PRODUCTIVITY MANAGEMENT IN YARD LONG BEAN
(*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)
THROUGH CROP GEOMETRY AND NUTRITION

By

PREETHA M. D.

THESIS

submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled **"Productivity management in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt) through crop geometry and nutrition"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **"Productivity management in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt) through crop geometry and nutrition"** is a record of research work done independently by **Miss.Preetha M.D.,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of **Miss. Preetha M.D.,** a candidate for the degree of **Master of Science in Horticulture** with major in **Olericulture,** agree that this thesis entitled **"Productivity management in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt) through crop geometry and nutrition "** may be submitted by **Miss. Preetha M.D.,** in partial fulfilment of the requirement for the degree.

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To my Family

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Introduction

1. INTRODUCTION

Vegetables play an important role in human nutrition as protective foods. Due to the greater appreciation of their nutritive value, the interest in vegetable production has increased rapidly during the recent years. Vegetable production is a significant contributor of income to the weaker sections of the society in the developing countries.

In the world scenario India is the second largest producer of vegetables next to China contributing about 12 per cent of the global vegetable production. We produce 96.54 million tonnes of vegetables annually from an area of 6.89 million hectare (GOI, 2003).

Kerala is blessed with a favourable agroclimatic condition for the production of many tropical and sub-tropical vegetables throughout the year. However, our vegetable production is only one third of our current requirement. The rest is met from neighbouring states. The area under vegetables in Kerala is 73,958 ha with a production of 5.92 lakh tonnes. The per capita consumption in Kerala is only 125 g per day as against the dietary requirement of 285 g (FIB, 2003).

Legumes are of major importance to the livelihood of millions of poor people in under developed countries. Rural families derive food, animal feed and further spillover benefits to their farmlands in the form of plant residues from growing these crops. In fresh form, the young leaves and immature pods are consumed as nutritious vegetable providing protein, vitamins and minerals. Another important feature is that legumes fix atmospheric nitrogen through symbiosis with nodule bacteria. In doing so, the crop contributes 25-35 kg N ha^{-1}.

Among the legumes the genus *Vigna* is widely grown as a vegetable in tropical regions of the world. It is a pantropic genus with about 84 species (Marechal et al., 1978). All cultivated forms of cowpea are grouped under *V. unguiculata*. The Transvaal region of South Africa is considered as the center of origin of *V. unguiculata*. There are three morphotypes of cowpea viz., grain type (*V. unguiculata* sub sp. *catjang* Wall), vegetable type (*V. unguiculata* var. *sesquipedalis* (L.) Verdcourt) and dual purpose type (*V. unguiculata* sub sp. *cylindrica* var. *eseltine*) (Gopalakrishnan, 2004).

Yard long bean is a very popular vegetable in China, Korea, Indonesia, Philippines and Thailand. It is also a highly relished vegetable in Kerala where it occupies second position in area and production after bitter gourd. It can be cultivated throughout the year in the state. During rainy season it is mainly cultivated as an upland crop either in open as a pure crop or as an intercrop in coconut gardens. In summer season it is cultivated as an irrigated crop in rice fallows.

Yard long bean is a trailing crop with indeterminate growth habit, protracted growth period and higher productivity. Naturally it demands a wider spacing and higher doses of fertilizers than the bush types. The production potential of pulse varieties is 4 t ha^{-1} and that of bush type vegetable varieties is 6 t ha^{-1}. Yard long bean types can give a yield of 10-12 t ha^{-1}. But only a general recommendation for grain and bush type cowpea is available (KAU, 1996). Since the vegetative growth and harvesting of the crop is continuous split application of fertilizers will be advantageous. This will result in prolonged harvesting period and consequently higher yield from the crop. Organically grown vegetables have export potential and fetch more price in local markets than traditionally grown vegetables. The palatability and taste of organically grown vegetables is also superior.

Hence the present study was undertaken with the following objectives

1) to standardize the optimum spacing and nutrient requirements of yard long bean
2) to assess the effect of split application of fertilizers in yard long bean
3) to study the feasibility of organic farming in yard long bean.

