EFFECT OF PLANT GROWTH REGULATORS, ORGANICS AND NUTRIENTS ON GROWTH, PHYSIOLOGY AND YIELD IN CLUSTERBEAN (*Cyamopsis tetragonoloba* L. Taub)

Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfillment of the requirements for the
Degree of

MARTER OF SCIENCE (AGRICULTURE)

IN

CROP PHYSIOLOGY

By.

PRABHAVATHI V. HANCHINAMATH

DEPARTMENT OF CROP PHYSIOLOGY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD-580005

AUGUST, 2005

ADVISORY COMMITTEE

Dharwad
AUGUST, 2005

(S.M. HIREMATH)
MAJOR ADVISOR

Approved by:

Chairman :______________________

(S.M. HIREMATH)

Members :1.____________________

(M.B. CHETTI)

2.____________________

(C.M. NAWALAGATTI)

3.____________________

(N. BASAVARAJ)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

I. INTRODUCTION

Clusterbean (*Cyamopsis tetragonoloba* L. Taub) locally known as gaur, guarpalli, chavali etc. belongs to the family leguminaceae. It is an important legume crop mainly grown under rainfed condition in arid and semiarid regions of tropical India during *kharif* season. It is a hardy and drought tolerant crop. 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, which is especially suited for soils and climates of Rajasthan. Its a good source of carbohydrates, protein, fibre and minerals like calcium, phosphorus and iron and contains appreciable amount of vitamin C.

Clusterbean is grown for different purposes from very ancient time viz., vegetable, green fodder, green manure and for production of seeds. Besides all these, 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 has its use in almost all types of industries viz., fertilizers, papers, petroleum, pharmaceuticals, food processing, cosmetics, mining explosives, 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.

Origin of clusterbean is not definitely known but it is being grown since long time in India, Africa, Sri Lanka, Burma, Peru, Java and Pakistan. In India, it is grown on an area of 23.30 lakh hectare with the production of 1.74 lakh tonnes and the productivity is 322.7 kg seeds per hectare (Anon., 2001). Karnataka contributes about 8777 tonnes of clusterbean seeds obtained from an area of 1517 ha with productivity of 6 tonnes per ha (Anon., 2001).

In general, pulse crops are energy rich plants but are cultivated largely under energy starvation conditions and more than 92 per cent of the area under pulses is still under rainfed (Anon., 2000). The lower mean productivity of these crops is mainly due to cultivation in marginal lands and with little or no monetary inputs (Anon., 2000).

Several attempts have been made to increase the yield potential of pulses, but they are primarily concerned with the use of fertilizers, pesticides and better management practices coupled with genetic improvement. But, very little attention has been given to the physiological processes, which limit the crop productivity.

Plant growth regulators (PGR's) are known to improve physiological efficiency including photosynthetic ability of plants and offer a significant role in realizing higher crop yields. The PGR's are also known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates, thereby increasing the productivity. Though, the plant growth regulators have great potential, its application and accural assessment etc. have to be judiciously planned in terms of optimal concentration, stage of application, species specificity and seasons. In their wide spectrum of effectiveness on every aspect of plant growth, even a modest increase of 10-15 per cent could bring about an increment in the gross annual productivity by 10-15 m tons.

Organic farming is a production system which largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock additives to the maximum extent (Ramesh and Manjunath, 2004). The basic reason that demands organic agriculture is the pollution of air, water and soil in varying degrees in different parts of the world which affects the environment and ultimately human welfare.

Organic agriculture is a crop production method respecting the rules of nature. The objective is to achieve a sustainable farming system that preserves the environment and soil fertility for our offspring too. Though, traditional agriculture is a repository of several indigenous practices in respect of nutrition management and plant protection measures, there is a gradual erosion of these principles and practices due to over dependency on fertilizers and chemicals in recent years. Therefore, the promotion of organic farming through the use of organic materials and adopting ecologically sound plant protection measures would go a long way in bringing back the soil health.

As pulses are cultivated under rainfed condition under marginal and sub-marginal soils with low fertility, for maximizing the productivity, the eventual plant nutrients must be supplied in balanced form. In recent years, more emphasis has been given on INSS (Integrated nutrient supply system) for enhancing productivity potential and also for sustaining crop productivity. Hence, there is a need to understand the influence of these nutrients on morpho-physiological, biochemical attributes, yield and yield components in clusterbean. Sharma (2003) reported that crop yields during initial phase of transition from conventional to organic agriculture generally decline in many cases. However, yields recover in 2-3 years, which substantially improve the economic status eventually and bring in health and quality consciousness.

Hence, there is a need to study the effect of plant growth regulators, organics and nutrients on physiological and biochemical parameters and yield components in clusterbean to boost up the productivity. With this background, the present investigation was undertaken to find out the suitable plant growth regulators, organics and nutrients for increasing the productivity potential in clusterbean with the following objectives ;

1. To find out the effect of plant growth regulators, organics and nutrients on growth, yield and yield components in cluster bean.
2. To study morphological characters and their relationship with productivity.
3. To know the biochemical changes due to the plant growth regulators, organics and nutrients.

II. REVIEW OF LITERATURE

Clusterbean is a *kharif* legume crop which produces more vegetative growth than is needed for maximum pod production and yield especially when climatic conditions favour vegetative growth, thereby directing the photo-assimilates towards the vegetative growth rather than reproductive growth. However, in the recent past, many plant growth regulators are used to control the excess vegetative growth and to boost the yield in various crops. But, the literature on the use of plant growth regulators, organics and nutrients on clusterbean are meagre. So in this chapter, a survey of literature has been made on the effect of growth regulators, nutrients and organics on morpho-physiological parameters, biochemical studies and yield components in clusterbean and related crops.

2.1 PLANT GROWTH REGULATORS AND NUTRIENTS

There is a great deal of experimental evidence in the literature showing that endogenous growth substances are involved in many processes which lead to growth and development. Plants have also been shown to respond to exogenous application of plant growth regulators. Considering their role in plants, plant growth regulators have been designated as magic chemicals which bring about an unprecedented growth and help in removing and circumventing many of the barriers imposed by genetics and environment. Crop yield is a complex heritable character influenced by many morphological and physiological characters of plant interacting with environment. An attempt has been made to present the impact of plant growth regulators on plant growth and development *vis-à-vis* physiological, biochemical and yield parameters.

In recent years, the use of micronutrients is gaining more importance in improving yield potential and also quality of the produce in several crops. Micronutrients though required in minute quantity, their role is the most deciding factor on yield and quality of many crops.

2.1.1 Morphological characters

Foliar spray of miraculan increased plant growth in soybean (Dashora and Jain, 1994). Shukla *et al.* (1997) found that double sprays of miraculan (1500 ppm) enhanced the plant height and number of branches in soybean.

Mandal *et al.* (1997) indicated a significant increase in the number of branches per plant due to the application of CCC @ 100 ppm in greengram. Foliar spray of cycocel @ 1000 ppm reduced the stem length in mungbean (Shah and Prathapsenan, 1991). Garai and Datta (2003) reported that foliar application of cycocel reduced the plant height and increased the primary branches per plant in greengram. Asane *et al.* (1998) found that cycocel at 500 and 1000 ppm reduced the plant height in pea. The application of cycocel at 1000 ppm not only reduced the plant height but also increased the chlorophyll content in sunflower (Kumari *et al.*, 1990).

Prakash *et al.* (2003) observed that the application of chamatkar at 120 ppm decreased the plant height and increased number of branches and leaves. Sorte *et al.* (1989) reported that increasing concentration of chloromequat increased the number of flowers in groundnut. Phulekar *et al.* (1998) reported that leaf area and leaf area index were decreased by 1000 ppm mepiquat chloride and 1000-3000 ppm of cycocel (chlormequat).

Dhaka and Anamika (2003) noticed that the application of mepiquat chloride (DPC) significantly decreased the plant height, number of branches per plant and number of leaves per plant. Wasnik and Bagga (1996) found that in chickpea cv. BG384, number of secondary and tertiary branches and leaf area were increased with mepiquat chloride. Application of 100, 125 or 150 ppm of mepiquat chloride at 25, 35 and 45 DAS or 100 ppm cycocel (chlormequat) at 45 DAS decreased shoot length and increased the root length (Jeyakumar and Thangaraj, 1996).

Kumaravelu *et al.* (2000) recorded that foliar application of 0.5 mg dm^{-2} triacontanol significantly promoted the plant height. Neelam *et al.* (1995) opined that foliar application of triacontanol (TRIA 1 g/ml) to lentil increased the plant height and number of branches/plant. Ogilvy (1985) indicated that, foliar application of cycocel (chlormaquat), cerone (ethephon) and terpla (mepiquat chloride) at the start of the stem extension resulted in retarded vegetative growth in rape, but none of the growth regulators affected the branching pattern. In soybean cultivars, reduction in plant height and increased LAI during the seed filling stage was observed by Singh *et al.* (1987) with the foliar spray of 300 ppm cycocel at flower initiation stage.

Umesh Singh and Yadav (1997) reported that the application of 30 kg S per ha gave better enhancement in growth attributes viz., plant height, branches and functional leaves. Kumawat and Khangarot (2002) found that application of 80 kg S ha^{-1} significantly increased the plant height at 60, 90 DAS and at harvest in cluster bean.

2.1.2 Dry matter accumulation and partitioning

Plant growth, development and economic yield depends on dry matter accumulation and its distribution at various growth stages. Therefore, dry matter production at each growth stage and its partitioning to reproductive organs during pre-flowering to maturity period has immense importance in determining the productivity. The pattern of translocation of photosynthate changes before and after flowering is important (Poehlman, 1991). Chandrababu *et al.* (1995) noticed that application of 125 ppm of mepiquat chloride resulted in maximum leaf weight, haulm weight, total plant dry weight in groundnut. The combination of N triacontanol with paras or planofix increased the dry matter accumulation in mustard (Ghosh *et al*., 1991).

Singh *et al.* (1994) reported that dry matter accumulation has increased significantly with application of 40 kg S/ha as gypsum in summer mung. Kale (1993) reported that application of 30 kg S/ha has given dry matter yield of 1.24 t/ha in groundnut. Shoot dry weight was increased significantly by sulphur addition only after the pod fill stage in pea (Zhao *et al*., 1999). Wasnik and Bagga (1996) reported that application of Mepiquat chloride in chickpea increased the leaf dry weight but had no effect on root and stem dry weights.

Sarkar *et al.* (1999) noticed that foliar application of 0.25 per cent KNO_3 + 0.20% Ca $(NO_3)_2$ resulted in highest dry matter production (14.60 g/plant) and pod weight per plant in groundnut. Mahla *et al.* (1999) noticed that dry matter production was highest in blackgram when sprayed with 2 ppm mixtalol (triacontanol) and/or 20 ppm NAA. Foliar spraying of triacontanol (0.5-1.0 mg/litre) exhibited higher dry matter accumulation in chilli (Ray, 1991).

Singh *et al.* (1993) noticed that application of 100 ppm cycocel has significantly increased pod dry weight and seed yield in mungbean. Shah and Prathapsenan (1991) studied effect of cycocel on greengram and indicated that there was an increase of leaf dry weight by 52.7 per cent over control. In sunflower, application of cycocel has significantly reduced the stem and leaf dry weight but has increased head dry weight (Kulkarni *et al*., 1995). Application of 160 ppm of cycocel (chlormequat) increased the allocation of dry matter to the pods (Brar *et al*., 1992).

2.1.3 Growth parameters

The expansion and differentiation of plant cells are the functions of the plant growth and are affected by environmental factors, plant growth regulators and nutrients. Growth analysis is a physiological probe on the development of crop chronological sequence to elucidate and account the causes for differences in yield throughout the events that have occurred at different stages of growth (Krishnamurthy *et al*., 1973). Patra *et al.* (1995) revealed that post flowering spraying of nutrient solutions (KNO_3 0.5%, Ca $(NO_3)_2$ 0.5% and urea (2.0%) at 50 per cent flowering and thereafter increased the LAI, CGR in groundnut. Dashora and Jain (1994) found that spraying of triacontanol significantly increased leaf area index (LAI) by 27.9 per cent in soybean.

Foliar application of TIBA, cycocel and mepiquat chloride significantly increased absolute growth rate (AGR), relative growth rate (RGR), net assimilation rate (NAR) and CGR in soybean (Patil, 1994). Jeyakumar and Thangaraj (1996) reported that the application of mepiquat chloride or cycocel (chlormequat) decreased the LAI and increased CGR in groundnut. Phulekar *et al.* (1998) found that application of cycocel (chlormequat), mepiquat chloride decreased the leaf area, leaf area index and leaf area duration while specific leaf weight was increased.

Specific leaf weight (SLW) is a stable character and was initially low and improved subsequently and reached the maximum value at 42 days in greengram genotypes. Similarly, crop growth rate (CGR) was found to be low during early vegetative phase but increased with the advancement of growth in greengram (Kalubarme and Pandey, 1979). Prakash *et al.* (2003) reported that foliar application of chamatkar @ 120 ppm in blackgram increased the LAI and specific leaf weight. Ray (1991) indicated that foliar spray of triacontanol gave higher relative growth rate, crop growth rate and leaf area index in *Capsicum*.

Application of mepiquat chloride (DPC) to cotton has recorded increase in leaf area (Varella and Yallejo, 1982). Li *et al.* (1987) noticed increased leaf area index in sesame when treated with 0.01 per cent Pix (mepiquat chloride) and similar results were also obtained by Child *et al.* (1989) in rape. According to Kulkarni (1993), LAD and SLA decreased significantly with a significant increase in specific leaf weight at all stages, except at 40 and 55 DAS in sunflower. Saishankar (2001) reported that application of miraculan (2000 ppm) recorded significantly higher leaf area, LAI, RGR, CGR, NAR, SLW, LAR, LAD and biomass duration (BMD) in greengram over control.

2.1.4 Biochemical parameters

Apart from morphological and physiological alterations, plant growth regulators, nutrients also influence various biochemical parameters and thereby alter quality parameters in various crops.

2.1.4.1 Chlorophyll content

Foliar application of triacontanol @ 10 ppm increased the chlorophyll content in pearl millet (Sivakumar *et al.*, 2002). Jeyakumar and Thangaraj (1998) indicated that mepiquat chloride 125 ppm resulted in higher amount of chlorophyll in groundnut. Janardhanan (1992) also found that soaking pigeonpea seeds with triacontanol (1-6 ml l^{-1}) increased leaf chlorophyll content in groundnut. Neelam *et al.* (1995) indicated that the foliar application of 1.5 g/ml of TRIA increased the leaf chlorophyll and decreased the chl. a/b ratio in lentil. Mahla *et al.* (1999) reported that application of 2 ppm of mixtalol (triacontanol) increased the leaf chlorophyll content in blackgram.

The chlorophyll content of leaf increased with mepiquat chloride compared to control during reproductive stage in chickpea (Wasnik and Bagga, 1996). Zhao *et al.* (1999) reported that sulphur addition significantly increased the leaf chlorophyll content in pea. Sorte *et al.* (1989) found that increasing chlormequat concentration increased the chlorophyll contents in leaves in peanut. Shah and Prathapasenan (1991) indicated that application of 1000 ppm cycocel increased the leaf chlorophyll content in mungbean.

Chetti (1991) reported that the application of mepiquat chloride and lihocin increased the chlorophyll 'a', chlorophyll 'b' and total chlorophyll contents, significantly as compared to control in groundnut genotypes JL-24 and DH-8. Saishankar (2001) found that the application of cycocel @ 20 ppm at 50 per cent flowering stage increased the chlorophyll content in greengram as compared to control. Ganiger (1992) reported increased photosynthetic pigements (Chl. a, Chl. b and total chlorophyll) by spraying cycocel and mepiquat chloride on seed tuber planted potato over control.

2.1.4.2 Nitrate reductase activity (NRA)

The nitrate reductase activity, which is the key enzyme in nitrogen metabolism is known to be regulated by various environmental factors apart from its own substrate, nitrate. It is also believed that reduction of nitrate to nitrite by nitrate reductase activity is the rate limiting process for the utilization of nitrogen in the form of nitrate. The enzyme nitrate reductase is cytoplasmic, containing molybdenum and flavin co-enzyme, FAD.

Antony (1995) reported that nitrate reductase activity was correlated with TDM at early stage but did not have positive correlation with any of the yield and yield components in groundnut. Kumaravelu *et al.* (2000) indicated that foliar spray of 0.5 and 1.0 mg dm^{-3} triacontanol increased the nitrate reductase activity in greengram. Muthuchelian *et al.* (1994) indicated that foliar spray of triacontanol significantly increased the nitrate reductase activity in *Erythrina variegata* seedlings.

Wasnik and Bagga (1992) reported that the application of cycocel @ 500 ppm increased the nitrate reductase activity in greengram leaves. Sivakumar *et al.* (2002) indicated that foliar application of triacontanol @ 10 ppm significantly increased the nitrate reductase activity at 60 DAS in pearl millet. Foliar application of cycocel with 3000 ppm to sunflower at 33 and 53 days after sowing decreased the nitrate reductase activity during growth stages, while 5000 ppm chlormequat decreased nitrate reductase activity throughout all growth stages (Pando *et al.*, 1988).

2.1.5 Yield and yield components

Grain yield is the ultimate economic product of the crop, which is determined mainly by grain weight and the number of grains per unit land area. Most of the yield components show a direct influence on grain yield.

Mishriky *et al.* (1990) reported that in peas, application of cycocel (500 ppm) significantly increased the number and weight of pods and the total yield. The application of 125 ppm of mepiquat chloride at 35 DAS recorded the higher pod yield of 2.61 t/ha in groundnut. (Jeyakumar and Thangaraj, 1996). Rathore *et al.* (1990) found that application of 2000 ppm cycocel has given the higher seed yield in clusterbean. Chandrababu *et al.* (1995) indicated that foliar spray of 125 ppm mepiquat chloride at 70 DAS increased the number of mature pods and pod yield and decreased the harvest index in groundnut.

The treatment combination of 0.25% KNO_3 + 0.20% Ca $(NO_3)_2$ showed highest pod yield and harvest index. The increased yield performance of treated plants was associated with higher number of pods per plant and pod weight per plant (Sarkar *et al.*, 1999). Application of cycocel (chlormequat) at the 50 per cent flowering stage increased the number of pods, number of seeds, seed size and yield/plant in chickpea (Arora *et al.*, 1998). Tripti Shrivastava *et al.* (2001) found that foliar application of 125 ml/ha triacontanol increased the grain yield by 25.8 per cent compared to control in chickpea.

Abdel Lateef (1997) indicated that sulphur application significantly increased the pod number and weight per plant and seed yield per plant in cowpea. Shivraj and Gowda (1993) found that in groundnut, application of 30 kg as gypsum increased the pod yield, haulm yield and 100-seed weight. Singh and Uttam (1992) reported that in wheat, application of 250 ml miraculan/ha increased the grain yield. Neelam *et al.* (1995) found that TRIA application increased the 1000-seed weight, pods per plant and harvest index with subsequent increase in seed yield of lentil. Naidu and Hanuman Rao (1996) reported that sulphur application @ 40 kg/ha produced greater number of pods as well as seed yield in greengram.

Kumawat and Khangarot (2002) indicated that in clusterbean, application of 80 kg sulphur per ha significantly increased number of pods per plant, number of seeds per pod and seed yield. Lynrah *et al.* (2002) reported that yield per ha was highest in 0.5 per cent KNO_3 treated plants followed by 1 per cent KNO_3 in Turmeric. Basuchaudhuri *et al.* (1986) reported that seed yields differed significantly by applying 400 ppm cycocel at 15 days prior to flowering in soybean. Singh *et al.* (1987) reported that foliar spray of 300 ppm cycocel at the flower initiation stage reduced the shedding of flowers and immature pods and induced flowering and development of pods with increased seed yield in soybean. Spraying of NAA and miraculan at flower initiation and seed filling stages also increased the seed yield in greengram and blackgram (Chaplot *et al.*, 1992).

Hunje *et al.* (1995) recorded increased seed yield of vegetative cowpea by foliar spray of 100 ppm cycocel at 30 DAS. The increase in seed yield was attributed to reduced plant height and delayed leaf senescence, increased lateral branches, pods per plant, seeds per pod and 100-seed weight.

2.2 ROLE OF ORGANICS

2.2.1 Farm yard manure

The FYM seems to act directly in increasing crop yields either by acceleration of respiration process by increasing cell permeability or by hormone growth action, or by increased combination of all these processes. It supplies N, P, K and S in available forms to the plants through biological decomposition. Indirectly it improves physical properties of soil such as aggregation, aeration, permeability and water holding capacity.

According to Palaniappan and Annadurai (1999), FYM and compost contain 0.5-1.0 per cent, N, 0.6 per cent P_2O_5 and 0.5 per cent K_2O. Ten tons of compost will thus supply 50-100 kg N, 20 kg P_2O_5 and 50 kg K_2O of which, about 15-30 kg N, 15 kg P_2O_5 and 35 kg K_2O become available during the first season of application.

The nutrient content of FYM varies with the composition of FYM. Chatterjee *et al.* (1979) studied the nutrient content of FYM and reported that it contains 0.64 per cent of N, 0.07 per cent P and 0.29 per cent K. While, Sharma and Mitra (1989) reported that the FYM contains 26.1 per cent C, 1.71 per cent N, 0.24 per cent P and 2.04 per cent K on dry weight basis and the C:N ratio was 15.1. Long term use of optimal dose of N, P and K with FYM or compost improved the soil physical health (Panda and Singh, 1996). Subbaiah and Kumaraswamy (1996) reported that the soil fertility status was higher in those treatments that have received one of the organic manures such as green manures, FYM, coir pith and compost along with NPK fertilizers as compared to only mineral fertilizers. Poonam *et al.* (2003) found that FYM @ 10 t/ha in combination with biofertilizers significantly increased the yield attributes viz., seeds/plant, pod length, pod number and pod dry weight. Application of FYM alone @ 10 t/ha increased the green pod yield by 16 per cent over the control in vegetable pea (Datt *et al.*, 2003).

