub> (0 % RDF) | 1809               | 180900                         | 3790                 | 1895                            | 182795                     | 15900               | 2360           | 18260               | 164535                            | 10.01     |
| <b>HG – 563</b>                         | –                  | –                              | –                    | –                               | –                          | –                   | –              | –                   | –                                 | –         |
| V <sub>4</sub> F <sub>0</sub> (0 % RDF) | 1676               | 167600                         | 4141                 | 2071                            | 169671                     | 15900               | –              | 15900               | 153771                            | 10.67     |
| V <sub>4</sub> F <sub>1</sub> (0 % RDF) | 1810               | 181000                         | 4163                 | 2082                            | 183082                     | 15900               | 3680           | 19580               | 163502                            | 9.35      |
| V <sub>4</sub> F <sub>2</sub> (0 % RDF) | 2233               | 223300                         | 4582                 | 2291                            | 225591                     | 15900               | 4270           | 20170               | 205421                            | 11.18     |
| V <sub>4</sub> F <sub>3</sub> (0 % RDF) | 2061               | 206100                         | 4341                 | 2171                            | 208271                     | 15900               | 2360           | 18260               | 190011                            | 11.41     |

**Cost of 5 tonne VC Rs. 2500**

**Cost of fertilizer Rs. 2360 (100 % RDF)**

**Total fixed cost Rs. 15900**

**Sale rate of seed 10,000 Rs/ q**

**Sale rate of straw 50 Rs/ q**

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