Review of Literature

2. REVIEW OF LITERATURE

Plants respond positively to applied nutrients and results in higher vegetative growth and consequently higher production. Little work has been done on yard long bean regarding its nutritional requirements. The available works have been reviewed here. Since research works in this crop is meagre, similar works on related crops like peas, beans and other legumes are also included in the review.

2.1. RESPONSE TO NITROGEN

Nitrogen plays a key role in proper growth and development of all cultivated crops. It is important for protein synthesis in legumes. Rhizobial nitrogen fixation accounts for majority of nitrogen demand of legumes. On an average legume fix 25-35 kg N ha^{-1}. Symbiotic system alone cannot supply all the nitrogen for maximum growth and response of leguminous plants (Allows and Bartholomen, 1959). They require a starter dose of nitrogen for early growth and development (Russel, 1961). Patel (1979) and Raj and Patel (1991) found that cowpea responds well to moderate application of nitrogen.

2.1.1. Growth characters

Application of 30 kg N ha^{-1} in two splits gave maximum plant height, number of leaves and leaf area index in pulse cowpea (George, 1981) and in vegetable cowpea (Chandran, 1987). Ramamurthy *et al.* (1990) found that application of 20 kg N ha^{-1} recorded maximum leaf area and leaf area index in cowpea. Jain *et al.* (1993) reported that, in cowpea plant height and number of branches did not vary due to different levels of nitrogen, but leaf area index, fresh and dry weight per plant increased significantly. Leaf area index significantly increased at 80 kg N ha^{-1} as compared to 40 kg. Cowpea produced maximum biomass of 26.1 gram per plant at N application of 45 kg ha^{-1} (Choudhary *et al.*, 2000a). The higher biomass per plant was due to increased plant height, branches, leaves and biomass per plant (87, 118, 89, and 270%) over control.

Baboo *et al.* (1998) observed enhanced growth in French bean with N application up to 120 kg ha^{-1}. Significant increase in plant height and number of branches was noticed. Ghosal *et al.* (2000) observed pronounced effect of N on dry matter accumulation in French bean. According to Singh (2000) graded levels of N application between 50 and 120 kg ha^{-1} significantly increased plant size. Whole plant weight showed a progressive increase with increase in nitrogen levels. Tewari and Singh (2000) obtained increased plant height, number of leaves and branches per plant in French bean with increase in N levels. Maximum response was found when nitrogen was applied @ 160 kg ha^{-1}.

In soybean, plant height, number of trifoliates , plant dry matter and leaf area index were significantly increased due to application of inorganic nitrogen combined with organic sources of nutrients. These characters showed maximum value with 50 kg N + 1 t neemcake per hectare. Branches per plant were maximum with recommended doses of N (Saxena *et al.*, 2001). Singh *et al.* (2001a) reported that linear growth of plant, number of leaves, root length, fresh weight of roots and dry weight of roots were maximum when N was applied at the rate of 90 kg ha^{-1}.

Bahadur and Singh (1990) observed that height of garden pea was increased significantly with increasing levels of nitrogen. Number of nodules per plant was significantly more at 45 kg N than at 30 kg N ha^{-1}.

In groundnut increased dry matter accumulation was observed at all stages of plant growth with increased doses of nitrogen. Nitrogen application at 60 kg ha^{-1} gave maximum dry matter accumulation (Ravikumar *et al.*, 1994).

Ramakrishna *et al.* (2002) reported increased dry matter accumulation in chickpea with increase in N levels. Application of 25 kg N produced superior growth through improved nodulation, leaf area index, leaf area duration, and dry matter production.