Tomar (1998) reported that PSB inoculation @ 10 g/kg seed and FYM @ 5 t per ha both singly and in combination gave a significant increase in yield and its attributes in blackgram. Application of FYM @ 15 t/ha significantly increased the grain yield of soybean (Nimje and Jagdish, 1987). Chattopadhyay and Chakraborty (1990) also reported higher yield in onion with the application of farm yard manure. Ahmed (1993) reported maximum fruit yield of tomato (19.01 t/ha) with the application of farm yard manure. Brears and Marenah (1969) reported that the application of FYM increased the groundnut pod yield from 701 lb per acre to 1236 lb per acre. Wey and Obton (1978) obtained increased yield of haulm (47%) and pods (24%) in groundnut by the application of 10 t per ha of FYM.

Rayar (1986) noticed that FYM application increased the nodulation, whereas, N and P application decreased the nodulation in groundnut. Cisse (1988) reported that the application of 10 t per ha organic manure increased the number of branches per plant, growth rate at later stage and nutrient uptake (N, P, K, Ca and Mg) rates were 2-3 fold greater during the period of 20-60 days after germination than in control in groundnut.

Agasimani and Hosamani (1989) reported that the application of 7.5 t per ha FYM increased the pod yield (2417 kg/ha) and also yield components in groundnut as compared to no FYM application.

2.2.2 Role of Vermicompost

The vermicompost is an aerobically degraded organic matter which has undergone chemical 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 nutrients and micronutrients, besides having plant growth promoting substances, humus forming microbes and nitrogen fixers (Bano *et al.*, 1987). Field studies on the effect of vermicompost on clusterbean are meager. However, studies on the effect of vermicompost on other field/horticulture crops are reviewed here.

Guled *et al.* (2003) reported that vermicast contains 1.88 per cent nitrogen, 0.60 per cent phosphorus and 1.00 per cent potash and provide required nutrients to the plants, such as, nitrogen (0.74 ± 0.14%), P_2O_5 (0.97 ± 0.11%), K_2O (0.45 ± 0.15%) and Ca, Mg and micronutrients like Fe, Mo, Zn, Cu, etc. Apart from this, it also contains plant growth regulators such as NAA, cytokinins, gibberellins, etc. It also harbours beneficial microflora within it.

Ramachandrareddy *et al.* (1998) observed that application of 10 t vermicompost + 100% recommended NPK increased the plant height at harvest, days to initial flowering and number of branches per plant, number of pods, number of seeds per pod and yield in pea. Fresh and dry weight and yield of cowpea was higher in soil amended with vermicompost (Karmegam and Daniel, 2000).

Ushakumari *et al.* (1999) reported that application of vermicompost at 12 t/ha + full recommended dose of inorganic fertilizers (50 kg N, 8 kg P_2O_5 and 25 kg K_2O/ha) resulted in the highest yield (5663 kg/ha) in okra. Das *et al.* (2002) found that application of vermicompost in integrated form in greengram increased the dry matter content, pod yield, plant height, leaf area and also flowering was earlier by 7 days. In groundnut, the application of vermicompost @ 2 t per ha gave highest pod yield of 27.84 q per ha, when compared with FYM (10 t/ha) and 1 t per ha of vermicompost (Pattar *et al.*, 1999). Application of vermicompost in cucumber increased the yield by 42.5 per cent over control (Huang and Zhao, 1987); whereas, Kale *et al.* (1987) observed an increase in number of inflorescence per plant as well as early flowering in salvia.

The application of vermicompost to wheat crop has been found to increase the plant height, number of leaves, total dry matter and grain number per ear (Nijhawan and Kanwar, 1952). A study conducted by Kale and Bano (1986) in summer paddy (IR 20) revealed that the vegetative growth (Shoot weight, root weight, root and shoot length) was influenced by the application of vermicompost in a better way than chemical fertilizers. While, the seed weight increased significantly with the application of vermicompost over other treatments in sunflower (Kale *et al*, 1992). Hapse (1993) reported that application of vermicompost @ 5 t per ha increased the cane yield by 12.7 per cent and sugar recovery by 0.92 per cent.

III. MATERIAL AND METHODS

A field experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *kharif,* 2004 with an objective to find out the influence of plant growth regulators, organics and nutrients on yield and quality in clusterbean. The details of the materials used and the methods followed in the present investigation are described in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was carried out in plot no. 126 of E. block on medium black soils of Main Agricultural Research Station, University of Agricultural Sciences, Dharwad which is situated at 15°12'N latitude and 75°07' E longitude with an altitude of 678 m above mean sea level.

3.2 CLIMATE

The data on climatic parameters such as rainfall, mean maximum and minimum temperature and relative humidity recorded at Meteorological Observatory, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during the experimental year and the mean of the last 54 years (1950-2003) are presented in Table 1.

The mean annual rainfall for the past 54 years at Main Agricultural Research Station, Dharwad was 750.43 mm). The maximum rainfall (145.76 mm) was received in the month of July, followed by October (130.99 mm). During 2004 the total rainfall received during the cropping period was 516 mm. The mean maximum temperature 37.4°C was observed during April month, while the mean minimum temperature was 12.5°C observed during December month. During the year the relative humidity ranged from 45 per cent during December 2004 to 83 per cent during August 2004.

3.3 SOIL AND ITS CHARACTERISTICS

The experimental site consisted of medium black loam soil. Composite soil samples were analysed from the experimental site for various physical and chemical properties as per the procedures of Piper (1966) and Jackson (1967) and the details are presented in Table 2.

3.4 EXPERIMENTAL DETAILS

3.4.1 Treatment details

The following treatment combinations involving three plant growth regulators viz., lihocin (1000ppm), mepiquat chloride (1000 ppm) and miraculan (1000 ppm); two organics viz., FYM (10 t/ha), vermicompost (2 t/ha) and two nutrients viz., potassium nitrate (1%) and sulphur (40 kg/ha) were applied on 40 and 60 days after sowing. These treatments were tested on two clusterbean genotypes viz., DWD-1 (local variety) and Pusa Naubahar. The details of the treatments are furnished below.

Table 1. Monthly meteorological data for the experimental year (*kharif*, 2004) and the mean of past 54 years (1950-2003) as recorded at the Meteorological Observatory, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka)

Month	Rainfall (mm)		Temperature (°C)				Relative humidity (%)	
			Mean maximum		Mean minimum			
	Actual 2004	Longterm Mean*	Actual 2004	Longterm Mean*	Actual 2004	Longterm Mean*	Actual 2004	Longterm Mean*
January	Trace	0.08	29.6	29.1	14.7	19.2	54	63.3
February	Trace	1.16	32.5	34.5	16.4	16.0	53	51.1
March	Trace	0.14	36.5	35.7	19.6	18.8	49	56.4
April	24.4	48.4	37.4	37.0	19.8	21.3	51	76.9
May	61.1	81.4	33.6	36.5	21.4	21.4	66	66.7
June	43.8	109.1	28.8	29.5	21.5	21.2	80	81.6
July	24.8	145.7	29.2	22.0	21.0	20.9	79	87.4
August	160.7	95.3	27.0	22.0	20.3	20.6	83	86.5
September	222.1	100.5	28.6	28.7	19.9	20.1	77	82.4
October	64.6	130.9	30.1	30.1	18.4	19.3	65	76.4
November	0.6	32.0	30.2	29.4	15.9	15.5	52	68.1
December	0.0	54.5	29.4	29.1	12.5	13.4	45	63.8
Total	604.1	799.1						

*Mean of 54 years (1950-2003)

Table 2. Physical and chemical properties of the soil of experimental site

Properties	Value	Method employed
I. Physical properties		
Coarse sand (%)	6.28	International pipettee method (Piper, 1966)
Fine sand (%)	14.27	International pipettee method (Piper, 1966)
Silt (%)	27.52	International pipettee method (Piper, 1966)
Clay (%)	51.99	International pipettee method (Piper, 1966)
Bulk density (mg m^{-3})	1.33	Core sampler method (Dastane, 1967)
II. Chemical properties		
Soil pH (1:2.5 soil :water)	7.6	pH meter (Piper, 1966)
Electrical conductivity (dSm^{-1})	0.28	Conductivity bridge (Jackson, 1967)
Organic carbon (%)	0.52	Walkley and Black wet oxidation method (Jackson, 1967)
Available nitrogen (kg ha^{-1})	221	Modified Kjeldahl method (Jackson, 1967)
Available phosphorus (kg ha^{-1})	32.4	Olsen's method (Jackson, 1967)
Available potassium (kg ha^{-1})	318.7	Flame photometer (Jackson, 1967)

Table 3. Salient features of the growth regulators used in the experiment

Sl. No.	Common name/trade name	Chemical name	Mode of action	Uses
1.	Chlormequat chloride/cycocel, cycogan, CCC, lihocin	2-chloroethyl trimethyl ammonium chloide	Anti-gibberellin, inhibits cell elongation, may increase chlorophyll formation and root development	Improves sturdiness, prevents lodging, increase yields, control vegetative growth, thus more compact plants
2.	Mepiquat chloride/pix, DPC, chamatkar	1, 1-dimethyl piperidinium chloride	Anti-gibberellins, bio-regulator, growth inhibitor	Length reduction and strengthening of straw in barley, controls vegetative growth, boll retention, uniform maturity and yield in cotton
3.	Miraculan/TRIA	Triacontanol (TRIA) the straight chain alcohol	Growth promoter, promotes cell elongation	Growth promoter has been found to increase crop yield, in dry beans, sweet corn, tomato, cucumber, rice, maize, cotton, sugarbeet; increases the photosynthetic activity, mobilization of photosynthates, rapid increase in reducing sugars, soluble protein, succinate and amino acids, increase in the activity of 6-phospho gluconate hydrogenase and changes the permeability of plant membranes.

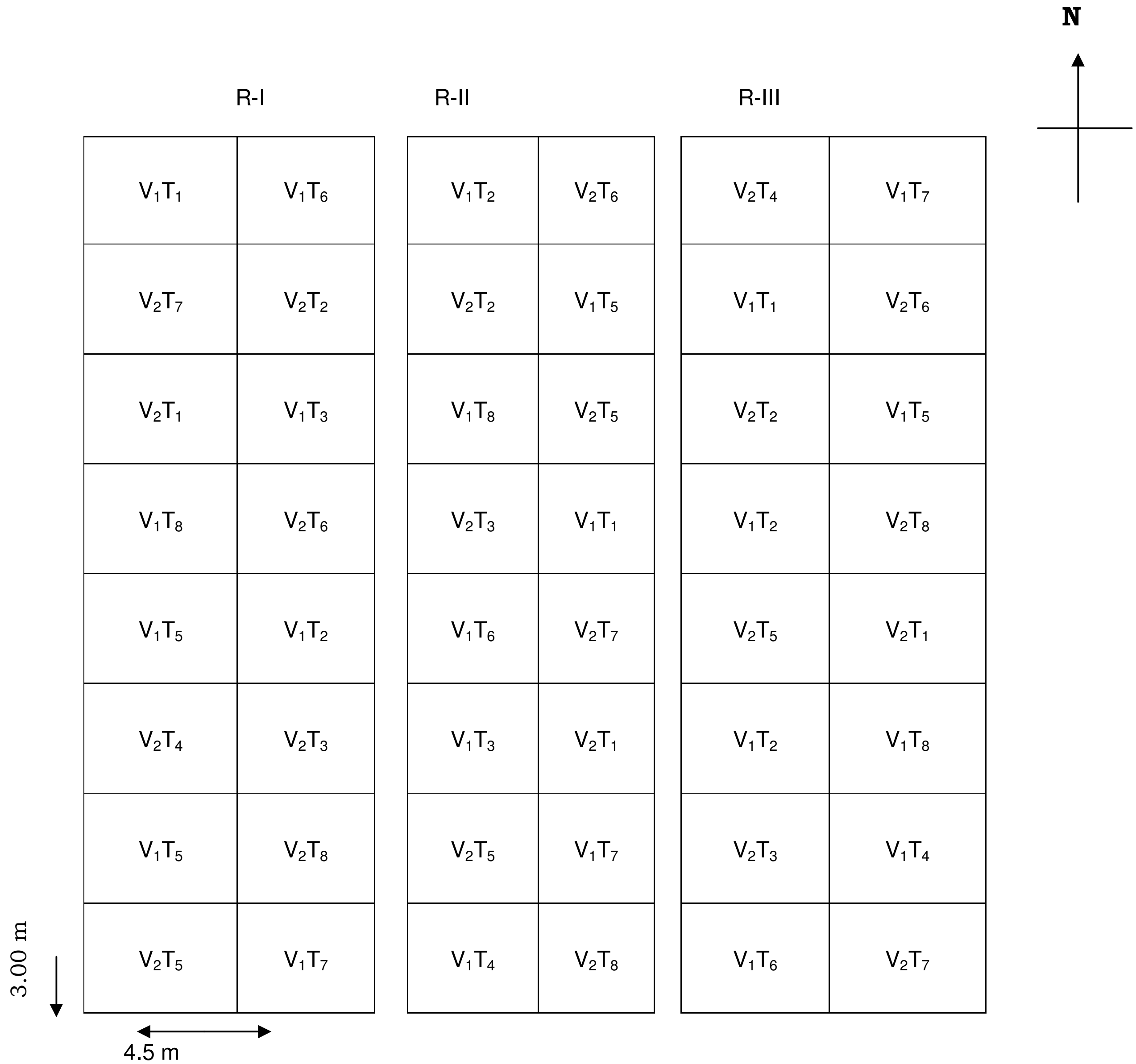

FIG 1. PLAN OF LAYOUT OF THE EXPERIMENT

Genotypes

V_1 - DWD-1 (Local)

V_2 - Pusa Naubahar

Treatments

T_1 - Foliar application of lihocin @ 1000 ppm

T_2 - Foliar application of potassium nitrate @ 1%

T_3 - Foliar application of mepiquat chloride (1000 ppm)

T_4 - Soil application of sulphur (40 kg/ha)

T_5 - Soil application of FYM (10 t/ha)

T_6 - Soil application of vermicompost (2 t/ha)

T_7 - Foliar application of miraculan (1000 ppm)

T_8 - Control

Treatment combinations - 16

3.4.2 Design and layout

The experiment was laid out in factorial randomized block design with three replications. The plan of layout of the experiment is given in Fig. 1.

Plot size

Gross Plot size - 4.5 m x 3.0 m

Net plot size - 3.6 m x 2.4 m

Spacing - 45 cm x 30 cm

3.4.3 Description of the cultivars used in the experiment

The cultivar DWD-1 is a branching type, stem is angled and hairy, trifoliate, ovate and serrate leaves. The pink coloured flowers borne on axillary receme and produces 7-8 branches. Seeds are oblong, creamy in colour with 2.5 to 3.0 g 100 seed weight.

The cultivar Pusa Naubahar released from IARI, New Delhi is having angular stems, leaves trifoliate, ovate and serrate. The white or pink coloured flowers borne on axillary receme, pods are longer (15 cm) and of better quality and susceptibility to bacterial blight and lodging.

3.5 CULTURAL PRACTICES

3.5.1 Land preparation

The land was ploughed and harrowed twice after the harvest of previous crop, followed by planking to bring the soil to a fine tilth.

3.5.2 Fertilization

The crop was fertilized with nitrogen, phosphorus and potassium @ 25:75:60 kg per ha in the form of urea, single super phosphate and muriate of potash, respectively as basal dose.

3.5.3 Spacing

Inter row spacing - 45 cm

Intra row spacing - 30 cm

3.5.4 Sowing

Healthy and bold seeds were dibbled with a spacing of 45 x 30 cm to a depth of 4 cm on 23rd June, 2004.

3.5.5 Thinning operation

After 15 days of sowing seedlings were thinned out by maintaining one plant per hill.

3.5.6 Plant protection and interculture operation

Interculture operation was carried out twice at 20 and 35 days after sowing immediately after hand weeding. The protective irrigation was given as and when needed.

Plate 1. General view of experimental plot

Plate 2. General view of experimental plot at harvest

The crop was sprayed with endosulfan @ 1.5 ml per litre to avoid the attack of leaf eating caterpillar. To control *Sclerotium* disease, soil drenching was done with bavistin @ 2 g per litre twice at 15 days interval.

3.5.7 Irrigation

Supplemental irrigation were provided whenever there was a drought situation.

3.5.8 Harvesting

In Pusa Naubahar, the hand pickings of green pods was done at regular intervals from 45 DAS onwards. Whereas, in DWD-1 (local) the harvesting of green pods was done after 60 DAS, at regular intervals. The total number of pickings were 7 and 3 times in Pusa Naubahar and DWD-1 (local), respetively.

3.6 COLLECTION OF EXPERIMENTAL DATA

Five plants were randomly selected form each plot and were tagged at 15 days after sowing for recording various morphological observations at different stages.

3.6.1 Morpho-physiological characters

3.6.1.1 Plant height

The plant height was measured from the cotyledonary node upto the growing tip and the mean was worked out from five plants, which were selected at random in each treatment and expressed in centimeters.

3.6.1.2 Number of branches

The number of branches per plant were counted at regular intervals and mean values of five plants were expressed as number per plant.

3.6.1.3 Number of green leaves per plant

Total number of green leaves were estimated by counting the individual leaves from top to bottom of the plant and the mean value of five plants selected at random in each treatment was expressed as number per plant.

3.6.1.4 Total dry matter production and its partitioning

Five plants were separated into leaf, stem and reproductive parts and dried in an oven at 80°C until a constant weight is obtained. Total dry matter was calculated by adding the dry weights of different plant parts and expressed as grams per plant.

3.6.2 Growth analysis

3.6.2.1 Leaf area (dm^2/plant)

Leaf area was determined by using leaf disc method. Twenty leaf discs having a known diameter were collected randomly from top 4-6 fully expanded leaves of the plant. As far as possible, the mid rib was avoided. The samples (disc and remaining leaves) were dried separately in hot air oven at 80°C for 72 hours. The dry weight of leaf discs and rest of the leaves was recorded and the leaf area was calculated by using the following formula :

$$\text{Leaf area} = \frac{a \times w}{b} \times \frac{1}{100} \ dm^2 \ plant^{-1}$$

a = Leaf area (cm^2) of 20 circular discs

b = Dry weight (g) of 20 circular discs

w = Dry weight (g) of rest of the leaves

3.6.2.2 Leaf area index (LAI)

The LAI was calculated by dividing the leaf area per plant by the land area occupied by the plant (Sestak *et al.*, 1971).

$$LAI = \frac{\text{Leaf area}}{\text{Land area}}$$

3.6.2.3 Absolute growth rate (AGR)

It is the dry matter production per unit time (g day^{-1}) and was calculated by using the formula

$$AGR = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

where,

W_1 = Dry weight of the plant at time t_1

W_2 = Dry weight of the plant at time t_2

3.6.2.4 Relative growth rate (RGR)

It is the rate of increase in the dry weight per unit dry weight already present and is expressed as g g^{-1} day^{-1} (Blackman, 1919).

Relative growth rate at various stage was calculated as follows

$$RGR = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

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

3.6.2.5 Crop growth rate (CGR)

Crop growth rate is the rate of dry matter production per unit ground area per unit time (Watson, 1952). It was calculated by using the following formula and expressed as g dm^{-2} day^{-1}.

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{A}$$

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 = Land area (dm^2)

3.6.2.6 Net assimilation rate (NAR)

Net assimilation rate is the rate of dry weight increase per unit leaf area per unit time. It was calculated by following the formula of Gregory (1926) and expressed as g dm^{-2} day^{-1}.

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\log_e A_2 - \log_e A_1)}{(A_2 - A_1)}$$

where,

A_1, W_1 = Leaf area (dm^2) and dry weight of the plant (g), respectively at time t_1

A_2, W_2 = Leaf area (dm^2) and dry weight of the plant (g), respectively at time t_2

$t_2 - t_1$ = Time interval in days

3.6.2.7 Specific leaf weight (SLW)

The specific leaf weight indicates the leaf thickness and was determined by the method of Radford (1967) and it was expressed as g dm^{-2}.

$$SLW = \frac{\text{Leaf dry weight (g)}}{\text{Leaf area } (dm^2)}$$

3.6.2.8 Specific leaf area (SLA)

The specific leaf area was worked out by using the following formula and expressed as dm^2/g leaf weight.

$$LAR = \frac{\text{Leaf area } (dm^2)}{\text{Leaf weight (g)}}$$

3.6.2.9 Leaf area duration (LAD)

Leaf area duration is the integral of leaf area index over a growth period (Watson, 1952). LAD for various growth periods was worked out as per the formula of Power *et al.* (1967) and expressed in days.

$$LAD = \frac{(L_i - L_{(i+1)})}{2} \times (t_2 - t_1)$$

where,

L_i = LAI at i^{th} stage

$L_{(i+1)}$ = LAI at $(i+1)^{th}$ stage

$t_2 - t_1$ = Time interval between i and (i + 1) stage (days).

3.6.2.10 Biomass duration (BMD)

The BMD was calculated by using the following formula and expressed in g day^{-1} (Sestak *et al.,* 1971)

$$BMD = \frac{TDM(i) + TDM(i+1)}{2} \times (t_2 - t_1)$$

where,

TDM(i) = Total dry matter at i^{th} stage

TDM (i+1) = Total dry matter $(i+1)^{th}$ stage

$t_2 - t_1$ = Time interval (days) between i^{th} stage and $(i+1)^{th}$ stage.