2.1.2. Yield and yield contributing parameters

Malik *et al.* (1972) found that application of 20 to 40 kg N ha^{-1} to cowpea had no effect on yield attributing characters like number of pods per plant, pod weight and 100 seed weight. Nangju (1976) reported maximum yield in vegetable cowpea with application of 30 kg N ha^{-1}. Viswanathan *et al.* (1978) observed that an increase in nitrogen levels from 0 to 40 kg ha^{-1} progressively increased yield in cowpea. Agbenin *et al.* (1990) observed that cowpea responded positively though non-significantly to nitrogen fertilization upto 30 kg ha^{-1}. Highest number of pods per plant and seeds per pod was obtained with nitrogen at 30 kg ha^{-1}. Maximum number of pods per plants, number of seeds per pod and pod length were obtained by nitrogen application @ 20 kg ha^{-1} (Ramamurthy *et al.*, 1990; Raj and Patel, 1991; Akter *et al.*, 1998). According to Chandran (1987) days to first flowering and days to first picking were not influenced by increase in nitrogen levels from 0 to 40 kg ha^{-1}. However, N at 30 kg ha^{-1} gave the highest vegetable yield in cowpea cultivar Kurutholapayar. Gandhi *et al.* (1991) obtained a seed yield of 1.75 t ha^{-1} in cowpea with 25 kg N ha^{-1} compared to 1.41 t in control where no fertilizers were applied. Angne *et al.* (1993) reported highest grain yield of 1.69 t ha^{-1} with 15 kg N ha^{-1}. Jain *et al.* (1993) found variation in yield components like pods per plant seeds per pod with varying levels of nitrogen (40, 60, and 80 kg ha^{-1}). Highest green pod yield in cowpea cv. kurutholapayar was realized with nitrogen application @ 10 kg ha^{-1} in Kumarokam soils (Syriac and Nair, 1994). Jain *et al.* (1993) reported highest yield in cowpea with 40 kg N ha^{-1} in summer crop. Choudhary *et al.* (1997) opined that fertilizer treatments have no significant influence on yield attributing characters like number of pods per plant, number of seeds per pod, and 1000 seed weight and seed yield. Mishra (1999) obtained highest green pod yield of 21.47 t ha^{-1} in cowpea variety Pusa Komal with 30 kg N along with Rhizobium inoculation compared to 9.28 t ha^{-1} in control. Choudhary *et al.*, (2000b) reported that pod length of cowpea significantly increased upto N application of 15 kg ha^{-1}. Liberal application of nitrogen had an inhibitory effect on nitrogen fixation and consequently on pod and grain yield in cowpea. Yield reduction with application of N above 20 kg N ha^{-1} was noticed. Geetha and Varughese (2001) also obtained similar results in vegetable cowpea.

Baboo *et al.* (1998) reported that nitrogen application significantly enhanced the growth and yield of French bean. Seed yield increased significantly with each successive increment in N upto 120 kg ha^{-1}. Number of pods per plant, number of seeds per pod, and 100 seed weight also exhibited the same trend. Singh (2000) obtained significantly higher yield in French bean with 125 kg N ha^{-1}. The number of pods per plant and pod weight significantly rose upto100 kg ha^{-1} though maximum value was observed with 125 kg ha^{-1}. Further increase in N had no favourable effect. Individual plant productivity progressively rose from 78 to 90 gram per plant with rising N levels from 50 to 125 kg ha^{-1}, but differences were non-significant. Delayed flowering in French bean was noticed when nitrogen doses were increased. Response of N upto 120 kg ha^{-1} was pronounced in yield attributing characters like number of pods per plant, number of seeds per pod, weight of seeds, test weight, and seed yield per hectare (Singh and Singh and Tewari and Singh, 2000).

Singh *et al.* (1969) observed no significant difference in yield of pea grains with varying levels of nitrogen. However, highest grain yield of 25.35 q ha^{-1} was obtained with 22 kg N compared to 0 and 11 kg N ha^{-1}. Bisen *et al.* (1985) found that nitrogen had no influence on yield and yield attributing characters in garden pea. According to Bahadur and Singh (1990) early flowering was noticed in garden pea at lower dose of N (20 kg ha^{-1}) and control. However, yield parameters like pods per plant, length of pods and number of seeds per pod were maximum at 45 kg N ha^{-1}. Vimala and Natarajan (2000) also reported increase in number of pods, pod length, pod width and yield at higher levels of nitrogen.

Pods per plant and seeds per pod were maximum with standard dose of NPK in soybean (Saxena *et al.* 2001). Singh *et al.* (2001b) showed that soybean crop gave significantly higher seed and biological yields with 60 kg N ha^{-1} and beyond this level there was only a marginal increase in yield.