3.6.3 Biochemical parameters

3.6.3.1 Chlorophyll content

Total chlorophyll, chlorophyll 'a' and chlorophyll 'b' contents were determined by following the method of Arnon (1949). Fresh fully opened leaves from top of the canopy were brought from the field in icebox and were cut into small pieces and 0.25 g of leaf fresh weight was weighed from each sample and homogenized with acetone. The extract was filtered through Whatman No.1 filter paper and washed 2-3 times, with 80 per cent acetone. The final volume of the extract was made upto 25 ml. The absorbance of the extract was read at 645 and 663 nm in spectrophotometer and for blank, 80 per cent acetone was used. Total chlorophyll, chlorophyll 'a' and chlorophyll 'b' contents were calculated by using the following formulae and expressed in mg g fresh $weight^{-1}$.

$$\text{Chlorophyll 'a'} = (12.7 \times A_{663}) - (2.69 \times A_{645}) \times \frac{V}{\quad}$$

$$1000 \times a \times W$$

$$\text{Chlorophyll 'b'} = (22.9 \times A_{645}) - (4.68 \times A_{663}) \times \frac{V}{1000 \times a \times W}$$

Total chlorophyll = Chlorophyll 'a' + Chlorophyll 'b'

where,

A = Absorbance at specific wavelengths (645 and 663 nm)

V = Final volume of chlorophyll extract

W = Fresh weight of the sample (g)

A = Path length of light (1 cm)

3.6.3.2 Nitrate reductase activity

The nitrate reductase activity (NRA) *in vivo* was estimated as regular intervals following by the method of Saradhambal *et al.* (1978). Leaves were cut into small round discs, weighed and suspended in 0.1 M KNO_3 under bright light for 1 hour for complete stomatal opening. The discs were transferred to 25 ml volumetric flasks containing 5 ml of stock solution having 0.1 M phosphate buffer (pH 7.5), 0.02 M KNO_3, propanol (5%) and 2 drop of chloremphenicol (0.5 mg/ml). The flasks were incubated at 30℃ for 30 minutes in dark and the reaction was stopped by adding 0.1 ml of zinc acetate (1.0 M) and 1.9 ml of ethanol (70%). The contents were centrifuged at 3000 rpm for 10 minutes and the supernatant was collected. To the supernatant, 1.0 ml of sulphanilamide (1%) and 1 ml of NNEDA (N-Naphthyl ethylene diamine dihydrochloride 0.02%) were added and incubated at room temperature for 20 minutes. The activity of nitrate reductase was determined from a standard curve of KNO_2 and expressed as µmoles NO_2 formed per gram fresh weight per hour.

3.6.4 Yield and yield components

3.6.4.1 Number of pods per plant

The number of pods were counted from five randomly selected plants and the mean was worked out.

3.6.4.2 Number of seeds per pod

The total number of seeds per pod was calculated based on total number of pods and seeds present in five randomly selected plants and the average was worked out.

3.6.4.3 Pod length (cm)

The length was measured for all pods present on the five tagged plants and average pod length was worked out.

3.6.4.4 100-seed weight

The weight of hundred seeds picked at random from each replication in each treatment was taken and expressed in gram.

3.6.4.5 Harvest index

Harvest index was calculated based on dry weight of pods and the total dry weight of the plant and expressed in percentage (Donald, 1962).

$$HI = \frac{\text{Economic yield}}{\text{Total biological yield}} \times 100$$

3.6.4.6 Pod yield

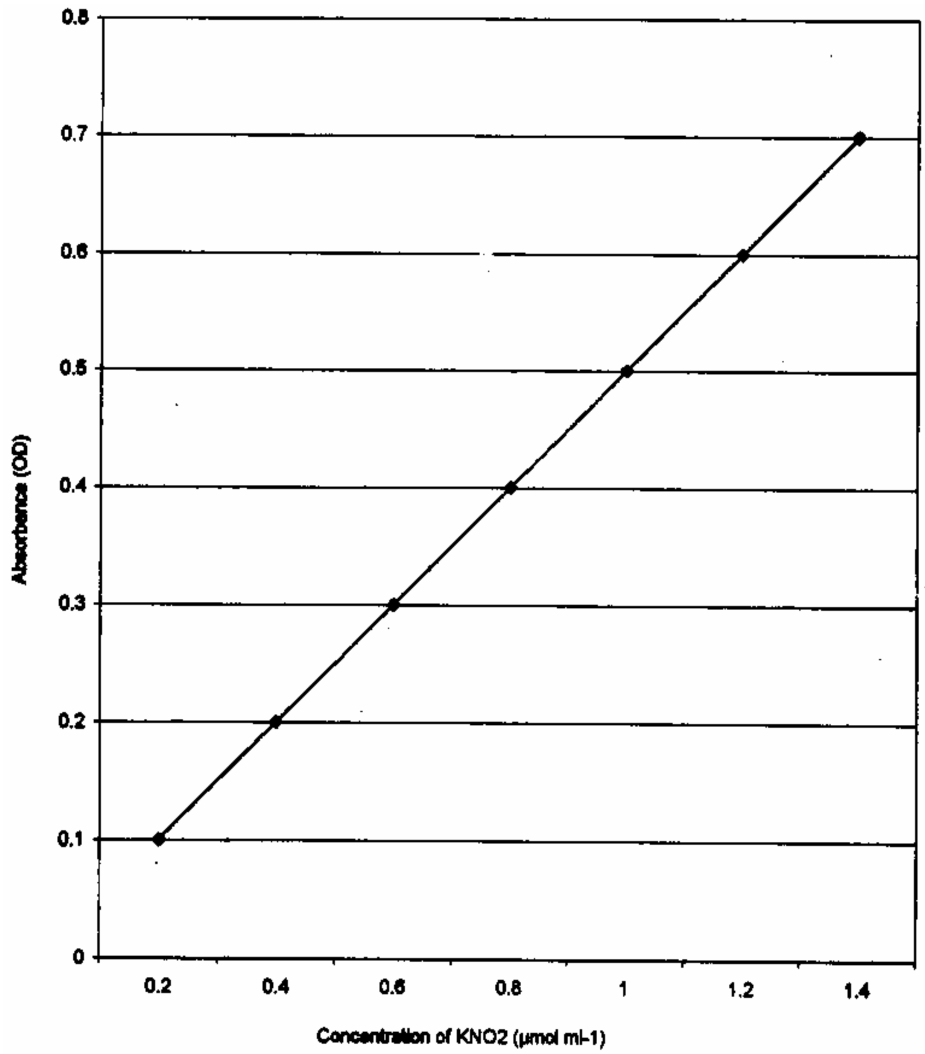

Figure 2. Standard curve for Nitrate reductase activity

Pod yield from one m^2 area in each treatment was recorded and the data was used to express the pod yield on hectare basis.

3.7 STATISTICAL ANALYSIS

The data was subjected to the analysis of variance by following the method of Panse and Sukhatme (1967). The level of significance used in P and t tests was P = 0.05. Critical differences were calculated whenever 'F' test was found significant.

3.8 ECONOMICS

The benefit cost ratio was worked out by using the data on green pod yield, selling rate, cost of inputs and total cost of cultivation.

LEGEND

Treatments :

T_1	- Foliar application of lihocin @ 1000 ppm
T_2	- Foliar application of potassium nitrate @ 1%
T_3	- Foliar application of mepiquat chloride (1000 ppm)
T_4	- Soil application of sulphur (40 kg/ha)
T_5	- Soil application of FYM (10 t/ha)
T_6	- Soil application of vermicompost (2 t/ha)
T_7	- Foliar application of miraculan (1000 ppm)
T_8	- Control

IV. EXPERIMENTAL RESULTS

A field experiment was conducted during *kharif*, 2004 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to study the influence of plant growth regulators, organics and nutrients on various morphological, physiological, biochemical and yield parameters of clusterbean (Var. DWD-1 (local) and Pusa Naubahar). The treatment combinations included three plant growth regulators viz., lihocin, mepiquat chloride, miraculan; two organics viz., farm yard manure, vermicompost and two nutrients viz., potassium nitrate and sulphur. These were applied at 40 and 60 days after sowing (DAS) and the results obtained are presented in this chapter.

4.1 MORPHOLOGICAL CHARACTERS

4.1.1 Plant height (cm)

The data on plant height at different stages indicated that plant height was maximum at harvest in both the varieties (Table 4). At 30 DAS, no significant differences were found among the plant growth regulators, organics and nutrients. At 60 and 90 DAS, miraculan (1000 ppm) followed by FYM (10 t ha^{-1}) treated plants recorded significantly higher plant height as compared to control whereas, vermicompost (2 t ha^{-1}) and sulphur (40 kg ha^{-1}) showed higher values over control. At harvest, FYM (10 t ha^{-1}) applied plants recorded significantly higher plant height and it was on par with sulphur (40 kg ha-1) and miraculan (1000 ppm).

While, lihocin (1000 ppm) and mepiquat chloride (1000 ppm), growth retardants decreased the plant height. The plant height was significantly lower in lihocin (1000 ppm) followed by mepiquat chloride (1000 ppm) as compared to other treatments at all the stages. Among the genotypes, DWD-1 (local) recorded significantly higher plant height as compared to Pusa Naubahar at all growth stages, except at 30 DAS.

4.1.2 Number of branches

The data presented in Table 5 indicated significant differences with respect to the number of branches per plant at harvest among the genotypes and the interaction effect was found significant. The genotype Pusa Naubahar did not possess any branches. Among the treatments, lihocin (1000 ppm) recorded higher number of branches per plant followed by mepiquat chloride (1000 ppm) as compared to control. The interaction effect between varieties and treatments was found to be significant.

4.1.3 Number of leaves per plant

The effect of plant growth regulators, organics and nutrients on number of leaves per plant presented in Table 6 indicated that the number of leaves increased from 30 to 90 DAS and decreased thereafter. The interaction between varieties and treatments was found significant at harvest and it was non-significant at all other growth stages. At 60 and 90 DAS significantly higher number of leaves was noticed in the treatment Miraculan (1000 ppm) which was on par with Mepiquat chloride (1000 ppm). Both the organics FYM (10 t ha^{-1}) and Vermicompost (2 t ha^{-1}) significantly increased the number of leaves over the control. Among the nutrients, Sulphur (40 kg ha^{-1}) and KNO_3 (1%) showed significantly higher number of leaves per plant over the control. Similar results were recorded even at harvest stage. Among the genotypes, DWD-1 (local) recorded significantly more number of leaves per plant over Pusa Naubahar at all stages.

4.2 DRY MATTER RPODUCTION

4.2.1 Leaf dry weight (g $plant^{-1}$)

The data on the leaf dry weight indicated that in DWD-1 (local) it was increased upto 90 DAS and declined steadily afterwards (Table 7). In case of Pusa Naubahar, leaf dry weight has increased only upto 60 DAS and then declined. At 30 DAS, there was no significant difference between the treatments and during 60 and 90 DAS, plant growth regulators, organics and nutrient treatments significantly increased the leaf dry weight over the control. Among the plant growth regulator treatments, Lihocin (1000 ppm) recorded significantly

Table 4. Effect of plant growth regulators, organics and nutrients on plant height (cm) at different stages in clusterbean

Treatments	Days after sowing											
	30			60			90			Harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	10.0	15.1	12.5	66.3	62.2	64.2	82.0	79.6	80.8	107.3	93.8	100.6
T_2 – KNO_3 (1%)	10.5	15.4	12.9	74.2	70.8	72.5	92.6	90.5	91.5	117.9	104.7	111.3
T_3 – Mepiquat chloride (1000 ppm)	11.3	15.4	13.3	71.0	65.9	68.5	88.3	85.3	86.8	112.6	98.38	105.5
T_4 – Sulphur (40 kg ha^{-1})	11.5	15.2	13.3	78.8	75.9	77.4	98.5	95.5	97.0	129.7	114.7	122.2
T_5 – FYM (10 t ha^{-1})	10.6	16.1	13.3	82.6	80.8	81.77	102.6	98.1	100.4	130.2	115.7	122.9
T_6 – Vermicompost (2 t ha^{-1})	11.1	16.3	13.7	76.7	72.4	74.6	95.5	92.6	94.0	119.9	106.4	113.2
T_7 – Miraculan (1000 ppm)	11.5	15.6	13.5	83.6	81.8	82.7	103.1	100.6	101.9	127.6	113.8	120.7
T_8 – Control	12.1	15.6	13.8	73.9	71.5	72.7	91.6	90.3	90.9	118.2	104.4	111.3
Mean	11.1	15.6	13.3	75.9	72.7	74.3	94.3	91.6	92.9	120.4	106.5	113.5

For comparing	S.Em± (30)	CD (5%) (30)	S.Em± (60)	CD (5%) (60)	S.Em± (90)	CD (5%) (90)	S.Em± (Harvest)	CD (5%) (Harvest)
Varieties (V)	0.15	0.45	0.78	2.26	0.93	2.69	1.32	3.82
Treatments (T)	0.31	NS	1.56	4.52	1.86	5.38	2.6	7.65
Interaction (V x T)	0.44	NS	2.21	NS	2.63	NS	3.74	NS

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Table 5. Effect of plant growth regulators, organics and nutrients on number of branches per plant at harvest in clusterbean

Treatment	At harvest		
	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	22.2 (4.72)	0.0 (1.0)	11.1 (2.86)
T_2 – KNO_3 (1%)	17.2 (4.16)	0.0 (1.0)	8.6 (2.58)
T_3 – Mepiquat chloride (1000 ppm)	20.0 (4.49)	0.0 (1.0)	10.0 (2.74)
T_4 – Sulphur (40 kg ha^{-1})	17.7 (4.22)	0.0 (1.0)	8.8 (2.61)
T_5 – FYM (10 t ha^{-1})	17.1 (4.13)	0.0 (1.0)	8.5 (2.57)
T_6 – Vermicompost (2 t ha^{-1})	17.3 (4.17)	0.0 (1.0)	8.65 (2.59)
T_7 – Miraculan (1000 ppm)	18.7 (4.32)	0.0 (1.0)	9.3 (2.66)
T_8 – Control	14.9 (3.87)	0.0 (1.0)	7.47 (2.43)
Mean	18.1 (4.26)	0.0 (1.0)	9.07 (2.63)
For comparing	S.Em±	CD (5%)	
Varieties (V)	0.041	0.119	
Treatments (T)	0.02	0.238	
Interaction (V x T)	0.116	0.336	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar

Figures in the parentheses indicate transformed $\sqrt{x + 1}$ values.

Table 6. Effect of plant growth regulators, organics and nutrients on number of leaves per plant at different stages in clusterbean

Treatments	Days after sowing											
	30			60			90			Harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	28.4	13.4	20.9	164.5	35.4	99.9	207.4	36.5	121.9	87.3	17.3	52.3
T_2 – KNO_3 (1%)	20.1	14.3	21.2	170.4	37.5	103.9	214.8	42.6	128.7	90.3	21.7	56.0
T_3 – Mepiquat chloride (1000 ppm)	28.6	13.9	21.3	175.4	41.3	108.3	220.3	49.5	134.9	93.2	24.2	58.7
T_4 – Sulphur (40 kg ha^{-1})	28.3	13.7	21.0	178.9	43.8	111.4	223.3	51.6	137.4	96.9	26.6	61.8
T_5 – FYM (10 t ha^{-1})	28.8	13.6	21.2	172.3	37.8	105.1	211.4	40.3	125.8	91.8	22.3	57.1
T_6 – Vermicompost (2 t ha^{-1})	27.8	13.2	20.5	172.8	39.6	106.2	218.5	45.6	132.1	92.2	22.7	57.4
T_7 – Miraculan (1000 ppm)	27.5	13.2	20.3	181.5	47.7	114.6	223.8	54.5	139.2	107.6	29.4	68.5
T_8 – Control	29.6	13.8	21.7	158.4	31.2	94.8	191.6	28.7	110.2	70.3	13.7	42.0
Mean	28.4	13.6	21.0	171.8	39.3	105.5	213.9	43.7	128.8	91.2	22.2	56.7
For comparing	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Varieties (V)	0.22		0.64	1.13		3.26	1.37		3.97	0.58		1.67
Treatments (T)	0.44		NS	2.26		6.53	2.75		7.94	1.16		3.35
Interaction (V x T)	0.63		NS	3.19		NS	3.88		NS	1.64		4.73

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Table 7. Effect of plant growth regulators, organics and nutrients on leaf dry weight (g $plant^{-1}$) at different stages in clusterbean

Treatments	Days after sowing											
	30			60			90			Harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	1.14	1.05	1.09	7.26	5.46	6.36	8.85	3.53	6.19	1.78	1.42	1.60
T_2 – KNO_3 (1%)	1.13	1.04	1.09	6.17	4.77	5.47	7.51	3.06	5.28	1.59	1.24	1.42
T_3 – Mepiquat chloride (1000 ppm)	1.13	1.04	1.09	6.90	5.21	6.05	8.66	3.34	6.00	1.71	1.36	1.54
T_4 – Sulphur (40 kg ha^{-1})	1.13	1.04	1.09	6.38	4.93	5.65	8.15	3.20	5.67	1.62	1.29	1.46
T_5 – FYM (10 t ha^{-1})	1.14	1.04	1.09	6.01	4.66	5.33	7.83	2.98	5.40	1.49	1.19	1.34
T_6 – Vermicompost (2 t ha^{-1})	1.14	1.04	1.09	6.58	5.05	5.81	8.34	3.27	5.80	1.66	1.34	1.50
T_7 – Miraculan (1000 ppm)	1.15	1.05	1.10	7.11	5.33	6.22	8.73	3.44	6.08	1.76	1.40	1.58
T_8 – Control	1.14	1.04	1.09	5.23	3.95	4.59	6.42	2.55	4.48	1.30	1.03	1.16
Mean	1.14	1.04	1.09	6.45	4.92	5.68	8.06	3.17	5.61	1.61	1.28	1.45
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.011	0.032		0.070	0.201		0.070	0.201		0.017	0.049	
Treatments (T)	0.022	NS		0.139	0.403		0.139	0.402		0.034	0.098	
Interaction (V x T)	0.031	NS		0.197	NS		0.197	0.568		0.048	NS	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Table 8. Effect of plant growth regulators, organics and nutrients on stem dry weight (g $plant^{-1}$) at different stages in clusterbean

Treatments	Days after sowing											
	30			60			90			Harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	0.93	0.83	0.88	9.72	8.41	9.06	11.67	10.86	11.26	16.41	14.34	15.37
T_2 – KNO_3 (1%)	0.93	0.83	0.88	8.35	7.25	7.80	10.06	9.38	9.72	14.14	12.26	13.20
T_3 – Mepiquat chloride (1000 ppm)	0.92	0.82	0.87	9.16	7.92	8.54	10.98	10.30	10.64	15.56	13.50	14.53
T_4 – Sulphur (40 kg ha^{-1})	0.93	0.83	0.88	8.52	7.58	8.05	10.39	9.56	9.97	14.74	12.57	13.65
T_5 – FYM (10 t ha^{-1})	0.93	0.82	0.88	8.10	7.01	7.55	9.72	9.01	9.36	13.61	11.84	12.72
T_6 – Vermicompost (2 t ha^{-1})	0.93	0.82	0.88	8.81	7.73	8.27	10.73	9.99	10.36	14.97	13.03	14.00
T_7 – Miraculan (1000 ppm)	0.93	0.82	0.88	9.51	8.22	8.86	11.40	10.58	10.99	16.04	14.02	15.03
T_8 – Control	0.93	0.82	0.88	7.02	6.07	6.45	8.42	7.84	8.13	11.84	10.39	11.11
Mean	0.93	0.82	0.88	8.64	7.52	8.08	10.42	9.69	10.05	14.66	12.74	13.70
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.009	0.026		0.153	0.442		0.156	0.439		0.149	0.446	
Treatments (T)	0.018	NS		0.306	0.884		0.309	0.881		0.302	0.887	
Interaction (V x T)	0.025	NS		0.433	NS		0.436	NS		0.429	NS	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar   NS – Non significant

higher leaf dry weight followed by Miraculan (1000 ppm) and Mepiquat chloride (1000 ppm). In case of organics at 60 and 90 DAS, Vermicompost (2 t ha^{-1}) recorded significantly higher leaf dry weight when compared to FYM (10 t ha^{-1}). While in case of nutrients, application of Sulphur (40 kg ha^{-1}) and KNO_3 (1%) resulted in significant increase of leaf dry weight and there was no significant difference between Lihocin (1000 ppm), Miraculan (1000 ppm), Mepiquat chloride (1000 ppm) and Vermicompost (2 t ha^{-1}) at 90 DAS. Among the genotypes, DWD-1 (local) recorded significantly higher leaf dry weight over Pusa Naubahar at all the growth stages. Leaf dry weight was significantly higher in DWD-1 (local) treated with Lihocin (1000 ppm) and lower in Pusa Naubahar treated with KNO_3 (1%), Sulphur (40 kg ha^{-1}) and FYM (10 t ha^{-1}) at harvest. The interaction between varieties and treatments was found significant at 90 DAS.

4.2.2 Stem dry weight

The data on stem dry weight revealed that it increased from 30 DAS to harvest in all the treatments in both the genotypes (Table 8). Treatments differed significantly at 60, 90 DAS and harvest and among the growth regulator treatments, Lihocin (1000 ppm) recorded highest stem dry weight and it is on par with Miraculan (1000 ppm) and Mepiquat chloride (1000 ppm) in both the genotypes at 60, 90 DAS and at harvest. Among the organics, Vermicompost (2 t ha^{-1}) gave significantly higher stem dry weight in both the genotypes and was superior over FYM (10 t ha^{-1}). Among the nutrients, Sulphur (40 kg ha^{-1}) recorded significantly higher stem dry weight compared to KNO_3 (1%) at 60 and 90 DAS. The least was recoded in control.

Significant difference between genotypes were observed at all growth stages. DWD-1 (local) recorded significantly higher stem dry weight at all the growth stages over Pusa Naubahar.

4.2.3 Dry weight of reproductive part (g $plnat^{-1}$)

The dry weight of reproductive part increased continuously from 60 DAS to harvest in Pusa Naubahar but DWD-1 (local) started bearing after 60 DAS and it also showed the same trend (Table 9). Significant differences among the treatments were noticed at all the stages. The treatment lihocin (1000 ppm) recorded higher reproductive dry weight and it was found superior over all other treatments.

Among the genotypes, Pusa Nuabahar recorded significantly higher reproductive part dry weight at all growth stages over DWD-1 (local). The treatment Lihocin (1000 ppm) gave maximum dry weight of reproductive parts in Pusa Naubahar and DWD-1 at harvest (25.39 g $plant^{-1}$ and 15.09 g $plant^{-1}$, respectively) followed by Miraculan (1000 ppm). Among the organics, vermicompost (2 t ha^{-1}) recorded significantly higher reproductive dry weight over FYM (10 t ha^{-1}). Among the nutrients sulphur (40 kg ha^{-1}) recorded higher reproductive dry weight over KNO_3 (1%). Whereas, the lowest dry weight was obtained in control. The interaction between varieties and treatments was found significant at 60 DAS and it was non significant at 90 DAS and at harvest. Reproductive part dry weight was found significantly higher in Pusa Naubahar treated with Lihocin (1000 ppm) and lower in DWD-1 (local) treated with FYM (10 t ha^{-1}) and KNO_3 (1%) at harvest when compared with other treatments.

4.2.4 Total dry weight

Total dry weight increased from 30 DAS to harvest in all the treatments (Table 10). The maximum total dry weight was noticed at harvest stage in all the treatments and the increase was higher between 90 DAS and at harvest. All the treatments recorded significantly higher total dry weight over control and the treatment lihocin (1000 ppm) was found on par with miraculan (1000 ppm) and mepiquat chloride (1000 ppm) at all stages. Among other treatments there was significant difference among the vermicompost (2 t ha^{-1}), sulphur (40 kg ha^{-1}) and KNO_3 (1%) at 60 DAS. The treatment vermicompost (2 t ha^{-1}) was found to be on par with sulphur (40 kg ha^{-1}) at both 90 DAS and at harvest.

Among the genotypes, DWD-1 (local) recorded significantly higher total dry weight over Pusa Naubahar at 30 DAS and 90 DAS.

Table 9. Effect of plant growth regulators, organics and nutrients on dry weight of reproductive parts (g plant^{-1}) at different stages in clusterbean

Treatments	Days after sowing								
	60			90			Harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	0.00 (1.00)	7.82 (2.96)	3.91 (1.98)	6.96	8.19	7.57	15.09	25.39	20.24
T_2 – KNO_3 (1%)	0.00 (1.00)	6.86 (2.80)	3.43 (1.93)	6.06	7.18	6.62	12.56	21.89	17.22
T_3 – Mepiquat chloride (1000 ppm)	0.00 (1.00)	7.65 (2.94)	3.82 (1.97)	6.76	7.95	7.35	14.44	24.28	19.36
T_4 – Sulphur (40 kg ha^{-1})	0.00 (1.00)	7.31 (2.88)	3.65 (1.94)	6.36	7.42	6.89	13.23	22.44	17.83
T_5 – FYM (10 t ha^{-1})	0.00 (1.00)	6.55 (2.74)	3.27 (1.87)	5.90	6.94	6.42	12.79	21.52	17.15
T_6 – Vermicompost (2 t ha^{-1})	0.00 (1.00)	7.05 (2.83)	3.52 (1.91)	6.46	7.54	7.00	13.78	23.18	18.48
T_7 – Miraculan (1000 ppm)	0.00 (1.00)	7.71 (2.95)	3.85 (1.97)	6.86	8.07	7.46	14.87	25.02	19.94
T_8 – Control	0.00 (1.00)	5.67 (2.58)	2.83 (1.79)	5.05	5.94	5.49	10.94	18.40	14.67
Mean	0.00 (1.00)	7.07 (2.84)	3.53 (1.92)	6.30	7.40	6.85	13.46	22.76	18.11
For comparing	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Varieties (V)	0.018		0.053	0.158		0.457	0.197		0.570
Treatments (T)	0.037		0.106	0.316		0.913	0.394		1.139
Interaction (V x T)	0.052		0.149	0.447		NS	0.558		NS

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Figures in the parentheses indicate transformed $\sqrt{x + 1}$ values.

Table 10. Effect of plant growth regulators, organics and nutrients on total dry weight (g plant^{-1}) at different stages in clusterbean

Treatment details	Days after sowing											
	30			60			90			Harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	2.07	1.87	1.97	16.98	21.69	19.33	27.48	22.58	25.03	33.28	41.15	37.21
T_2 – KNO_3 (1%)	2.06	1.87	1.96	14.52	18.88	16.70	23.63	19.66	21.64	28.26	35.39	31.82
T_3 – Mepiquat chloride (1000 ppm)	2.05	1.86	1.96	16.06	20.78	18.42	26.40	21.59	23.99	31.71	39.14	35.42
T_4 – Sulphur (40 kg ha^{-1})	2.06	1.87	1.96	14.90	19.82	17.36	24.90	20.18	22.54	29.59	36.30	32.94
T_5 – FYM (10 t ha^{-1})	2.07	1.86	1.96	14.11	18.22	16.16	23.45	18.93	21.19	27.89	34.55	31.22
T_6 – Vermicompost (2 t ha^{-1})	2.07	1.86	1.96	15.39	19.83	17.61	25.53	20.80	23.16	30.41	37.55	33.98
T_7 – Miraculan (1000 ppm)	2.08	1.87	1.97	16.62	21.26	18.94	26.99	22.09	24.54	32.67	40.44	36.55
T_8 – Control	2.06	1.86	1.96	12.25	15.69	13.97	19.89	16.33	18.11	24.08	29.82	26.95
Mean	2.07	1.86	1.96	15.10	19.52	17.31	24.78	20.27	22.52	29.73	36.79	33.26
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.020	0.059		0.204	0.589		0.244	0.705		0.341	0.986	
Treatments (T)	0.041	NS		0.408	1.179		0.488	1.410		0.683	1.971	
Interaction (V x T)	0.058	NS		0.577	NS		0.690	NS		0.965	NS	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Table 11. Effect of plant growth regulators, organics and nutrients on leaf area ($dm^2\ plant^{-1}$) at different stages in clusterbean

Treatments	Days after sowing											
	30			60			90			Harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	2.10	1.84	1.97	10.83	7.94	9.38	14.75	5.71	10.23	2.84	2.08	2.46
T_2 – KNO_3 (1%)	1.76	1.75	1.75	8.39	4.32	6.35	11.52	3.59	7.55	2.26	1.60	1.93
T_3 – Mepiquat chloride (1000 ppm)	1.95	1.79	1.87	10.14	7.30	8.72	14.49	4.85	9.67	2.67	2.00	2.34
T_4 – Sulphur (40 kg ha^{-1})	1.80	1.77	1.79	9.03	5.41	7.22	13.35	3.89	8.62	2.45	1.83	2.14
T_5 – FYM (10 t ha^{-1})	1.77	1.71	1.74	6.99	3.79	5.39	10.79	3.07	6.93	1.99	1.44	1.71
T_6 – Vermicompost (2 t ha^{-1})	2.220	1.75	1.97	9.40	5.58	7.49	13.66	4.14	8.90	2.57	1.95	2.26
T_7 – Miraculan (1000 ppm)	2.65	1.91	2.28	10.85	8.37	9.61	18.57	8.08	13.32	2.86	2.25	2.56
T_8 – Control	1.73	1.65	1.69	5.13	2.99	4.06	7.36	2.38	4.87	1.49	1.26	1.37
Mean	1.99	1.77	1.88	8.84	5.71	7.28	13.06	4.46	8.76	2.39	1.80	2.10
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.02	0.07		0.09	0.28		0.11	0.32		0.02	0.08	
Treatments (T)	0.04	0.14		0.19	0.56		0.22	0.65		0.05	0.16	
Interaction (V x T)	0.06	0.19		0.27	0.79		0.31	0.91		0.07	NS	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

4.3 GROWTH PARAMETERS

4.3.1 Leaf area (dm^2 $plant^{-1}$)

The data on leaf area indicated that it increased from 30 to 90 DAS, it declined at harvest and the increase was rapid between 30 to 60 DAS (Table 11). Significant differences among the treatments were noticed at all the stages. The treatment miraculan (1000 ppm) was found superior compared to all other treatments at 30 DAS. Among the growth regulator, the treatment miraculan (1000 ppm) recorded significantly higher leaf area followed by lihocin (1000 ppm) at all the stages. Among the organics, vermicompost (2 t ha^{-1}) recorded significantly higher leaf area over FYM (10 t ha^{-1}). In case of nutrients, the treatment sulphur (40 kg ha^{-1}) showed significantly higher leaf area over the treatment KNO_3 (1%).

Among the genotypes, DWD-1 (local) recorded significantly higher leaf area at all the growth stages as compared to Pusa Naubahar. The interaction between varieties and treatments was found to be significant at all the stages except at harvest.

4.3.2 Leaf area index

The data pertaining to influence of plant growth regulators, organics and nutrients on leaf area index (LAI) presented in Table 12 indicated that it increased steadily from 30 DAS and reached a maximum at 90 DAS and declined later. There was a significant differences in LAI due to various treatments at all the stages. Among the growth regulators, the maximum LAI was noticed in the treatment miraculan (1000 ppm) at all the stages and it was found on par with lihocin (1000 ppm) at 30 DAS and at harvest. Among organics, treatment Vermicompost (2 t ha-1) recorded maximum LAI over FYM (10 t ha^{-1}) at all the growth stages and in case of nutrients, sulphur (40 kg ha^{-1}) was found on par with the treatment KNO_3 (1%) at 30 DAS and at harvest but at 60 DAS and 90 DAS, sulphur (40 kg ha^{-1}) showed maximum LAI over KNO_3 (1%).

Among the genotypes, DWD-1 (local) recorded the highest LAI over Pusa Naubahar at all the stages. The interaction effect between varieties and treatments were found significant at all the stages except at harvest.

4.3.3 Absolute growth rate

The absolute growth rate (AGR) increased from 30-60 DAS and declined from 60-90 DAS in all the treatments (Table 13). AGR was found significant due to all the treatments at 30-60 DAS and 90 – harvest. The maximum AGR was noticed in the plants treated with lihocin (1000 ppm) and it was on par with the treatment miraculan (1000 ppm) and mepiquat chloride (1000 ppm) at all the stages. Among other treatments, vermicompost (2 t ha^{-1}) recorded higher AGR and it was on par with the treatments sulphur (40 kg ha^{-1}), KNO_3 (1%) and FYM (10 t ha^{-1}) at all the stages. The least AGR noticed in control at all the growth stages.

Among the genotypes, Pusa Naubahar recorded significantly higher AGR at 30-60 DAS and 90-harvest stage over DWD-1 (local). The interaction between varieties and treatments was found to be significant at 60-90 DAS and at 90-harvest stages.

4.3.4 Crop growth rate

The data presented in Table 14 indicated significant differences in crop growth rate (CGR) due to plant growth regulators, organics and nutrient treatments. CGR was found maximum at 30-60 DAS and decreased at 60-90 DAS. All the treatments significantly increased the CGR at all the stages over control. The maximum CGR was recorded in the plants treated with lihocin (1000 ppm) at all the stages followed by miraculan (1000 ppm) and mepiquat chloride (1000 ppm) at all the stages. At 60-90 DAS, all the treatments were found on par with each other except control. At 90-harvest, the treatment vermicompost (2 t ha^{-1}) was found on par with the treatments sulphur (40 kg ha^{-1}), $KN0_3$ (1%) and FYM (10 t ha^{-1}). The least CGR was recorded in control at all the stages.

Among the genotypes, Pusa Naubahar maintained significantly higher CGR over DWD-1 (local) at 30-60 and 90 DAS-at harvest stage. but Pusa Naubahar showed significantly higher CGR between 60-90 DAS. The interaction between varieties and treatments was fond to be non-significant at all the stages except at 90-harvest stage.

Table 12. Effect of plant growth regulators, organics and nutrients on leaf area index at different stages in clusterbean

Treatments	Days after sowing											
	30			60			90			Harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	0.15	0.13	0.14	0.80	0.58	0.69	1.08	0.42	0.75	0.20	0.15	0.17
T_2 – KNO_3 (1%)	0.21	0.12	0.12	0.61	0.31	0.46	0.84	0.26	0.55	0.16	0.11	0.13
T_3 – Mepiquat chloride (1000 ppm)	0.13	0.13	0.13	0.74	0.53	0.64	1.06	0.35	0.71	0.19	0.14	0.16
T_4 – Sulphur (40 kg ha^{-1})	0.12	0.12	0.12	0.66	0.39	0.53	0.98	0.28	0.63	0.17	0.13	0.15
T_5 – FYM (10 t ha^{-1})	0.12	0.12	0.12	0.51	0.27	0.39	0.79	0.22	0.50	0.14	0.10	0.12
T_6 – Vermicompost (2 t ha^{-1})	0.15	0.12	0.14	0.69	0.41	0.55	1.01	0.30	0.65	0.18	0.14	0.16
T_7 – Miraculan (1000 ppm)	0.19	0.13	0.16	0.80	0.62	0.71	1.37	0.59	0.98	0.20	0.16	0.18
T_8 – Control	0.12	0.11	0.12	0.37	0.22	0.29	0.54	0.17	0.35	0.10	0.09	0.09
Mean	0.14	0.12	0.13	0.65	0.42	0.53	0.96	0.32	0.64	0.17	0.13	0.14
For comparing	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Varieties (V)	0.002		0.007	0.007		0.021	0.008		0.024	0.002		0.006
Treatments (T)	0.005		0.013	0.014		0.042	0.016		0.047	0.004		0.013
Interaction (V x T)	0.007		0.019	0.020		0.059	0.023		0.067	0.006		NS

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Table 13. Effect of plant growth regulators, organics and nutrients on absolute growth rate (g day^{-1}) at different stages in clusterbean

Treatments	Days after sowing								
	30-60			60-90			90-Harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	0.49	0.65	0.57	0.35	0.02	0.19	0.19	0.61	0.40
T_2 – KNO_3 (1%)	0.41	0.56	0.48	0.30	0.02	0.16	0.15	0.52	0.33
T_3 – Mepiquat chloride (1000 ppm)	0.46	0.62	0.54	0.34	0.02	0.18	0.17	0.58	0.37
T_4 – Sulphur (40 kg ha^{-1})	0.42	0.59	0.50	0.33	0.01	0.17	0.15	0.53	0.34
T_5 – FYM (10 t ha^{-1})	0.39	0.54	0.46	0.31	0.02	0.16	0.14	0.52	0.33
T_6 – Vermicompost (2 t ha^{-1})	044	0.59	0.51	0.33	0.03	0.18	0.15	0.55	0.35
T_7 – Miraculan (1000 ppm)	0.48	0.64	0.56	0.34	0.02	0.18	0.18	0.61	0.39
T_8 – Control	0.33	0.45	0.39	0.25	0.02	0.13	0.13	0.44	0.28
Mean	0.42	0.58	0.50	0.31	0.02	0.17	0.16	0.54	0.35

For comparing	30-60 S.Em±	30-60 CD (5%)	60-90 S.Em±	60-90 CD (5%)	90-Harvest S.Em±	90-Harvest CD (5%)
Varieties (V)	0.007	0.020	0.004	0.012	0.005	0.016
Treatments (T)	0.014	0.041	0.008	0.024	0.011	0.031
Interaction (V x T)	0.020	NS	0.012	0.034	0.015	0.044

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Table 14. Effect of plant growth regulators, organics and nutrients on crop growth rate (g dm^{-2} day^{-1}) at different stages in clusterbean

Treatments	Days after sowing								
	30-60			60-90			90-harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	0.036	0.048	0.042	0.025	0.002	0.014	0.014	0.045	0.029
T_2 – KNO_3 (1%)	0.030	0.042	0.036	0.022	0.001	0.012	0.011	0.0.38	0.024
T_3 – Mepiquat chloride (1000 ppm)	0.034	0.046	0.040	0.025	0.002	0.014	0.013	0.043	0.028
T_4 – Sulphur (40 kg ha^{-1})	0.031	0.044	0.037	0.024	0.001	0.012	0.011	0..039	0.025
T_5 – FYM (10 t ha^{-1})	0.029	0.040	0.035	0.023	0.002	0.012	0.010	0.038	0.024
T_6 – Vermicompost (2 t ha^{-1})	0.032	0.044	0.038	0.025	0.02	0.014	0.012	0.041	0.026
T_7 – Miraculan (1000 ppm)	0.035	0.047	0.041	0.025	0.002	0.014	0.014	0.045	0.029
T_8 – Control	0.025	0.034	0.029	0.018	0.001	0.010	0.010	0.033	0.021
Mean	0.032	0.043	0.037	0.024	0.002	0.013	0.012	0.040	0.026
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.001	0.001		0.000	0.001		0.000	0.001	
Treatments (T)	0.001	0.003		0.001	NS		0.001	0.002	
Interaction (V x T)	0.001	NS		0.001	NS		0.001	0.003	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar   NS – Non significant

Table 15. Effect of plant growth regulators, organics and nutrients on relative growth rate (g g^{-1} day^{-1}) at different stages in clusterbean

Treatments	Days after sowing								
	30-60			60-90			90-harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	sV_2	Mean
T_1 – Lihocin (1000 ppm)	0.070	0.081	0.076	0.016	0.001	0.008	0.006	0.020	0.013
T_2 – KNO_3 (1%)	0.064	0.077	0.071	0.017	0.001	0.009	0.005	0.019	0.012
T_3 – Mepiquat chloride (1000 ppm)	0.068	0.080	0.074	0.016	0.001	0.009	0.006	0.019	0.012
T_4 – Sulphur (40 kg ha^{-1})	0.065	0.078	0.0.72	0.017	0.001	0.009	0.005	0.019	0.012
T_5 – FYM (10 t ha^{-1})	0.0.63	0.076	0.070	0.016	0.001	0.009	0.005	0.020	0.012
T_6 – Vermicompost (2 t ha^{-1})	0.066	0.078	0.072	0.016	0.002	0.009	0.005	0.019	0.012
T_7 – Miraculan (1000 ppm)	0.069	0.081	0.075	0.015	0.001	0.008	0.007	0.020	0.014
T_8 – Control	0.059	0.071	0.065	0.016	0.001	0.008	0.006	0.020	0.013
Mean	0.066	0.078	0.072	0.016	0.001	0.009	0.006	0.019	0.012
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.001	0.002		0.000	0.001		0.000	0.000	
Treatments (T)	0.001	0.004		0.000	NS		0.000	NS	
Interaction (V x T)	0.002	NS		0.001	NS		0.000	NS	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Table 16. Effect of plant growth regulators, organics and nutrients on net assimilation rate (g dm^{-2} day^{-1}) at different stages in clusterbean

Treatments	Days after sowing								
	30-60			60-90			90-harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	0.093	0.157	0.125	0.027	0.004	0.015	0.026	0.172	0.099
T_2 – KNO_3 (1%)	0.096	0.198	0.147	0.031	0.006	0.018	0.026	0.212	0.119
T_3 – Mepiquat chloride (1000 ppm)	0.093	0.160	0.127	0.025	0.004	0.014	0.025	0.181	0.103
T_4 – Sulphur (40 kg ha^{-1})	0.095	0.182	0.139	0.030	0.002	0.016	0.024	0.195	0.109
T_5 – FYM (10 t ha^{-1})	0.105	0.208	0.156	0.035	0.014	0.024	0.028	0.358	0.193
T_6 – Vermicompost (2 t ha^{-1})	0.089	0.180	0.135	0.029	0.006	0.018	0.024	0.191	0.107
T_7 – Miraculan (1000 ppm)	0.083	0.147	0.115	0.024	0.003	0.013	0.022	0.133	0.077
T_8 – Control	0.108	0.203	0.156	0.041	0.007	0.024	0.037	0.254	0.145
Mean	0.095	0.180	0.137	0.030	0.006	0.018	0.026	0.212	0.119
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.001	0.004		0.001	0.002		0.002	0.005	
Treatments (T)	0.003	0.008		0.001	0.003		0.004	0.011	
Interaction (V x T)	0.004	0.011		0.002	0.005		0.005	0.015	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

4.3.5 Relative growth rate

It is evident from the Table 15 that the relative growth rate (RGR) was highest at 30-60 DAS and then declined at 60-90 DAS and 90-harvest in all the treatments. At 30-60 DAS, all the treatments recorded significantly higher RGR over the control and the treatment lihocin (1000 ppm), mepiquat chloride (1000 ppm) and miraculan (1000 ppm) recorded maximum RGR and these treatments were found to be on par with the treatments vermicompost (2 t ha^{-1}) and sulphur (40 kg ha^{-1}). At 60-90 DAS and 90-harvest there was no significant difference among the treatments but the treatment KNO_3 (1%), sulphur (40 kg ha^{-1}), mepiquat chloride (1000 ppm), FYM (10 t ha^{-1}) and vermicompost (2 t ha^{-1}) showed higher RGR over control. The treatments, Miraculan (1000 ppm) showed higher RGR over control at 90-harvest stage.

Among the genotypes, Pusa Naubahar recorded significantly higher RGR at 30-60 and 90-harvest stages over DWD-1 but at 60-90 DAS DWD-1 (local) recorded significantly higher RGR over Pusa Naubahar. The interaction effect between varieties and treatments was found to be non-significant at all the stages.