Singh and Rajput (1985) obtained best results for green pod weight and number of seeds per pod with highest N rates of 40 kg ha^{-1} compared to 0 and 20 kg in cluster bean. Ravikumar *et al.* (1994) observed maximum pod yield in groundnut with 60 kg N. Gunjkar *et al.* (1999) obtained no significant increase in pod and seed yield in blackgram with increase in nitrogen application beyond 25 kg ha^{-1}. Krishna *et al.* (2001) reported highest number of pods per plant, seed yield and test weight in chickpea with 30 kg N ha^{-1}. A significant increase in grain yield of faba bean was observed with application of nitrogen and highest yield was obtained at 20 kg N ha^{-i}.

2.1.3. Nutrient content and uptake

Kumar *et al.* (1979) reported maximum uptake when N was applied at the rate of 20 kg ha^{-1} in cowpea. Chandran (1987) opined that there was increase in N uptake with increase in N level upto 30 kg ha^{-1}in vegetable cowpea cv. kurutholapayar. Increased N application also increased P uptake, but did not show any effect on K uptake. Agbenin *et al.* (1990) observed that in cowpea increase in nitrogen levels from 0 to 60 kg ha^{-1} had no effect on N, P, and K contents of index leaves.

Nayak *et al.* (1997) observed significant increase in total N uptake in faba bean upto 40 kg N ha^{-1} where the maximum uptake of 109.21 kg N ha^{-1} was recorded.

Akbari *et al.* (2001) noticed that in soybean, maximum P uptake was recorded with application of 45 kg N ha^{-1}, which was significantly higher than the control. Nitrogen and potassium contents in grain and straw did not change significantly due to N fertilization.

Deka *et al.* (2001) found that application of N led to increased N and P levels in both kernel and stover in groundnut. Uptake of nitrogen, phosphorus and potassium increased significantly up to 40 kg N ha^{-1}.

In French bean accumulation of nitrogen in all plant parts increased significantly with increase in N levels. Application of N had an additive effect on availability and accumulation of P and K (Ramakrishna *et al.*, 2002).

2.1.4. Quality

Dekov and Alvares (1980) obtained higher protein and starch contents in cowpea seeds with 40 kg N ha^{-1}, but N had no effect on the mineral composition. Gandhi *et al.* (1991) reported that protein content of cowpea increased from 20.7 percent to 22.7 percent when N was applied at the rate of 25 kg ha^{-1}. However, Malik *et al.* (1972), Kurdikeri *et al.* (1973) and Jain *et al.* (1993) did not observe any significant increase in protein content of cowpea with increase in levels of nitrogen.

Singh *et al.* (1969) observed that protein content in pea grains increased progressively with an increase in level of nitrogen and it was highest at 22 kg N ha^{-1}. Application of 22 kg N gave an increase of 12.4% in protein content over control. Vimala and Natarajan (2000) reported no significant increase in total soluble solids due to application of N fertilizers in peas. Protein content and crude fibre showed an increasing trend with increase in fertilizers from 30 to 120 kg ha^{-1}.

Singh and Rajput (1985) observed higher protein and low crude fibre in cluster bean when nitrogen at the rate of 20 kg ha^{-1} was applied. Singh and Singh (2000) observed increase in protein content with increase in N dose from 0 to 120 kg ha^{-1} in French bean. Akbari *et al.* (2001) and Singh *et al.* (2001a) reported that in soybean protein and oil content of grains did not increase significantly due to N fertilization.

2.2. RESPONSE TO PHOSPHORUS

Various workers have emphasized the role of phosphorus in proper root development of legumes. Cowpea, being a pulse crop responds well to the application of phosphorus. Phosphorus is highly essential for nodulation, growth and development of reproductive parts, energy relations and protein synthesis in legumes. Experiments on vegetable cowpea in general revealed that the crop responded well to P_2O_5 levels from 30-50 kg ha^{-1} (Chandran, 1987, Jyothi, 1995).