4.3.6 Net assimilation rate

The data on net assimilation rate (NAR) presented in table 16 indicated that NAR was higher at 30-60 DAS and decreased at 60-90 DAS. Among the treatments, FYM (10 t ha^{-1}) recorded significantly higher NAR over other treatments at all the stages. All the treatments except FYM (10 t ha^{-1}) recorded significantly lower NAR over the control at all the stages.

Pusa Naubahar recorded significantly higher NAR when compared to DWD-1 (Local) at 30-60 DAS and 90-harvest and DWD-1 (local) recorded significantly higher NAR over Pusa Naubahar at 60-90 DAS. The interaction effect between varieties and treatments was found to be significant at all the stages.

4.3.7 Leaf area duration

The data pertaining to leaf area duration (LAD) presented in Table 17 indicated that LAD increased from 30-60 and 60-90 DAS and then it was decreased at 90-harvest stage compared to 60-90 DAS. Significant differences were registered among the treatments at all the stages. Among the treatments, miraculan (1000 ppm) recorded significantly higher LAD values at all the stages and it was found to be superior over all other treatments. Among the organics, vermicompost (2 t ha^{-1}) registered significantly maximum LAD as compared to FYM (10 t ha^{-1}). In case of nutrients, sulphur (40 kg ha^{-1}) recorded significantly higher LAD as compared to KNO_3 (1%).

Among the genotypes, DWD-1 (local) recorded significantly higher LAD as compared to Pusa Naubahar. The interaction effect between varieties and treatments was found to be significant at 60-90 DAS and 90-harvest.

4.3.8 Biomass duration

The data on biomass duration (BMD) presented in Table 18 indicated that BMD increased from 30 to harvest stage. Significant differences were registered among the treatments at all the stages. Among the plant growth regulator treatments, lihocin (1000 ppm) recorded significantly higher BMD followed by miraculan (1000 ppm) and mepiquat chloride (1000 ppm) at all the stages. Among the organics, the treatment vermicompost (2 t ha^{-1}) registered higher BMD over the treatment FYM (10 t ha^{-1}) at all the stages. In case of nutrients, sulphur (40 kg ha^{-1}) recorded maximum BMD as compared to KNO_3 (1%) at all the stages. The least BMD was recorded in control at all the stages.

Pusa Naunahar recorded significantly higher BMD as compared to DWD-1 (local) at 30-60 DAS and 90-harvest. There was non-significant difference among the varieties at 60-90 DAS. The interaction effect between varieties and treatments was found to be non-significant at all the stages.

Table 17. Effect of plant growth regulators, organics and nutrients on leaf area duration (days) at different stages in clusterbean

Treatments	Days after sowing								
	30-60			60-90			90-harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	14.47	10.88	12.68	28.42	15.18	21.80	19.55	8.67	14.11
T_2 – KNO_3 (1%)	11.29	6.76	9.02	22.13	8.80	15.47	15.32	5.77	10.54
T_3 – Mepiquat chloride (1000 ppm)	13.45	10.11	11.78	27.37	13.52	20.44	19.08	7.63	13.35
T_4 – Sulphur (40 kg ha^{-1})	12.04	8.00	10.02	24.87	10.34	17.61	17.57	6.37	11.97
T_5 – FYM (10 t ha^{-1})	9.75	6.12	7.93	19.77	7.63	13.70	14.21	5.02	9.62
T_6 – Vermicompost (2 t ha^{-1})	12.89	8.16	10.52	25.63	10.81	18.22	18.04	6.78	12.41
T_7 – Miraculan (1000 ppm)	15.01	11.43	13.22	32.70	18.29	25.49	23.83	11.52	17.67
T_8 – Control	7.63	5.17	6.40	13.88	5.97	9.93	9.84	4.05	6.95
Mean	12.06	8.33	10.20	24.35	11.32	17.83	17.18	6.98	12.081
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.125	0.362		0.227	0.856		0.130	0.377	
Treatments (T)	0.251	0.725		0.455	1.313		0.261	0.753	
Interaction (V x T)	0.355	NS		0.643	1.857		0.369	1.065	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Table 18. Effect of plant growth regulators, organics and nutrients on biomass duration (g days) at different stages in clusterbean

Treatments	Days after sowing								
	30-60			60-90			90-harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	285.7	353.4	319.5	666.9	664.0	665.4	911.4	955.9	933.6
T_2 – KNO_3 (1%)	248.7	311.2	279.9	572.2	578.1	575.1	778.3	825.7	802.0
T_3 – Mepiquat chloride (1000 ppm)	271.6	339.6	305.6	636.9	635.5	636.2	871.6	910.9	891.3
T_4 – Sulphur (40 kg ha^{-1})	254.4	325.3	289.8	597.0	600.0	598.5	817.3	847.2	832.2
T_5 – FYM (10 t ha^{-1})	242.7	301.1	271.9	563.4	557.2	560.3	770.1	802.2	786.1
T_6 – Vermicompost (2 t ha^{-1})	261.9	325.3	293.6	613.8	609.4	611.6	839.1	875.2	857.1
T_7 – Miraculan (1000 ppm)	280.4	346.9	313.7	620.8	650.2	635.5	894.9	937.9	916.4
T_8 – Control	214.6	263.2	238.9	482.1	480.3	481.2	659.5	692.2	675.9
Mean	257.5	320.7	289.1	594.1	596.8	575.5	817.8	855.9	836.8
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	3.05	8.82		6.48	NS		8.57	24.77	
Treatments (T)	6.11	17.65		12.97	37.46		17.15	49.54	
Interaction (V x T)	8.64	NS		18.34	NS		24.26	NS	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Table 19. Effect of plant growth regulators, organics and nutrients on specific leaf weight (g dm^{-2}) at different stages in clusterbean

Treatments	Days after sowing											
	30			60			90			Harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	0.63	0.60	0.61	0.85	1.22	1.03	0.72	0.96	0.84	0.74	0.81	0.77
T_2 – KNO_3 (1%)	0.70	0.59	0.64	0.73	1.13	0.93	0.64	0.85	0.74	0.69	0.76	0.73
T_3 – Mepiquat chloride (1000 ppm)	0.57	0.57	0.57	0.67	0.71	0.69	0.59	0.68	0.63	0.63	0.67	0.65
T_4 – Sulphur (40 kg ha^{-1})	0.62	0.57	0.60	0.70	0.90	0.80	0.60	0.81	0.71	0.65	0.69	0.67
T_5 – FYM (10 t ha^{-1})	0.65	0.62	0.63	1.01	1.31	1.16	0.87	1.03	0.95	0.86	0.81	0.83
T_6 – Vermicompost (2 t ha^{-1})	0.52	0.58	0.55	0.69	0.90	0.79	0.60	0.78	0.69	0.64	0.67	0.65
T_7 – Miraculan (1000 ppm)	0.42	0.54	0.48	0.65	0.63	0.64	0.46	1.42	0.44	0.60	0.60	0.60
T_8 – Control	0.51	0.56	0.53	0.66	0.68	0.67	0.59	0.61	0.60	0.62	0.67	0.64
Mean	0.58	0.58	0.58	0.74	0.43	0.84	0.63	0.77	0.70	0.68	0.71	0.69
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.008	NS		0.008	0.023		0.011	0.031		0.008	0.023	
Treatments (T)	0.016	0.046		0.016	0.045		0.022	0.062		0.016	0.045	
Interaction (V x T)	0.022	0.065		0.022	0.064		0.030	0.088		0.022	NS	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Table 20. Effect of plant growth regulators, organics and nutrients on specific leaf area ($dm^2\ g^{-1}$) at different stages in clusterbean

Treatments	Days after sowing											
	30			60			90			Harvest		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	1.91	1.76	1.83	1.49	1.45	1.47	1.67	1.61	1.64	1.60	1.52	1.56
T_2 – KNO_3 (1%)	1.55	1.67	1.61	1.36	0.90	1.13	1.53	1.17	1.35	1.42	1.25	1.34
T_3 – Mepiquat chloride (1000 ppm)	1.74	1.72	1.73	1.46	1.40	1.43	1.67	1.45	1.56	1.57	1.47	1.52
T_4 – Sulphur (40 kg ha^{-1})	1.59	1.71	1.65	1.41	1.09	1.25	1.63	1.21	1.42	1.52	1.36	1.44
T_5 – FYM (10 t ha^{-1})	1.56	1.65	1.60	1.16	0.81	0.98	1.37	1.03	1.20	1.34	1.15	1.24
T_6 – Vermicompost (2 t ha^{-1})	1.92	1.69	1.80	1.42	1.10	1.26	1.63	1.26	1.44	1.55	1.40	1.47
T_7 – Miraculan (1000 ppm)	2.33	1.82	2.07	1.52	1.57	1.54	2.12	2.35	2.23	1.63	1.84	1.73
T_8 – Control	1.52	1.59	1.55	0.98	0.75	0.86	1.14	0.93	1.03	1.15	1.18	1.16
Mean	1.76	1.70	1.73	1.35	1.13	1.24	1.59	1.37	1.48	1.47	1.40	1.43
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.021	0.061		0.011	0.033		0.023	0.066		0.025	0.073	
Treatments (T)	0.042	0.121		0.023	0.066		0.046	0.132		0.050	0.145	
Interaction (V x T)	0.059	0.172		0.033	0.094		0.065	0.187		0.071	NS	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar   NS – Non significant

Table 21. Effect of plant growth regulators, organics and nutrients on chlorophyll 'a' content (mg g fresh weight^{-1}) at different stages in clusterbean

Treatments	Days after sowing					
	40			60		
	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	0.92	0.85	0.88	1.23	1.03	1.13
T_2 – KNO_3 (1%)	0.43	0.51	0.47	1.03	0.77	0.90
T_3 – Mepiquat chloride (1000 ppm)	0.92	0.83	0.87	1.19	0.95	1.07
T_4 – Sulphur (40 kg ha^{-1})	0.77	0.72	0.74	1.15	0.89	1.02
T_5 – FYM (10 t ha^{-1})	0.69	0.50	0.59	0.99	0.88	0.93
T_6 – Vermicompost (2 t ha^{-1})	0.71	0.65	0.68	1.13	0.88	1.00
T_7 – Miraculan (1000 ppm)	0.82	0.71	0.77	1.14	0.89	1.02
T_8 – Control	0.45	0.26	0.36	0.89	0.62	0.76
Mean	0.71	0.63	0.67	1.09	0.86	0.98

For comparing	S.Em± (40)	CD (5%) (40)	S.Em± (60)	CD (5%) (60)
Varieties (V)	0.003	0.008	0.002	0.006
Treatments (T)	0.006	0.016	0.004	0.013
Interaction (V x T)	0.008	0.023	0.006	0.018

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

4.3.9 Specific leaf weight

Specific leaf weight (SLW) as influenced by the application of different treatments in both the genotypes at various growth stages is presented in Table 19. There was an increase in the SLW from 30 to 60 DAS and there was slight decline at 90 DAS and at harvest in both the genotypes. Significant differences were found among the treatments at all the stages. The treatment FYM (10 t ha^{-1}) recorded significantly higher SLW over the control at all the stages and there was no significant difference between the treatment vermicompost (2 t ha^{-1}) and sulphur (40 kg ha^{-1}).

Among the genotypes, Pusa Naubahar recorded significantly higher SLW as compared to DWD-1 (local) at all the stages except at 30 DAS where it was found non-significant. The interaction effect between varieties and treatments was found to be significant at all the growth stages except at harvest.

4.3.10 Specific leaf area

There was a decrease in specific leaf area (SLA) from 30 to 60 DAS and increased slightly at 90 DAS and then declined slightly at harvest in all the treatments and in both the genotypes (Table 20). Among the plant growth regulator treatments, miraculan (1000 ppm) recorded significantly higher SLA over all the treatments at all the growth stages. Among the organics, vermicompost (2 t ha-1) recorded higher SLA over FYM (10 t ha^{-1}) at all the growth stages and in case of nutrients, sulphur (40 kg ha^{-1}) recorded higher SLA as compared to KNO_3 (1%) at all the growth stages except at harvest.

Among the genotypes, DWD-1 (local) recorded significantly higher SLA over Pusa Naubahar. The interaction effect between varieties and treatments was found to be significant at all the stages except at harvest.

4.4 BIOCHEMICAL PARAMETERS

4.4.1 Chlorophyll ‘a’ content

The data on the influence of plant growth regulators, organics and nutrients on chl ‘a’ content in leaf at different growth stages indicated an increase in chl ‘a’ content at 60 DAS than at 40 DAS in all the treatments (Table 21). In all the treatments, significant differences were noticed at 40 and 60 DAS. Among the plant growth regulator treatments, lihocin (1000 ppm) registered significantly higher chl. ‘a’ content over all other treatments and control recorded the least chl ‘a’ content at 40 and 60 DAS. The treatment, mepiquat chloride (1000 ppm) was on par with lihocin (1000 ppm) at 40 DAS. The treatments miraculan (1000 ppm), vermicompost (2 t ha^{-1}) and sulphur (40 kg ha^{-1}) were found to be on par with each other at 60 DAS.

Genotypes differed significantly with respect to chlorophyll ‘a’ content at all the growth stages. DWD-1 (local) recorded significantly higher chl ‘a’ content over Pusa Naubahar at 40 and 60 DAS. The interaction effect between varieties and treatments was found to be significant at both 40 and 60 DAS. DWD-1 (local) treated with lihocin (1000 ppm) and Pusa Naubahar treated with KNO_3 (1%) recorded significantly higher and lower chl ‘a’ content respectively over other treatments at 60 DAS.

4.4.2 Chlorophyll ‘b’ content

It was observed that chlorophyll ‘b’ content increased at both 40 and 60 DAS in all the treatments (Table 22). Significant differences were observed in all the treatments with respect to chlorophyll ‘b’ content at 40 and 60 DAS. Among the growth regulator treatments lihocin (1000 ppm) was significantly superior over all other treatments at both 40 and 60 DAS followed by the treatment mepiquat chloride (1000 ppm). The least chlorophyll ‘b’ content was noticed in control at both 40 and 60 DAS. Among other treatments, sulphur (40 kg ha^{-1}) recorded significantly higher chlorophyll ‘b’ content at 60 DAS.

Significant differences with respect to chlorophyll ‘b’ content were noticed between the genotypes at 40 and 60 DAS. The genotype DWD-1 (local) was found to be significantly superior over Pusa Naubahar with respect to chlorophyll ‘b’ content. The interaction effect between varieties and treatments was found to be significant at both the stages.

Table 22. Effect of plant growth regulators, organics and nutrients on chlorophyll 'b' content (mg g fresh weight^{-1}) at different stages in clusterbean

Treatments	Days after sowing					
	40			60		
	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	0.41	0.27	0.34	0.48	0.41	0.45
T_2 – KNO_3 (1%)	0.28	0.19	0.24	0.37	0.32	0.35
T_3 – Mepiquat chloride (1000 ppm)	0.42	0.26	0.34	0.42	0.39	0.41
T_4 – Sulphur (40 kg ha^{-1})	0.38	0.23	0.31	0.44	0.36	0.39
T_5 – FYM (10 t ha^{-1})	0.38	0.28	0.33	0.42	0.32	0.37
T_6 – Vermicompost (2 t ha^{-1})	0.37	0.23	0.29	0.42	0.32	0.37
T_7 – Miraculan (1000 ppm)	0.26	0.22	0.24	0.42	0.36	0.39
T_8 – Control	0.17	0.10	0.14	0.35	0.26	0.30
Mean	0.33	0.22	0.28	0.41	0.34	0.38
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.002	0.006		0.004	0.011	
Treatments (T)	0.004	0.013		0.007	0.021	
Interaction (V x T)	0.006	0.018		0.010	0.030	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

Table 23. Effect of plant growth regulators, organics and nutrients on total chlorophyll content (mg g fresh weight^{-1}) at different stages in clusterbean

Treatments	Days after sowing					
	40			60		
	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	1.34	0.12	1.23	1.72	1.45	1.58
T_2 – KNO_3 (1%)	0.71	0.72	0.72	1.40	1.09	1.25
T_3 – Mepiquat chloride (1000 ppm)	1.33	1.09	1.21	1.62	1.35	1.49
T_4 – Sulphur (40 kg ha^{-1})	1.15	0.95	1.05	1.59	1.25	1.42
T_5 – FYM (10 t ha^{-1})	1.06	0.75	0.90	1.41	1.21	1.31
T_6 – Vermicompost (2 t ha^{-1})	1.07	0.87	0.97	1.56	1.21	1.38
T_7 – Miraculan (1000 ppm)	1.07	0.93	1.00	1.57	1.26	1.41
T_8 – Control	0.62	0.36	0.49	1.25	0.89	1.07
Mean	1.04	0.85	0.94	1.52	1.21	1.36

For comparing	40 S.Em±	40 CD (5%)	60 S.Em±	60 CD (5%)
Varieties (V)	0.005	0.016	0.004	0.012
Treatments (T)	0.011	0.031	0.009	0.025
Interaction (V x T)	0.015	0.044	0.0.12	0.035

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar

Table 24. Effect of plant growth regulators, organics and nutrients on nitrate reductase activity (μ moles NO_2 g fr.wt^{-1} hr^{-1}) in clusterbean

Treatments	Days after sowing					
	40			60		
	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	133.6	52.8	93.2	57.9	131.7	94.8
T_2 – KNO_3 (1%)	77.5	25.3	51.4	22.4	66.9	44.7
T_3 – Mepiquat chloride (1000 ppm)	120.3	45.8	83.0	50.7	105.6	78.1
T_4 – Sulphur (40 kg ha^{-1})	87.9	32.0	59.9	44.3	88.0	66.1
T_5 – FYM (10 t ha^{-1})	75.2	24.2	49.7	20.0	65.9	42.9
T_6 – Vermicompost (2 t ha^{-1})	83.2	28.3	55.7	44.0	97.3	70.7
T_7 – Miraculan (1000 ppm)	132.8	40.0	86.4	54.1	129.6	91.9
T_8 – Control	72.2	16.0	44.1	9.6	65.1	37.3
Mean	97.8	33.1	65.4	37.9	93.7	65.8
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.32	0.92		0.20	0.59	
Treatments (T)	0.64	1.84		0.41	1.18	
Interaction (V x T)	0.90	2.60		0.58	1.66	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

4.4.3 Total chlorophyll content

The data on total chlorophyll content revealed that it increased at 60 DAS compared to 40 DAS in all the treatments (Table 23). Significant differences were noticed due to plant growth regulator, organic and nutrient treatments at both 40 and 60 DAS. Among the plant growth regulator treatments, lihocin (1000 ppm) recorded significantly higher total chlorophyll content over the mepiquat chloride (1000 ppm) and miraculan (1000 ppm) at both the stages. Among the other treatments sulphur (40 kg ha^{-1}) recorded significantly higher total chlorophyll content followed by vermicompost (2 t ha-1) at both 40 and 60 DAS. The lowest total chlorophyll was noticed in control at both 40 and 60 DAS.

Significant differences with respect to total chlorophyll content was noticed between the genotypes at 40 and 60 DAS. DWD-1 (local) was fond to be significantly superior over Pusa Naubahar. The interaction effect between varieties and treatments was found to be significant at both 40 and 60 DAS.

4.4.4 Nitrate reductase activity

The data on nitrate reductase activity as influenced by plant growth regulators, organic and nutrients at different stages is presentedin Table 24. Significant differences among the treatments existed at 40 and 60 DAS. The treatment, lihocin (1000 ppm) recorded significantly higher NRA values over all other treatments at 40 and 60 DAS. The lowest NRA values was recorded in control at 40 and 60 DAS.

Genotypes differed significantly with respect to NRA at 40 and 60 DAS and the treatment lihocin (1000 ppm) recorded higher NRA in both the genotypes at 40 and 60 DAS. DWD-1 (local) showed significantly higher NRA over Pusa Naubahar at 40 DAS and at 60 DAS. Pusa Naubahar recorded significantly higher NRA over DWD-1 (local). The interaction effect between varieties and treatments was found to be significant at 40 and 60 DAS.

4.5 YIELD AND YIELD COMPONENTS

4.5.1 Number of pods per plant

The data on pod number per plant indicated significant differences between the plant growth regulator, organic and nutrient treatments and unsprayed control (Table 25). The highest number of pods per plant was recorded in lihocin (1000 ppm) and the lowest number with unsprayed control in both the genotypes. The treatments mepiquat chloride (1000 ppm) and miraculan (1000 ppm) were found to be on par with the treatment lihocin (1000 ppm). Among the organic and nutrient treatments, vermicompost (2 t ha^{-1}) showed significantly higher number of pods per plant followed by the treatment sulphur (40 kg ha-1). But the treatment FYM (10 t ha^{-1}) recorded numerically higher number of pods per plant over the control.

Among the genotypes, Pusa Naubahar recorded significantly higher number of pods as compared to DWD-1 (local). The interaction effect between varieties and the treatments was found to be non significant.

4.5.2 Pod yield (g plant^{-1})

Pod yield per plant (Table 25) differed significantly among the treatments, with the treatment lihocin (1000 ppm) recorded highest pod yield per plant (109.39 g plnat^{-1}) which was on par with mepiquat chloride (1000 ppm) and miraculan (1000 ppm). Among the organics, vermicompost (2 t ha^{-1}) recorded higher pod yield as compared to FYM (10 t ha^{-1}). In case of nutrients, sulphur (40 kg ha^{-1}) showed higher pod yield as compared to KNO_3 (1%).

Among the genotypes, Pusa Naubahar recorded significantly higher pod yield (g plant^{-1}) over DWD-1 (local). The interaction effect between varieties and treatments was found to be non significant.

4.5.3 Pod yield (q ha^{-1})

The data on pod yield (q ha^{-1}) followed the similar trend (Table 25) as that of pod yield (g plant^{-1}). All the treatments increased the pod yield (q ha^{-1}) over the control. Among the plant growth regulator, lihocin (1000 ppm) significantly increased the pod yield (q ha^{-1})

Table 25. Effect of plant growth regulators, organics and nutrients on yield and yield components in clusterbean

Treatment details	No. of pods/plant			Pod yield (g/plant)			Pod yield (q/ha)		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	54.0	97.9	75.9	100.6	118.1	109.4	74.5	82.7	78.6
T_2 – KNO_3 (1%)	43.3	78.4	60.8	80.7	94.3	87.5	59.7	66.3	63.0
T_3 – Mepiquat chloride (1000 ppm)	50.5	93.3	71.9	93.6	112.3	102.9	69.5	78.8	74.2
T_4 – Sulphur (40 kg ha^{-1})	45.9	83.6	64.7	85.6	100.8	93.2	63.4	70.6	67.0
T_5 – FYM (10 t ha^{-1})	42.4	77.5	59.9	79.0	93.5	86.3	58.5	65.6	62.0
T_6 – Vermicompost (2 t ha^{-1})	47.9	89.6	68.7	89.3	108.1	98.7	66.1	75.4	70.8
T_7 – Miraculan (1000 ppm)	52.2	95.6	73.9	97.2	115.4	106.3	72.0	80.8	76.4
T_8 – Control	40.0	70.8	55.4	74.0	85.0	79.5	54.8	59.9	57.3
Mean	47.0	85.8	66.4	87.5	103.4	95.5	64.8	72.5	68.7
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.831	2.399		1.169	3.375		0.984	2.843	
Treatments (T)	1.661	4.798		2.337	6.749		1.969	5.686	
Interaction (V x T)	2.349	NS		3.305	NS		2.784	NS	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

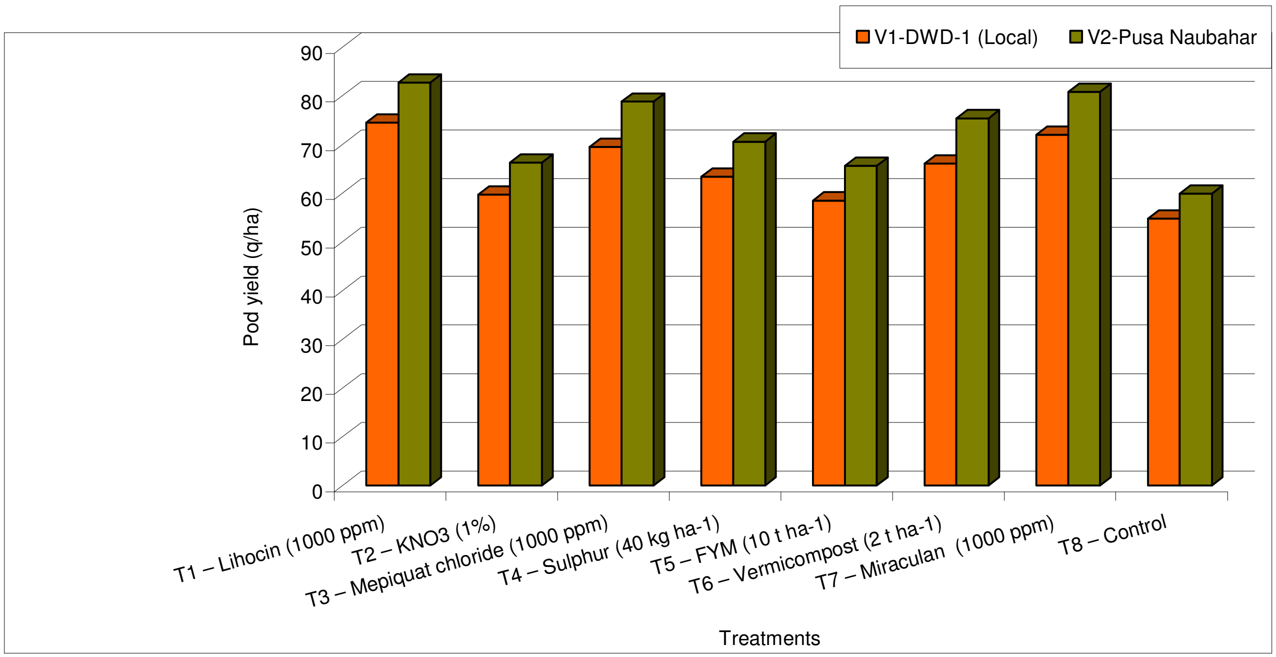

Fig. 3 : Effect of plant growth regulators, organics and nutrients on yield potential in clusterbean

Fig. 3. Effect of plant growth regulators, organics and nutrients on yield potential in clusterbean

Table 26. Effect of plant growth regulators, organics and nutrients on yield and yield components at different stages in clusterbean

Treatments	Pod length (cm)			No. of seeds/pod			100-seed weight (g)			Harvest index (%)		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 – Lihocin (1000 ppm)	8.0	9.5	8.7	8.9	9.5	9.2	4.0	3.8	3.9	45.3	61.7	53.5
T_2 – KNO_3 (1%)	7.8	9.1	8.4	8.2	8.7	8.4	3.8	3.7	3.8	44.4	61.8	61.8
T_3 – Mepiquat chloride (1000 ppm)	8.0	9.4	8.7	8.5	9.1	8.8	3.9	3.8	3.9	45.5	62.0	62.0
T_4 – Sulphur (40 kg ha^{-1})	7.9	9.4	8.6	8.3	8.8	8.6	3.9	3.7	3.8	44.3	61.8	61.8
T_5 – FYM (10 t ha^{-1})	7.4	9.0	8.2	8.1	8.5	8.3	3.8	3.6	3.7	45.8	62.3	62.3
T_6 – Vermicompost (2 t ha^{-1})	7.9	9.2	8.5	8.4	8.9	8.6	3.9	3.7	3.8	45.3	61.7	61.7
T_7 – Miraculan (1000 ppm)	8.1	9.5	8.8	8.8	9.3	9.0	4.0	3.9	3.9	45.5	61.9	61.9
T_8 – Control	6.8	8.8	7.8	7.6	8.1	7.8	3.3	3.1	3.2	45.4	61.7	61.7
Mean	7.7	9.2	8.5	8.4	8.9	8.6	3.8	3.7	3.7	45.2	61.9	61.9
For comparing	S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)		S.Em±	CD (5%)	
Varieties (V)	0.088	0.254		0.129	0.373		0.051	0.147		0.442	1.278	
Treatments (T)	0.176	0.507		0.507	0.745		0.102	0.295		0.885	NS	
Interaction (V x T)	0.249	NS		NS	NS		0.144	NS		1.251	NS	

V_1 – DWD-1 (Local) V_2 – Pusa Naubahar NS – Non significant

followed by miraculan (1000 ppm) and mepiquat chloride (1000 ppm). In case of organics, vermicompost (2 t ha^{-1}) showed higher yield (q ha^{-1}) over FYM (10 t ha^{-1}) treatment. Among the nutrients, sulphur (40 kg ha^{-1}) recorded higher pod yield (q ha^{-1}) over KNO_3 (1%) treatment.

Among the genotypes Pusa Naubahar recorded significantly higher pod yield (q ha^{-1}) as compared to DWD-1 (local). The interaction effect between varieties and treatments was found to be non significant.

4.5.4 Pod length (cm)

The data on pod length indicated significant differences among all the treatments (Table 26). The small sized pods were significantly higher in the unsprayed control than any other treatments. The maximum pod length was recorded in the treatment with miraculan (1000 ppm) and it was found to be on par with the treatments lihocin (1000 ppm), mepiquat chloride (1000 ppm), KNO_3 (1%), sulphur (40 kg ha^{-1}) and vermicompost (2 t ha^{-1}).

Among the genotypes, Pusa Naubahar recorded significantly higher pod length as compared to DWD-1 (local) the interaction effect between varieties and treatments was found to be non significant.

4.5.5 Number of seeds per pod

The data on number of seeds per pod indicated significant differences among the treatments (Table 26). The number of seeds per pod was significantly higher (9.25) in the treatment lihocin (1000 ppm) which was on par with all other treatments except KNO_3 (1%) and FYM (10 t ha^{-1}). Minimum number of seeds (7.84) were observed in unsprayed control. Among the genotypes Pusa Naubahar recorded significantly higher number of seeds per pod. The interaction between varieties and treatments was found to be non significant.

4.5.6 100-seed weight (g)

Significant differences (Table 26) among the treatments were evident with the treatment miraculan (1000 ppm) having maximum 100-seed weight value (3.94 g) which was on par with all the treatments. Minimum seed weight (3.20 g) was observed in unsprayed control.

Among the genotypes, DWD-1 (local) recorded significantly higher 100-seed weight as compared to Pusa Naubahar. The interaction effect between varieties and treatments was found to be non-significant.

4.5.7 Harvest index (%)

The data on harvest index (Table 26) indicated that treatments showed no significant difference among themselves. The treatment FYM (10 t ha^{-1}) having the maximum harvest index (54.06%) followed by miraculan (61.86%). The lowest harvest index (53.03%) was noticed with sulphur (40 kg ha^{-1}). Among the genotypes, Pusa Naubahar recorded significantly higher harvest index as compared to DWD-1. The interaction effect between varieties and treatments was found to be non-significant.

4.6 ECONOMICS

The benefit : cost ratio indicated that it was higher in lihocin @ 1000 ppm (1:5.22) followed by miraculan @ 1000 ppm (1:5.10) and mepiquat chloride @ 1000 ppm (1:4.97) as compared to other treatments in the cv. Pusa Naubhar. Similarly for DWD-1 (local) variety the B:C ratio was also calculated and it was found that higher B:C ratio was recorded in lihocin @ 1000 ppm (1:4.70) followed by miraculan @ 1000 ppm (1:4.54) and mepiquat chloride @ 1000 ppm (1.4.39).

Table 27. Effect of plant growth regulators, organics and nutrients on economics in clusterbean varieties

Treatments	Fresh green pod yield (q ha^{-1})	Gross returns (Rs. ha^{-1})	Cost of treatment (Rs. ha^{-1})	Total cost of cultivation (Rs. ha^{-1})	Benefit : cost ratio
DWD-1 (Local)					
T_1 – Lihocin (1000 ppm)	74.54	37270	320	7920	1:4.70
T_2 – KNO_3 (1%)	59.74	29870	1400	9000	1:3.31
T_3 – Mepiquat chloride (1000 ppm)	69.55	34775	320	7920	1:4.39
T_4 – Sulphur (40 kg ha^{-1})	63.41	31705	1000	8600	1:3.68
T_5 – FYM (10 t ha^{-1})	58.54	29270	3200	10800	1:2.71
T_6 – Vermicompost (2 t ha^{-1})	66.15	33075	4200	11800	1:2.80
T_7 – Miraculan (1000 ppm)	72.02	36010	320	7920	1:4.54
T_8 – Control	54.81	27405	-	7600	1:3.60
Pusa Naubahar					
T_1 – Lihocin (1000 ppm)	82.74	41370	320	7920	1:5.22
T_2 – KNO_3 (1%)	66.28	33140	1400	9000	1:3.68
T_3 – Mepiquat chloride (1000 ppm)	78.85	39425	320	7920	1:4.97
T_4 – Sulphur (40 kg ha^{-1})	70.65	35325	1000	8600	1:4.10
T_5 – FYM (10 t ha^{-1})	65.56	32780	3200	10800	1:3.04
T_6 – Vermicompost (2 t ha^{-1})	75.37	37685	4200	11800	1:3.19
T_7 – Miraculan (1000 ppm)	80.83	40415	320	7920	1:5.10
T_8 – Control	59.87	29935	-	7600	1:3.93

V. DISCUSSION

Clusterbean, a *kharif* crop is considered as one of the most drought tolerant crop among grain legumes. It is an important vegetable legume crop grown under rainfed condition in arid and semi arid regions of tropical India during *kharif* season. The productivity potential of clusterbean is low since it is cultivated as rainfed crop. The lower mean productivity of these crops is mainly due to cultivation in marginal lands and with little or no monetary inputs (Anon., 2000). Hence there is an urgent need to improve the productivity through manipulation of source-sink relationship by using plant growth regulators, organics and nutrients to boost the productivity. Hence, the research efforts should be concentrated on avenues to improve the present productivity levels. Relevant research studies on improvement of production potential in clusterbean are meagre and the present investigation is aimed at increasing the production potential of clusterbean by the use of plant growth regulators, organics and nutrients.

Plant growth regulators modify plant organs differentially and influence the source-sink relationship and improve yield potential. Such substances are therefore potentially useful in agriculture, because suitable concentrations applied at appropriate times will increase the yield either by altering dry mater distribution in the plant or by regulating growth (Watson, 1958).

Organics also provide balanced nutrition in addition to enhancing waterholding capacity and improving physical, chemical and biological properties (microorganisms) of soils which assist in better uptake of nutrients. After the green revolution, increase in production was achieved at the cost of soil health and that sustainable production at higher levels is possible only by the proper use of resources which help to maintain the fertility of soil.

Clusterbean (*Cyamopsis tetragonaloba* L. Taub.) being grown under rainfed condition, its productivity relies greatly on external factors which include weather conditions prevailing during critical phases of crop growth and the nutrient supply which influence the internal physiological processes that results in yield. An attempt has been made to find out the influence of plant growth regulators, organics and nutrients on crop growth and yield in two clusterbean varieties, DWD-1 (local) and Pusa Naubahar). The results obtained from the investigation are discussed in this chapter.

5.1 MORPHOLOGICAL CHARACTERS

The growth regulators, organics and nutrients significantly influenced the morphological characters such as plant height, number of branches and number of leaves per plant. All these morphological traits were significantly higher in DWD-1 (local) as compared to Pusa Naubahar.

Basially, plant height is a genetically controlled character. But several studies indicated that the plant height can either be increased or decreased by the application of synthetic plant growth regulators. However, in the present investigation, significant differences in plant height were noticed among the plant growth regulators, organics and nutrients. It is interesting to note that there was an increase in plant height over control in all the treatments except lihocin (1000 ppm) and mepiquat chloride (1000 ppm), where there was a significant decrease in plant height. Further, the plant height was significantly higher with miraculan (1000 ppm) followed by FYM (10 t ha^{-1}) and sulphur (40 kg ha^{-1}). This clearly indicated that the mode of action of growth regulator, organics and nutrients is quite different. Similarly, in soybean, the application of triacontanol was more effective and increased the plant height and such increase was due to increased photosynthetic activity (Shukla *et al.*, 1997).

An increase in the plant height due to the growth regulators could be attributed to an increase in the meristematic activity of apical tissues. Growth regulators are involved in increasing photosynthetic activity, efficient translocation and utilization of photosynthates causing rapid cell elongation and cell division at growing region of the plant leading to stimulation of growth, besides increasing the uptake of nutrients (Dicks, 1980). Another probable reason may be due to the oxidative decarboxylation of synthetic auxins which could be catalysed by the enzyme peroxidase (Reinecke and Bandurski, 1987). Similar beneficial effect of growth promoter on plant height has been reported by Dashora and Jain (1994) in soybean and Neelam *et al.* (1995) in lentil.

Further, the plant height was significantly higher with FYM (10 t ha^{-1}). Similar results were also reported in chilli (Surlekov and Rankov, 1989). An increase in plant height due to sulphur (40 kg ha^{-1}) was recorded due to increased photosynthetic activity as it helps in chlorophyll formation and is an essential constituent of amino acids like cystine, cystine and methionine and responsible for the synthesis of biotine and thiamine, metabolism of carbohydrates, protein and fats (Kumawat and Khangarot, 2002).

The mechanism of reduction in plant height due to application of CCC and mepiquat chloride appears to be due to slowing down of cell division and reduction in cell expansion. It has been suggested that CCC and mepiquat chloride are antigibberellin dwarfing agents, leading to a deficiency of gibberellin in the plant and reduce the growth by blocking the conversion of geranyl pyrophosphate to cpalyl pyrophosphate which is the first step of gibberellin synthesis (Moore, 1980). Thus, the reduced plant height is due to retardation of transverse cell division particularly in cambium, which is the zone of meristematic activity at the base of the internode (Grossman, 1990). Similarly, Garai and Datta (2003), Jeyakumar and Thangaraj (1996) also reported decreased plant height in greengram and groundnut, respectively due to application of growth retardants, CCC and mepiquat chloride.

The application of growth retardants increased the number of branches significantly and the increase was more pronounced at higher concentrations of the growth retardants. The increase in the number of branches could be due to the suppression of apical dominance as a result of increase in the auxin activity due to the application of growth retardants, thereby diverting the polar transport of auxins towards the basal buds leading to increased branching. Similarly, Mandal *et al.* (1997) and Dhaka and Anamika (2003) reported that application of CCC and mepiquat chloride (DPC) increased the number of branches in greengram and broad bean, respectively.

In general, leaf is considered as an important functional unit of plant which contributes to the formation of yield. The number of leaves were maximum at 90 DAS and declined later due to shedding. In general, the application of growth regulators, organics and nutrients increased the number of leaves. Among the growth regulators, miraculan (1000 ppm) was found to be more effective followed by mepiquat chloride (1000 ppm). However, at later stages of crop growth, application of miraculan (1000 ppm) was more effective in retention of more number of leaves. Manian *et al.* (1995) also reported that the application of triacontanol at vegetative stage increased the number of leaves in mulberry. Similarly, the application of chamatkar at 120 ppm also increased the number of leaves in blackgram (Prakash *et al.*, 2003).

The present study indicated that all the morphological traits were significantly higher in DWD-1 (local) as compared to Pusa Naubahar at all the growth stages studied. Further, most effective growth regulators were lihocin (1000 ppm), mepiquat chloride (1000 ppm) and miraculan (1000 ppm). In general, the response of clusterbean genotypes to organics and nutrients was less as compared to plant growth regulator treatments. The present study clearly indicated the significant role of PGR’s in improving expression of morphological traits in clusterbean.

5.2 DRY MATTER PRODUCTION AND PARTITIONING

Poor translocation of photo-assimilates to the growing reproductive parts is the major constraint in clusterbean. This constraint can be overcome by applying synthetic plant growth regulators, organics and nutrients which improve the canopy structure and increase the productivity through the manipulation of source-sink relationship.

The dry matter accumulation in the leaf increased upto 90 DAS and declined thereafter till harvest in all the growth regulator, organics and nutrient treatments including control. This could be due to the tanslocation of stored photo-assimilates towards the development of reproductive organs and senescence. In general, the leaf dry weight was significantly higher with the application of lihocin (1000 ppm), miraculan (1000 ppm) and mepiquat chloride (1000 ppm) due to the beneficial effect of these growth regulators on leaf development. Similarly, application of CCC lead to increased leaf dry weight by 52.7 per cent over control in greengram (Shah and Prathapsenan, 1991). Wasnik and Bagga (1996) reported that the application of mepiquat chloride increased the leaf dry weight in chickpea.

The present study also revealed that the genotype DWD-1 (local) possessed significantly higher dry matter at all the stages as compared to Pusa Naubahar. The stem dry weight increased significantly due to application growth regulators, vermicompost (2 t ha^{-1}) had sulphur (40 kg ha^{-1}). It is further seen from the data that these parameters were more in lihocin (1000 ppm), miraculan (1000 ppm) and mepiquat chloride (1000 ppm) at all the stages studied.

Dry matter production, particularly of reproductive parts is an important yield contributing character and the basic vegetative phase is essential for the development of reproductive organs. Although, the dry matter production in general is an indication of the efficiency of the genotype, the pattern in which it is distributed in different plant parts would give a better understanding of the genotype. Among the growth regulators, lihocin (1000 ppm) followed by miraculan (1000 ppm) maintained higher dry weight of reproductive parts due to better source sink relationship. The enhanced dry weight of reproductive parts by growth regulators, organics and nutrients may be due to increased translocation of assimilates from leaf and stem to the reproductive parts. Similar effects were found in mungbean and chickpea due to application of CCC (Singh *et al.*, 1993 and Brar *et al.*, 1992). Improvement in dry weight of reproductive parts due to the growth regulators application was recorded by Dashora and Jain (1994). The present study also revealed that the genotype DWD-1 (local) started bearing after 60 DAS and this genotype had putforth maximum dry matter and hence translocation of assimilates towards reproductive parts was less. It is thus inferred that, the plant growth regulators, organics and nutrients had profound influence on the production of dry matter and its partitioning between the various organs of the plant.

The amount of total dry matter (TDM) produced is an indication of the overall efficiency of the utilization of the resources and better light interception. The data pertaining to total dry weight per plant indicated that, it increased continuously from 30 DAS to harvest. At later stages of crop growth, the dry matter accumulation followed decreasing trend, which could be attributed to reduced source activity leading to lesser dry matter accumulation in leaf and stem.

The application of growth regulators, organics and nutrients significantly increased the total dry matter and it was found that the increase was more with lihocin (1000 ppm) followed by miraculan (1000 ppm). The effect of growth regulators was more pronounced than the organics and nutrients which indicated that growth regulators have the capacity to alter source sink relationship to a greater extent than the organics and nutrients. Mahla *et al.* (1999) and Ray (1991) also reported increased dry matter production due to the application of triacontanol in blackgram and chilli, respectively. Jeyakumar and Thangaraj (1998) reported that the application of cycocel was found to increase the RuBP caeboxylase enzyme activity, photosynthesis and drymatter partitioning in groundnut, while the combination of N-triacontanol with paras or planofix increased the dry matter accumulation in mustard (Ghosh *et al*, 1991). The present data also indicated that the total dry matter was significantly higher in lihocin (1000 ppm) treatments as compared to control and other growth regulators, organics and nutrient treatments. The higher leaf area, and leaf dry weight could be attributed to higher dry matter accumulation in reproductive parts.