2.2.1. Growth characters

Phosphorus application in general has no significant effect on growth characters of cowpea. Although increasing levels showed improvement in growth characters the effects were not significant. Singh (1985) observed an increase in plant height in summer cowpea when phosphorus was applied @ 60 kg P_2O_5 ha^{-1}. Chandran (1987) obtained higher number of leaves and increased vine length at the same level of phosphorus. Swaroop *et al.* (2001) reported that in vegetable cowpea, phosphorus had no significant effect on plant height, length of root, number of branches per plant and number of leaves per plant. The maximum plant height and number of branches were recorded for the control. However, number of leaves and length of root were maximum at 120 kg P_2O_5 ha^{-1} but was not significant.

Singh (2000) observed that in French bean application of phosphorus did not show any significant effect on plant height and whole weight of plant. Singh and Singh (2000) recorded an increase in number of branches in French bean upon phosphorus application, the highest being at 120 kg P_2O_5 ha^{-1}.

In soybean, growth parameters like plant height, dry weight, number of trifoliates, branches per plant, relative growth rate and leaf area duration increased with P up to 40 kg ha^{-1}. Fresh weight, number of root nodules, leaf area index, net assimilation and crop growth rate increased up to 80 kg P_2O_5 ha^{-1} (Abbas *et al.*, 1994). Singh *et al.* (2001b) noticed maximum values for these parameters at 90 kg P_2O_5 ha^{-1}. The results were on par with treatments where 60 kg P_2O_5 ha^{-1} was applied.

Significant improvement in root growth of chickpea was noticed due to phosphorus application (Joseph and Varma, 1994; Sonboir and Sarawgi, 2000).

Yadav *et al.* (1994) reported that an increase in P level from 0 to 26.4 kg P_2O_5 ha^{-1} increased the leaf area index from 2.58 to 3.02. Response to phosphorus showed an increasing trend up to 60 kg P_2O_5 ha^{-1} in groundnut (Mishra, 1994) and green gram (Angayarkanni *et al.*, 2001).

In peas, application of phosphorus significantly improved leaf area index of the plant over control (Yadav *et al.*, 1993). Kanaujia *et al.* (1999) reported that phosphorus at 80 kg ha^{-1} registered significantly more plant height and number of branches per plant.

2.2.2. Yield and yield attributing characters

Nangju (1976) recorded maximum grain yield in cowpea when phosphorus was applied @ 30 kg ha^{-1}. Subramanian *et al.* (1977) opined that application of 25 kg P_2O_5 ha^{-1} was sufficient as it produced highest number of pods per plant, number of seeds per pod and grain yield. Similar results have been reported by Viswanathan *et al.* (1978) and Kumar *et al.* (1979). Patel (1979) found that in vegetable cowpea application of 60 kg P_2O_5 ha^{-1} significantly increased the number and weight of green pods per plant and total yield compared to 0, 20 and 40 kg P_2O_5 ha^{-1}. Chandran (1987) opined that days to first flowering, flowering period, days to first picking and length of pods remained unaffected due to phosphorus application. However, phosphorus application influenced other yield contributing factors viz. number of pods per plant and number of seeds per pod and eventually the fresh pod yield. Maximum response was observed at 60 kg P_2O_5 ha^{-1}. According to Gandhi *et al.* (1991), application of 50 and 75 kg P_2O_5 ha^{-1} produced seed yields of 1.75 t and 1.71 t ha^{-1} respectively compared to 1.41 t with no fertilizers. Phosphorus application at the rate of 50 or 75 kg P_2O_5 ha^{-1} gave similar seed yields, which were significantly higher than control or lower doses (Mahaldar *et al.*, 1991). Cowpea variety California

Black Eye produced maximum number of pods per plant at 150 to 200 kg P_2O_5 ha^{-1}, but seed number per pod was not affected. Seed yields increased only with increasing phosphorus application up to 100 kg ha^{-1} (Naceur, 1991). Angne *et al.* (1993) reported a yield of 1.69 t ha^{-1} with 30 kg P_2O_5 ha^{-1} compared to 0.97 t ha^{-1} in control. Higher phosphorus rates of 60 kg reduced the number of days to flowering by 5-8 days in cowpea and produced higher pod yields (Okeleye and Okelana, 1997; Mishra, 1999). Mini (1997) obtained minimum days for flowering and maximum pod yield with 45 kg P_2O_5 ha^{-1} which was on par with 60 kg. Mathew (1999) also reported similar results in vegetable cowpea. The number of pods per plant and pod yield were maximum at 30 kg P_2O_5 ha^{-1}. Days to first harvest decreased with phosphorus application. The crop fertilized with 120 kg P_2O_5 produced maximum length of pods whereas number of seeds per pod was maximum at 80 kg P_2O_5 ha^{-1} (Swaroop *et al.*, 2001).