5.3 GROWTH PARAMETERS

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 upto 90 DAS and decreased thereafter due to senescence and ageing of leaves. In general, the application of growth regulators, organics and nutrients showed a profound effect over these parameters and significant differences were noticed among the growth regulator treatments at all the growth stages. However, growth regulators miraculan (1000 ppm) and lihocin (1000 ppm) recorded significantly higher leaf area and LAI as compared to control at all the growth stages.

Growth promoting substance, miraculan had a positive effect on cell division and cell elongation leading to enhanced leaf expansion. This is in accordance with Saishankar (2001) who reported that with the foliar application of miraculan (2000 ppm), there was an increase in the leaf area in greengram. Similarly, Dashora and Jain (1994) also reported an increase in

LAI due to the application of triacontanol (10 ppm) in soybean. The application of organics and nutrients also enhanced leaf area and LAI due to their positive influence on leaf development. In general, the genotype DWD-1 (local) recorded significantly higher leaf area and LAI as compared to Pusa Naubahar at all the stages.

Growth analysis technique has made substantial contribution to the current understanding of the physiological basis of yield variation in different crops, but the information on clusterbean is very meager. The relative growth rate (RGR), absolute growth rate (AGR), crop growth rate (CGR) and net assimilation rate (NAR) are important growth parameters influencing yield which are dependent not only on the genotype but also on the environmental and management practices.

In the present investigation, it was observed that all the growth parameters studied i.e. AGR, RGR, CGR and NAR declined with an advancement in the crop growth from 30 to harvest stage in all the treatments of both the genotypes. This indicates that growth rate was maximum between 30-60 DAS. RGR represents the increase in dry matter per unit of dry matter already present per unit time. The decline in RGR with the advancement in crop growth could be due the decline in the rate of dry matter production. The increase in RGR due to growth regulators, organics and nutrients treatments would be due to the effectiveness of these chemicals in increasing not only the total dry matter but also the rate of increment in total dry matter. This could also be attributed to increased photosynthetic efficiency by increasing leaf thickness and retaining more chlorophyll content and efficient translocation. Similarly, Patil (1994) also reported that foliar application of CCC significantly increased AGR, RGR in soybean.

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 (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. In present study, the growth regulators, organics and nutrients significantly increased CGR over control. The application of lihocin (1000 ppm), miraculan (1000 ppm) and mepiquat chloride (1000 ppm) significantly increased CGR at all the growth stages. Similarly, Jeyakumar and Thangaraj (1996) reported that application of mepiquat chloride or CCC (chloremequat) increased the CGR in groundnut. Ray (1991) reported that the foliar spray of triacontanol increased the CGR in capsicum. Patra (1995) reported that post flowering spraying of nutrient solutions at 50 per cent flowering increased the CGR in groundnut.

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 value recoded in FYM (10 t ha^{-1}). Watson (1952) suggested that NAR does not measure real photosyntheses but represents net result of photosynthetic gain over respiratory loss and it gives no direct indication 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 into account while computing NAR, the leaf area steadily increased with crop growth and maximum in miraculan treated plants, thereby causing a mutual shading of leaves in the canopy leading to lower NAR values.

The specific leaf weight is the indicator of leaf thickness and it increased upto 60 DAS. The SLW was more with the treatment FYM (10 t ha^{-1}) which may due to the presence of growth promoting substances present in the FYM. These growth promoting substances found to have established role in cell division and elongation which might have contributed for increased number of cells and facilitated the better stacking of the mesophyll cells of the leaves. 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 all the treatments. The LAD was higher with miraculan (1000 ppm). Similarly, Saaishankar (2001) reported that miraculan (2000 ppm) also increased the LAD in greengram.

The biomass duration (BMD) indicates the maintenance of dry matter over a period of time and is essential for prolonged supply of photosynthates to the developing sinks. The biomass duration was significantly increased due to the application of growth regulators, organics and nutrients, which could be attributed to the increased dry matter production and its maintenance. Similarly, Saishankar (2001) reported that foliar application of miraculan (2000 ppm) in greengram increased the BMD.

5.4 BIOCHEMICAL PARAMETERS

From the data it is clear that chlorophyll ‘a’, chlorophyll ‘b’ and total chlorophyll contents were maximum at 60 DAS. The effect of growth regulators, organics and nutrients on total chlorophyll content in leaf exhibited significant differences. At both 40 and 60 DAS, the application of lihocin (1000 ppm), mepiquat chloride (1000 ppm) and sulphur (40 kg ha^{-1}) resulted in significantly higher chlorophyll content (‘a’, ‘b’ and total). The variation in chlorophyll content due to growth regulators, organics and nutrients may be attributed to the decreased chlorophyll degradation and increased chlorophyll synthesis. These results were in accordance with Jeyakumar and Thangaraj (1998) who explained that mepiquat chloride (125 ppm) resulted in higher amount of chlorophyll in groundnut. Similarly, Shah and Prathapsenan (1991) reported that application of 1000 ppm CCC increased the leaf chlorophyll content in mungbean. Zhao *et al.* (1999) reported that sulphur addition significantly increased the leaf chlorophyll content in pea. It has also been suggested that the application of growth regulators increased the availability of assimilates, which inturn caused prolonged chlorophyll synthesis (Stoddart, 1965).

The enzyme nitrate reductase catalyze the reduction of nitrate to nitrite and is a rate limiting step in the nitrogen metabolism (Beevers and Hageman, 1969). It has been observed that the activity of nitrate reductase increased significantly with the application of growth regulators, organics and nutrients. The present study revealed that nitrate reductase activity was maximum at 40 DAS in the genotype DWD-1 (local) but Pusa Naubahar had maximum nitrate reductase activity at 60 DAS. The treatment lihocin (1000 ppm) recorded significantly higher nitrate reductase activity followed by miraculan (1000 ppm). Similarly, Lawlor and Fock (1975) suggested that CCC induced increase in photosynthesis is associated with an increase in the enzyme activity and nucleic acid metabolism. CCC is also reported to increase cytokinin content in leaves leading to higher chlorophyll content (Skene, 1968). Possibly, CCC induced higher NRA and chlorophyll content may be due to the combination of various factors cited above, which inturn manifest the final yield. Similarly, Sivakumar *et al.* (2002) also reported that foliar application of triacontanol @ 10 ppm increased the nitrate reductase activity in pearl millet.

5.5 YIELD AND YIELD COMPONENTS

Improvement in yield, according to Humphries (1979) could happen in two ways i.e., by adopting the existing varieties to grow better in their environment or by altering the relative proportion of different plant parts so as to increase the yield of economically important parts. The growth regulators are capable of redistribution of dry matter in the plant, thereby bring about an improvement in yield potential (Chaplot *et al*, 1992). In addition, crop yields depends not only on the accumulation of photosynthates during the crop growth and development, but also on its partitioning in the desired storage organs. These inturn, are influenced by the efficiency of metabolic processes within the plant. The growth retardants are capable of redistribution of dry matter in the plant thereby bringing about improvement in yield (Chetti, 1991 and Chandrababu *et al.*, 1995).

The pod yield in clusterbean depends on the accumulation of photoassimilates and partitioning in different plant parts. The yield in clusterbean was found to be strongly influenced by the application of different growth regulators, organics and nutrients and thus indicating the importance of these compounds in increasing the yield potential through their effect on various morpho-physiological and biochemical traits.

The application of lihocin (1000 ppm) resulted in significantly higher pod yield (109.39 g $plant^{-1}$) followed by miraculan @ 1000 ppm (106.3 g $plant^{-1}$), mepiquat chloride @ 1000 ppm (102.9 g $plant^{-1}$), vermicompost @ 2 t per ha (98.7 g $plant^{-1}$), sulphur @ 40 kg per ha (93.2 g $plant^{-1}$), KNO_3 @ 1 per cent (87.5 g $plant^{-1}$) and FYM @ 10 t per ha (86.2 g $plant^{-1}$) as compared to control (79.5 g $plant^{-1}$). The increased yield may be attributed to higher dry matter production and its accumulation in reproductive parts, higher AGR, CGR and enhanced chlorophyll and nitrate reductase activity.

In addition, the present study also revealed that the application of different growth regulators significantly increased the number of pods per plant, number of seeds per pod, pod weight, pod length which are the most important yield determining components in clusterbean. Several research workers have indicated that the foliar spray of 300 ppm cycocel at the flower initiation stage reduced the shedding of flowers and immature pods and induced flowering and development of pods with increased seed yield in soybean (Singh *et al*., 1987). There was significant increase in the number and weight of pods and the total yield in peas due to the application of CCC (500 ppm) (Mishriky *et al*., 1990). There was increase in number of pods, number of seeds, seed size and yield per plant in chickpea due to application of cycocel (chlormequat) at 50 per cent flowering stage (Arora *et al*., 1998).

From the present study, it can also be inferred that the application of mepiquat chloride (1000 ppm), miraculan (1000 pm), vermicompost (2 t ha^{-1}), sulphur (40 kg ha^{-1}), KNO_3 (1%) and FYM (10 t ha^{-1}) were effective in increasing the yield potential in clusterbean. Several research workers have also indicated that the application of TRIA increased the 1000-seed weight, pods per plant and harvest index with subsequent increase in seed yield in lentil (Neelam *et al*., 1995). Jeyakumar and Thangaraj (1996) reported that application of 125 ppm mepiquat chloride produced highest pod yield in groundnut. Similar results were also recorded by (Chandrababu *et al*., 1995). Kumawat and Khangarot (2002) also reported that the application of 80 kg sulphur per ha significantly increased number of pods per plant, number of seeds per pod and seed yield in cluster bean. Sarkar *et al.* (1999) also reported that the treatment combination of 0.25 per cent KNO_3 + 0.20% Ca $(NO_3)_2$ showed highest pod yield and harvest index in groundnut. Pattar *et al.* (1999) also reported that the application of vermicompost @ 2 t per ha gave highest pod yield in groundnut. It is well known that vermicompost is rich in both macro and micro nutrients, besides has plant growth promoting substances, humus forming microbes and nitrogen fixers (Bano *et al*., 1987).

5.6 ECONOMICS

The benefit : cost ratio indicated that it was higher in lihocin @ 1000 ppm (1:5.22) followed by miraculan @ 1000 ppm (1:5.10) and mepiquat chloride @ 1000 ppm (1:4.97) as compared to other treatments in the cv. Pusa Naubhar. Similarly for DWD-1 (local) variety the B:C ratio was also calculated and it was found that higher B:C ratio was recorded in lihocin @ 1000 ppm (1:4.70) followed by miraculan @ 1000 ppm (1:4.54) and mepiquat chloride @ 1000 ppm (1.4.39).

5.7 FUTURE LINE OF WORK

Based on the results obtained in the present investigation, following suggestions have been indicated for further studies.

1. There is a need to evaluate commercially available plant growth regulators for optimizing yield potential in clusterbean
2. There is a need to study the effect of plant growth regulators, organics and nutrients on different cultivars of clusterbean
3. There is a need to study the source-sink relationship by using radio labeled carbon
4. The seed quality parameters may be initiated due to the application of plant growth regulators, organics and nutrients.

VI. SUMMARY

A field experiment was conducted to find out effect of plant growth regulators, organics and nutrients on various morphological, physiological, biochemical, and yield and yield components in two clusterbean genotypes cv. DWD-1 (local) and Pusa Naubahar during *kharif*, 2004, at Main Agricultural Research Station, Dharwad. The experiment was laid out in a factorial randomised block design with two genotypes and eight treatments in three replications. The treatments included three growth regulators i.e., two growth retardants (lihocin and mepiquat chloride) and one growth promoter (miraculan), two organics (FYM and vermicompost) and two nutrients (KNO_3 and sulphur). The results obtained are summarized in this chapter.

1. The plant height increased due to the application of miraculan (1000 ppm) while, FYM (10 t ha^{-1}) and the treatment lihocin (1000 ppm) and mepiquat chloride (1000 ppm) reduced the plant height. The treatment vermicompost (2 t ha^{-1}) and the nutrients also increased the plant height.
2. The growth regulators, organics and nutrient treatments showed profound effect on number of branches per plant. This parameter increased significantly with lihocin (1000 ppm) followed by mepiquat chloride (1000 ppm) and miraculan (1000 ppm) at harvest in DWD-1 (Local).
3. The number of leaves per plant differed due to the application of growth regulators, organics and nutrients and growth regulator treatments, miraculan (1000 ppm) followed by mepiquat chloride (1000 ppm) significantly increased the number of leaves per plant at 60, 90 DAS and at harvest.
4. Leaf dry matter was maximum at 90 DAS and decreased thereafter. The application of growth regulators, lihocin (1000 ppm) followed by miraculan (1000 ppm) and mepiquat chloride (1000 ppm) increased the leaf dry weight.
5. All the treatments increased the stem dry weight at 60, 90 DAS and harvest. Among the treatments, all the three growth regulators, vermicompost (2 t ha^{-1}) and sulphur (40 kg ha^{-1}) significantly increased the stem dry weight.
6. The dry matter accumulation in reproductive parts increased significantly due to the application of growth regulators, organics and nutrients. Among the treatment lihocin (1000 ppm) followed by miraculan (1000 ppm) were most effective.
7. The total dry matter increased significantly due to application of growth regulators, organics and nutrients. The treatment lihocin (1000 ppm) and miraculan (1000 ppm) recorded significantly higher TDM values over other treatments.
8. The leaf area and leaf area index increased upto 90 DAS and declined thereafter. The treatment with growth regulators, organics and nutrients increased the leaf area and leaf area index and the effect was more pronounced with growth regulators.
9. The application of growth regulators, organics and nutrients increased the AGR and CGR. The lihocin (1000 ppm) followed by miraculan (1000 ppm) showed maximum RGR value at 30-60 DAS. The FYM (10 t ha^{-1}) showed maximum NAR at all the stages.
10. Specific leaf weight (SLW) was more with the treatment FYM (10 t ha^{-1}).
11. The leaf area duration differed significantly due to the growth regulator, organics and nutrient treatments and LAD values were higher with miraculan (1000 ppm) and lihocin (1000 ppm).
12. The BMD increased as growth advanced and growth regulator, organics and nutrient treatments significantly increased BMD over control.
13. The chlorophyll content (‘a’, ‘b’ and total chlorophyll) increased at 60 DAS. The application of growth regulators, organics and nutrients enhanced the chlorophyll content and effect was more with lihocin (1000 ppm) followed by mepiquat chloride (1000 ppm) and sulphur (40 kg ha^{-1}).
14. Nitrate reductase activity in DWD-1 (local) was higher at 40 DAS and in Pusa Naubahar the enzyme activity was higher at 60 DAS. The application of lihocin (1000

ppm) recorded significantly higher nitrate reductase activity followed by miraculan (1000 ppm).

15. The pod yield was significantly higher with lihocin (1000 pm) followed by miraculan (1000 pm), mepiquat chloride (1000 pm), vermicompost (2 t ha^{-1}) and sulphur (40 kg ha^{-1}).
16. The results on various yield and yield attributes indicated that, all the yield contributing characters viz., number of seeds per pod, pod length, number of pods per plant, 100-seed weight increased due to growth regulator, organics and nutrient treatments.
17. The benefit : cost ratio indicated that it was higher in lihocin @ 1000 ppm (1:5.22) followed by miraculan @ 1000 ppm (1:5.10) and mepiquat chloride @ 1000 ppm (1:4.97) as compared to other treatments in the cv. Pusa Naubhar. Similarly for DWD-1 (local) variety the B:C ratio was also calculated and it was found that higher B:C ratio was recorded in lihocin @ 1000 ppm (1:4.70) followed by miraculan @ 1000 ppm (1:4.54) and mepiquat chloride @ 1000 ppm (1.4.39).

VII. REFERENCES

ABDEL LATEEF, E.M., 1997, Cowpea (*Vigna radiata* L. Walf.) yield and seed macro nutrient content as affected by combined nitrogen and sulphur application. *Egyptian Journal of Physiological Sciences*, 21 (2) : 129-138.

AGASIMANI, C.A. AND HOSAMANI, M.M., 1989, Response of groundnut crop to farm yard manure, nitrogen and phosphorus in rice fallows in coastal sandy soils. *Journal of Oilseeds Research*, 6 (2) : 360-363.

AHMED, S.R., 1993, Influence of composted coconut coir dust on soil physical properties, growth and yield of tomato. *South Indian Horticulture*, 41 : 264-269.

ANONYMOUS, 2000, A little impetus needed. *The Hindu Survey of Indian Agriculture*, pp. 1-10.

ANONYMOUS, 2000, Industry, market size and shares, CMIE.

ANONYMOUS, 2001, Horticultural crop statistics of Karnataka state at a Glance. 2000-01, Directorate of Horticulture, Lalbagh, Bangalore, p. 25.

ANONYMOUS, 2001, *Guar in India*, Agriculture Gazettee, New South Wails, 22 : 1000.

ANTONY, E., 1995, Nitrogen utilization studies in groundnut (*Arachis hypogaea* L.) genotypes. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

ARNON, D.I., 1949, Copper enzyme in isolated chloroplasts polyphenol oxidase in *Beta vulgaris. Plant Physiology*, 24 : 1-15.

ARORA, N., BALWINDER KAUR, PARMIL SINGH, USHA PARMAR, KAUR, B., SINGH, P. AND PARMAR, U., 1998, Effect of IAA and cycocel on yield contributing parameters of chickpea (*Cicer arietinum* L.). *Annals of Agricultural Research*, 19 (3) : 279-281.

ASANE, G.B., LAWANDE, K.E., NIRMAL, S.V., SHINDE, K.G. AND DESALE, S.B., 1998, Effect of cytozyme, triacontanol and cycocel on growth, yield and quality of pea (*Pisum sativum* L.). *Advances in Plant Science*, 11 (2) : 31-34.

BANO, K., KALE, R.D. AND GAJANAN, G.G., 1987, Culturing earthworm *Edurillus euginae* for cast production and assessment on worm cast as biofertilizer. *Journal of Soil Biology and Ecology*, 7 : 98-104.

BASUCHAUDHURI, P., MUNDA, P.G. AND PATEL, C.S., 1986, Some aspects of source-sink relation in soybean. *Annals of Agricultural Research*, 7 (2) : 271-274.

BEEVERS, L. AND HAGEMAN, R.H., 1969, Nitrate reduction in higher plants. *Annual Review of Plant Physiology*, 20 : 495-522.

BLACKMAN, V.H., 1919, The compound interest law and plant growth. *Annals of Botany*, 33 : 353-360.

BRAR, Z.S., DEOL, J.S. AND KAUL, J.N., 1992, Influence of plant growth regulators on grain production and dry matter partitioning in chickpea. *International Chickpea Newsletter*, 27 : 25-27.

BREARS, C.R. AND MARENAH, L.J., 1969, Department of Agriculture. Gambia, 1969, Twelth Annual Report of Specialist Serices, Yendum Agricultural Research Station for the year 1967-68, Bathurst, 1969, p. 54, FCA (1976) 822 (1).

CHANDRABABU, R., MANIAN, K., NAGARAJAN, M. AND RAMACHANDRAN, T.K., 1995, Effect of mepiquat chloride on growth and yield of groundnut. *Madras Agricultural Journal*, 82 (3) : 229-230.

CHAPLOT, P.C., BHATNAGAR, G.S. AND PORWAL, M.K., 1992, Effect of plant growth regulators in blackgram, greengram and soybean. *International Journal of Tropical Agriculture*, 10 (1) : 72-74.

CHATTERJEE, B.N., SINGH, K.I., PAL, A. AND MAITI, S., 1979, Organic manure as a substitute for chemical fertilizers for high yielding rice varieties. *Indian Journal of Agricultural Sciences*, 49 (3) : 188-192.

CHATTOPADHYAY, N.C. AND CHAKRABORTY, A.K., 1990, *Tomato Nutrition of Vegetable Crops*, Ed. Mitra, S.K., Sadhu, M.K. and Bose, T.K., Naya Prakash, Calcutta, p. 74.

CHETTI, M.B., 1991, Evaluation of chamatkar on groundnut. *Pestology*, 15 : 43-50.

CHILD, R.D., BUTLER, D.R. AND EVANS, D.E., 1989, Effects of changes in canopy structure with growth retardants on the yield of oilseed rape. *Proceedings of the Plant Growth Regulator Society of American Annual Meeting*, 16 : 173-179.

CISSE, L., 1988, Effect of organic matter application on millet and groundnut on a degraded soil in North Senegal. *Agronomie*, 8 (5) : 411-417.

DAS, P.K., SARANGI, D., JENA, M.K. AND MOHANTY, S., 2002, Response of greengram (*Vigna radiata* L.) to integrated application of vermicompost and chemical fertilizer in acid lateritic soil. *Indian Agriculturist*, 46 (1-2) : 79-87.

DASHORA, L.D. AND JAIN, P.M., 1994, Effect of growth regulators and phosphorus levels on growth and yield of soybean. *Madras Agricultural Journal*, 81 : 235-237.

DASTANE, N.G., 1967, *A Practical Manual for Water Use Research*, Naubharat Prakashan Publication, Poona.

DATT, N., SHARMA, R.P. AND SHARMA, G.D., 2003, Effect of supplementary use of FYM along with chemical fertilization, productivity and nutrient uptake by vegetable pea and buildup of soil fertility in Lahaul valley of Himachal Pradesh. *Indian Journal of Agricultural Sciences*, 73 (5) : 266-268.

DHAKA, T.V.S. AND ANAMIKA, 2003, Effect of mepiquat chloride (DPC) and urea on growth and yield attributes of broad bean (*Vicia faba* L.). *Plant Archives*, 3 (2) : 291-293.

DICKS, J.W., 1980, Mode of action of growth retardants. In *Research Development on the Use of Plant Growth Retardants*, Ed. Clifford, D.R. and Lenton, J.R., British Plant Growth Regulator Group, Monograph, 4 : 1-14.

GANIGER, V.M., 1992, Use of growth retardants in potato (*Solanum tuberosum* L.) production. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

GARAI, A.K. AND DATTA, J.K., 2003, Effect of phosphorus sources and cycocel spray on greengram (*Vigna radiata* (L.) Wilczek). *Legume Research*, 26 (1) : 15-19.

GHOSH, R.K., MANDAL, B.K. AND CHATTERJEE, B.N., 1991, Effect of growth regulator on productivity of some major oilseed crops. *Journal of Agronomy and Crop Science*, 167 : 221-228.

GREGORY, F.G., 1926, The effect of climatic conditions on growth of barley. *Annals of Botany*, 40 : 1-26.

GROSSMAN, K., 1990, Plant retardants as tools in physiological research. *Physiologia Plantarum*, 78 : 642-648.

GULED, M.B., SARAWAD, I.M. AND GONDLUR, S.S., 2003, Organic manures. *The Elixir of Plant Nutrition in Tropical Agriculture*, Published by University of Agricultural Sciences, Dharwad, 2 (8) : 62.

HAPSE, D.G., 1993, Organic farming in the light of reduction in use of chemical fertilizers. *Proceedings of 43rd Annual Deccan Sugar Technologists Association*, Pune, part I, SA 37 SASI.

HUANG, F.Z. AND ZHAO, S.W., 1987, Studies on the distribution of earthworm and comprehensive utilization in China. *Earthworm, their Ecology and Relationship with Soil*, pp. 143-147.

HUMPHRIES, 1979, Response of crop plants to growth regulators. Monograph 31, *Rothmsted Experimental Station*, p. 33.

HUNJE, R.V., KULKARNI, G.N., VYAKARNAHAL, B.S. AND SHASHIDHARA, S.D., 1995, Effect of growth regulators on growth and yield in cowpea. *Karnataka Journal of Agricultural Sciences*, 8 : 429-431.

JACKSON, M.L., 1967, *Soil and Chemical Analysis*, Prentice hall of India Pvt. Ltd., New Delhi.

JANARDHANAN, K., 1992, Triacontanol promoted seed germination, seedling growth and chloroplast pigment content in leguminous crops. *Advances in Plant Sciences*, 5 : 290-295.

JEYAKUMAR, P. AND THANGARAJ, M., 1996, Effect of mepiquat chloride on certain physiological and yield characteristics of groundnut (*Arachis hypogaea* L.). *Journal of Agronomy and Crop Science*, 176 (3) : 159-164.

JEYAKUMAR, P. AND THANGARAJ, M., 1998, Physiological and biochemical effects of mepiquat chloride in groundnut (*Arachis hypogaea*). *Madras Agricultural Journal*, 85 : 23-26.

KALE RADHA, D., MALLESH, B.C., KUBRABANO AND BAGYARAJ, D.J., 1992, Influence of vermicompost application on the available micronutrients and selected microbial populations in paddy field. *Soil Biology and Biochemistry*, 24 : 1317-1320.

KALE, M.R., 1993, Effect of sulphur on growth and yield of groundnut (*Arachis hypogaea). Indian Journal of Agronomy*, 38 (3) : 504-505.

KALE, R.D. AND BANO KUBRA, 1986, Field trials with vermicompost on organic fertilizer. *Proceedings of National Seminar on Organic Waste Utilization Vermicompost*, pp. 151-160.

KALE, R.D., BANO, K., SREENIVASA, M.N. AND BAYARAJ, D.J., 1987, Influence of wormcast on the growth and mycorrhizal colonization of two ornamental plants. *South Indian Horticulture*, 35 : 433-437.

KALUBARME, M.H. AND PANDEY, R.K., 1979, Note on the growth analysis of greengram genotypes. *Indian Journal of Agricultural Sciences*, 49 : 975-977.

KARMEGAM, N. AND DANIEL, T., 2000, Effect of biodigested slurry and vermicomopst on the growth and yield of cowpea (*Vigna unguiculata* (L.). Walp. Variety C1. *Environment and Ecology*, 18 (2) : 367-370.

KRISHNAMURTHY, K., BOMMEGOUDA, A., VENUGOPAL, N., JAGANNATH, M.K., RAGHUNATH, C. AND RAJASHEKAR, B.G., 1973, Investigations on the varietal differences in the growth components of sorghum. *Mysore Journal of Agricultural Sciences*, 8 : 52-59.

KULKARNI, S.S., 1993, Influence of growth retardants on growth and development of sunflower (*Helianthus annus* L.) genotypes. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

KULKARNI, S.S., CHETTI, M.B. AND AMAREGOUD, A., 1995, Influence of growth retardants on morphological characters in sunflower (*Helianthus annus* L.) genotypes. *Karnataka Journal of Agricultural Sciences*, 8 : 40-45.

KUMARI, S., BHARATI, S. AND KHAN, M.I., 1990, Effect of cycocel on growth and metabolism on sunflower (*Helianthus annuus* L.). *Indian Journal of Agricultural Research*, 24 (2) : 87-93.

KUMARVELU, G., LIVINGSTONE, V.D. AND RAMANUJAM, M.P., 2000, Triacontanol-induced changes in the growth, photosynthetic pigments, cell metabolites, flowering and yield in greengram. *Biologia Plantarum*, 43 (2) : 287-290.

KUMAWAT, P.D. AND KHANGAROT, S.S., 2002, Response of sulphur, phosphorus and rhizobium inoculation on growth and yield of clusterbean (*Cyamopsis tetragonalaba* (L.) Taub). *Legume Research*, 25 (4) : 276-278.

LAWLOR, D.W AND FOCK, H., 1975, Photosynthesis and photorespiratory CO_2 evolution of water stressed sunflower leaves. *Planta*, 126 : 381-387.

LI, C.H., TU, Y.C. AND XIE, L.H., 1987, Study on physiological effects of sesame seed treatment. *Oilseed Crops of China*, 2 : 44-47.

LYNRAH, P.G., CHAKRABORTY, B.K. AND CHANDRA, K., 2002, Effect of CCC, kinetin and KNO_3 on yield and curcumin content of turmeric. *Indian Journal of Plant Physiology*, 7 (1) : 94-95.

MAHLA, C.P.S., DADHEECH, R.C. AND KULHARI, R.K., 1999, Effect of plant growth regulators on growth and yield of blackgram (*Vigna mungo* (L.) Hepper) at varying levels of phosphorus. *Annals of Biology,* Ludhiana, 15 (2) : 205-207.

MANDAL, S., CHAKRABORTY, T. AND DATTA, J.K., 1997, Influence of growth retardant and rock phosphate on growth and development of greengram (*Vigna radiata* L. Wilczek). *Indian Journal of Plant Physiology*, 2 : 32-35.

MANIAN, K., NAGARAJAN, M., PADMANABHAN, G. AND ANNAMALAINATHAN, K., 1995, Influence of bioregulators on biomass production in mulberry (*Morus alba*). *Madras Agricultural Journal*, 82 : 85-87.

MISHRIKY, J.F., EL-FADALY, K.A. AND BADAWI, M.A., 1990, Effect of gibberellic acid (GA_3) and chloromequat (CCC) on growth yield and quality of peas (*Pisum sativum* L.). *Bulletin of Faculty of Agriculture*, 41 (3) : 785-797.

MOORE, J.L., 1980, *Biochemistry and Physiology of Plant Hormones*, Narosha Publishing House, New Delhi, pp. 107-131.

MUTHUCHELIAN, K., MURUGAN, C., HARIGOVINDAN, R. AND NEDUNCHELHIAN, S., 1994, Effect of triacontanol in flooded *Erythrina variegata*. Changes in CO_2 fixation and RUBP lase, photosystem and NRAase activities. *Phytosynthetica*, 40 : 407-413.

NAIDU, M.V.S. AND HANUMANRAO, 1996, Effect of sulphur and rhizobium inoculation on dry matter, grain yield and protein content in greengram (*Vigna radiata* L.). *Legume Research*, 19 (1) : 10-14.

NEELAM SETIA SANGEETA, SETIA, R.C. AND SETIA, N., 1995, Effect of triacontanol on lentil yield and yield components. *Lens Newsletter*, 22 (1-2) : 24-27.

NIJHAWAN, S.D. AND KANWAR, J.S., 1952, Physico-chemical properties of earthworm castings and their effect on the productivity of soil. *Indian Journal of Agricultural Sciences*, 2 : 357-373.

NIMJE, P.M. AND JAGDISH SETH, 1987, Effect of P and FYM on soybean and their residual effect on succeeding winter maize. *Indian Journal of Agricultural Sciences*, 57 (6) : 404-409.

OGILVY, S., 1985, Changing the shape of oilseeds rape. *Annual Review of High Mowthrope Experimental Husbandry Farm*, 8 : 24-27.

PALANIAPPAN, S.P. AND ANNADURAI, K., 1999, *Organic Farming Theory and Practice*. Scientific Publishers, Jodhpur, pp. 176-179.

PANDA, D. AND SINGH, D.P., 1996, Integrated nutrient management for rice. In : *Abstracts of International Symposium on Rainfed Rice for Sustainable Food Security*, Central Rice Research Institute, Cuttack, India, 23-25 September, 1996, pp. 49-51.

PANDO, S.B., SRIVASTAVA, G.C. AND DESHMUKH, P.S., 1988, Influence of cycocel (2-chloroethyl trimethyl ammonium chloride) on nitrogen metabolism in sunflower. *Annals of Plant Physiology*, 2 : 212-215.

PANSE, V.G. AND SUKHATME, P.V., 1967, *Statistical Methods for Agricultural Workers*, ICAR, New Delhi, pp. 167-174.

PATIL, S.B., 1994, Effect of population levels and growth retardants on growth, yield and yield attributes and quality of soybean. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

PATRA, A.K., TRIPATHY, S.K. AND SAMUI, R.C., 1995, Effect of post flowering foliar application of nutrients on growth, yield and economics of rainfed groundnut (*Arachis hypogaea*). *Ndian Journal of Plant Physiology*, 38 : 203-206.

PATTAR, P.S., NADAGOUDA, V.B., SALKINKOP, S.R., KANNUR, V.S. AND GADDI, A.V., 1999, Effect of organic manures and fertilizer level on nutrient uptake, soil nutrient status and yield of groundnut. *Journal of Oilseeds Research*, 16 : 123-127.

PHULEKAR, C.S., CHETTI, M.B., NALINI, A.S. AND PATIL, A.B., 1998, Relationship of leaf characters with total dry matter and yield in groundnut as influenced by growth retardants. *Indian Journal of Agricultural Research*, 32 (3) : 195-200.

PIPER, C.S., 1966, *Soil and Plant Analysis*, Academic Press, New York, p. 368.

POEHLMAN, J.M., 1991, The mungbean. Oxford and IBH Publishing Co. Pt. Ltd., New Delhi, pp. 375-380.

POONAM GAUTAM, AGNIHOTRI, A.K. AND PANT, L.M., 2003, Effect of phosphorus rates and *Pseudomonas* sps. In combination with *Bradyrhizobium japonicum* and FYM on seed yield and yield attributes of soybean. *Indian Journal of Agricultural Sciences*, 73 (8) : 426-428.

POWER, J.E., WILLS, W.O., GRANES, D.L. AND REICHMAN, G.A., 1967, Effect of soil temperature, phosphorus and plant age on growth analysis of barley. *Journal of Agronomy*, 59 : 231-234.

PRAKASH, M., SIDDESHKUMAR, J., KANNAN, K., SENTHILKUMAR, M. AND GANESHAN, J., 2003, Effect of plant growth regulators on growth, physiology and yield of blackgram. *Legume Research*, 26 (3) : 183-187.

RADFORD, D.J., 1967, Growth analysis formulae : their use and abuse. *Crop Science*, 7 : 171-175.

RAMACHANDRAREDDY, REDDY, N.S., ANJANAPPA, M. AND REDDY, R., 1998, Effect of organic and inorganic sources of NPK on growth and yield of pea (*Pisum sativum). Legume Research*, 21 (1) : 57-60.

RAMESH, T. AND GONDI MANJUNATH, 2004, Organic farming boon or bane for Indian farmers. *Kissan World*, 16 : 205-310.

RATHORE, S.V.S., PUNEET KUMAR, SINGH, D.R. AND KUMAR, P., 1990, Effect of intra-row spacing and cycocel on the performance of seed crop of vegetable cluster bean (*Cyamopsis tetragonaloba* L. Taub). *Haryana Journal of Horticultural Sciences*, 19 (1-2) : 219-221.

RAY, R.C., 1991, Effect of triacontanol on growth and yield of capsicum (*Capsicum annum* L.). *Advances in Horticultural Sciences*, 5 (4) : 153-156.

RAYAR, A.J., 1986, Response of groundnut to application of farm yard manure, nitrogen and phosphate on light sandy loam savanna soils of north Nigeria. *International Journal of Tropical Agriculture*, 4 (1) : 46-54.

REINECKE, D.M. AND BANDURSKI, 1987, Auxin biosynthesis and metabolism. *Plant Hormones and Their Role in Plant Growth and Development*, Ed. Devies, P.J., Boston, Martinus, Nijhoff, pp. 24-42.

SAISHANKAR, S., 2001, Influence of plant growth regulators, chemicals and nutrients in greengram (*Vigna radiata* (L.) Wilczek). *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

SARADHAMBAL, K.V., SINGH, S.P., PRAKASH, S. AND NAIK, M.S., 1978, Effect of bacterial blight on the activities of nitrate reductase and peroxidase in rice plants. *Indian Journal of Biochemistry and Biophysics*, 15 : 105-107.

SARKAR, R.K., CHAKRABORTY, A., ANITA, SAHA AND SAHA, A., 1999, Effect of foliar application of potassium nitrate and calcium nitrate on groundnut (*Arachis hypogaea*). *Indian Journal of Agronomy*, 44 (4) : 809-812.

SESTAK, Z., CATASKY, J. AND JARVIS, P.G., 1971, *Plant Photosynthetic Production : Manual of Methods*, Ed. Junk, N.V. The Hague Publishers, pp. 72-78.

SHAH, T. AND PRATHAPASENAN, G., 1991, Effect of cycocel on the growth and yield of mungbean (*Vigna radiata* (L.) Wilczek var. Guj-2). *Journal of Agronomy*, 166 (1) : 40-47.

SHARMA, A.R. AND MITRA, B.N., 1989, Direct and residual effect of organic materials and phosphorus fertilizer in rice based cropping system. *Indian Journal of Agronomy*, 36 : 299-303.

SHARMA, P.D., 2003, Prospectus of organic farming in India. *Proceeding of Organic Products and Their Future Prospectus*, pp. 26-30.

SHIVRAJ, B. AND GOWDA, A.,1993, Influence of levels and sources of sulphur on yield and quality of groundnut. *Current Research*, 22 (3-5) : 45-47.

SHUKLA, K.C., SINGH, O.P. AND SAMAIYA, R.K., 1997, Effect of foliar spray of plant growth regulator and nutrient complex on productivity of soybean var. JS 79-81. *Crop Research*, 13 : 213-215.

SINGH, H., CHANDRA, S. AND JOLLY, R.S., 1987, Effect of growth regulator in relation to time of sowing and yield of soybean cultivars. *Annals of Biology*, 3 (1) : 36-43.

SINGH, J., KAVEL, J.N. AND BRAR, Z.S., 1993, Compartmentation of canopy dry matter and seed yield of summer mungbean in relation to irrigation and cycocel regimes. *Indian Journal of Pulses Research*, 6 : 207-209.

SINGH, S.K., ROOMSINGH, SINGH, H.P. AND SINGH, R., 1994, Effect of sulphur on growth and yield of summer moong (*Vigna radiata* (L.) Wilczek). *Legume Research*, 17 (1): 53-56.

SINGH, V.P. N. AND UTTAM, S.K., 1992, Effect of levels of triacontanol based growth substance miraculan on growth and yield attributes and yield of wheat (*Triticum aestivum* L.). *Indian Agriculturist*, 36 (2) : 127-130.

SIVAKUMAR, R., PATHMANABAN, G., KALARANI, M.K., MALLIKA VANANGAMUDI AND SRINIVASAN, P.S., 2002, Effect of foliar application of growth regulators on biochemical attributes and grain yield in pearl millet. *Indian Journal of Plant Physiology*, 7 (1) : 79-82.

SKENE, K.G.M., 1968, Increase in cytokinin in bleeding sap of *Vitis vinifera* L. after CCC treatment. *Science*, 159 : 1477-1478.

SORTE, N.V., DEOTALE, R.V., RATNAPARKHI, V.P. AND SHASTRI, N.R,. 1989, Effect of foliar application of cycocel on peanut (*Arachis hypogaea* L.). *Annals of Plant Physiology*, 3 (2) : 203-211.

STODDART, J.L., 1965, Chemical changes in *Lolium femulentum* L. after treatment with (2-chloroethyle) trimethyl ammonium chloride (CCC). *Journal of Experimental Botany*, 16 : 604-613.

SUBBAIAH, S. AND KUMARASWAMY, K., 1996, Integrated nutrient management for rice through organic farming. In : *Abstracts of National Seminar on Organic Farming and Sustainable Agriculture*, 9-11 October, 1996, pp. 74-75.

SURLEKOV, P. AND RANKOV, V., 1989, The effect of fertilization on *Capsicum annuum* reproductivity and soil agrochemical and biological properties in monoculture. *Pochronzanic Agrochimiya*, 24 : 17-23.

TOMAR, R.K., 1998, Effect of phosphate solubilizing bacteria and farm yard manure on the yield of blackgram. *Indian Journal of Agricultural Sciences*, 68 (2) : 81-83.

TRIPTI SHRIVASTAVA, NAMDEO, K.N., KUMAR, M.M., DWIVEDI, R.K., TIWARI, R.K., 2001, Effect of plant growth regulators on growth, yield and nutrients uptake by chickpea (*Cicer arietinum* L.). *Crop Research,* Hissar, 21 (3) : 301-307.

UMESH SINGH AND YADAV, D.S., 1997, Studies on sulphur and zinc nutrition on greengram (*Phaseolus radiatus* L.) in relation to growth attributes, seed protein yield and S, Zn uptake. *Legume Research*, 20 (3/4) : 224-226.

USHAKUMARI, K., PRABHAKUMARI, P. AND PADMAJA, P., 1999, Efficiency of vermicompost on growth and yield of summer crop okra (*Abdelmoschus esculentus* Moench). *Journal of Tropical Agriculture*, 37 (1-2) : 87-88.

VARELLA, G.R. AND YALLEJO, R.R., 1982, Effect of growth regulator mepiquat chloride on the main agronomic characteristics and fiber quality of cotton (*Gossypium hirsutum* L.). *Review Institute*, Colombo Agropec, 17 : 1-9.

WASNIK, K.G. AND BAGGA, A.K., 1992, Effect of cycocel on nitrate reductase activity and grain yield in mungbean (*Vigna radiata* L. Wilczek). *Indian Journal of Plant Physiology*, 35 : 104-107.

WASNIK, K.G. AND BAGGA, A.K., 1996, Effect of mepiquat chloride on growth and yield of chickpea (*Cicer arietinum* L.). *Indian Journal of Plant Physiology*, 1 (4) : 239-242.

WATSON, D.J., 1952, The physiological basis of variation in yield. *Advances in Agronomy*, 4 : 101-145.

WATSON, D.J., 1958, The dependence of net assimilation rate on leaf area index. *Annals of Botany*, 22 : 37.

WEY, J. AND OBTON, M., 1978, Incidence of some cultivation method on nitrogen fixation and groundnut yield. *Agronomic Tropicle*, 13 (2) : 129-135.

ZHAO, F.J., WOOD, A.P. AND McGRATH, S.P., 1999, Effects of sulphur nutrition on growth and nitrogen fixation of pea (*Pisum sativum* L.). *Plant and Soil*, 212 (2) : 209-219.

EFFECT OF PLANT GROWTH REGULATORS, ORGANICS AND NUTRIENTS ON YIELD AND QUALITY OF CLUSTERBEAN (*Cyamopsis tetragonoloba* L. Taub)

Prabhavathi V. Hanchinamath **2005** **Dr. S.M. Hiremath**
Major Advisor

ABSTRACT

A field experiment was conducted at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *kharif* 2004 to study the effect of plant growth regulators, organics and nutrients on yield and quality of clusterbean. The experiment was laid out in factorial randomized block design which consisted two genotypes, DWD-1 (local) and Pusa Naubahar with eight treatments in three replications. The treatments included are lihocin (1000 ppm) mepiquat chloride (1000 ppm), miraculan (1000 ppm), potassium nitrate (1%), sulphur (40 kg ha^{-1}), FYM (10 t ha^{-1}), vermicompost (2 t ha^{-1}) and control. The treatments were imposed at 40 and 60 DAS.

The results revealed that the application of miraculan (1000 ppm) recorded highest plant height, number of leaves, leaf area, leaf area index and leaf area duration. There was a decrease in plant height and increase in number of branches, total dry matter, absolute growth rate, crop growth rate and biomass duration with the application of lihocin (1000 ppm) in both the genotypes but DWD-1 (local) recorded significantly higher in these components as compared to Pusa Naubahar. The biochemical parameters viz., chlorophyll 'a', chlorophyll 'b', total chlorophyll and nitrate reductase activity recorded significantly higher with the application of lihocin (1000 ppm). Pusa naubahar recorded highest yield and yield components (number of pods, pod yield, number of seeds per pod) with the application of lihocin (1000 ppm) and highest pod length and 100-seed weight recorded with the application of miraculan (1000 ppm) over DWD-1.