Maximum green pod yield (87.30 q ha^{-1}) and pod length were registered in French bean with 80 kg P_2O_5 ha^{-1} (Kanaujia *et al.* 1999; Kanaujia and Rajnarayan, 2000). Singh (2000) reported that for French bean 50 kg P_2O_5 ha^{-1} was optimum. It improved the length, diameter and weight of pods, and total pod yield, though it had little effect on number and yield of pods per plant. At the same time Singh and Singh (2000) obtained significantly higher yields with 120 kg P_2O_5 ha^{-1}.

Garg *et al.* (1978) reported that application of phosphorus in peas did not affect significantly either the number of pods per plant or the grain yield per hectare. Although application of phosphorus gave significantly more pods per plant than control, the differences between 20, 40 and 60 kg ha^{-1} were not significant. An improvement in yield characters was reported with phosphorus application ranging from 20-90 kg ha^{-1} in field pea (Rathi *et al.*, 1995). Sinha *et al.* (2000) observed that each incremental dose of phosphorus from 45 to 75 kg ha^{-1} significantly reduced the days to 50 per cent flowering and harvest in garden pea. Yield attributing traits remarkably increased with application of 60 kg P_2O_5 ha^{-1}.

Mishra (1994) reported 52 per cent increase in pod yield over control for groundnut at 60 kg P_2O_5 ha^{-1}. Similar results were also obtained by Ramesh and Sobale (2001). They reported 50 kg phosphorus as the optimum dose for groundnut. Further increase in levels of P_2O_5 did not show a proportionate increase in yield.

Joseph and Varma (1994) observed that in chickpea application of 45 kg P_2O_5 ha^{-1} gave significantly higher yield than 15 or 30 kg ha^{-1}. Chaubey and Kaushik (2000) noticed a linear increase in grain yield in summer green gram as the levels of phosphorus increased, the highest yield being obtained with 100 kg P_2O_5 ha^{-1}. However, the increase in yield was significant only up to 50 kg P_2O_5 ha^{-1}. Ramasamy *et al.* (2000) observed marked increase in number of pods per plant and yield with 80 kg P_2O_5 ha^{-1} but was on par with 60 kg ha^{-1}. Akbari *et al.* (2001) reported increased grain yield with 30 kg P_2O_5 ha^{-1}. Majumdar *et al.* (2001) and Angayarkanni *et al.* (2001) obtained better results with application of 60 kg P_2O_5 ha^{-1} in soybean and green gram respectively. In black gram successive increase in phosphorus levels up to 60 kg ha^{-1} increased seed and straw yields by 39.0 and 27.7 per cent over control (Tanwar *et al.*, 2003)

2.2.3. Nutrient content and uptake

Phosphorus application at the rate of 60 and 90 kg P_2O_5 ha^{-1} helped the cowpea plants to take up significantly more P in comparison to the plants receiving 30 or 0 kg P_2O_5 ha^{-1} (Sharma *et al.*, 1974). Kumar *et al.* (1979) reported maximum uptake at 40 kg P_2O_5 ha^{-1} while Chandran (1987) recorded maximum uptake at 60 kg ha^{-1}. Phosphorus application improved plant uptake of N and K in cowpea (Mali and Mali, 1991).

Rai and Sinha (1986) opined that application of 30-90 kg P_2O_5 ha^{-1} to peas increased the NPK uptake of peas. According to Rathi *et al.* (1993), nitrogen content of seeds of field pea was maximum when phosphorus was applied @ 40-60 kg ha^{-1} while P content was the highest at 40 kg P_2O_5 ha^{-1}. Kanaujia *et al.* (2000) reported that nitrogen, phosphorus and potassium content in plant as well as in seed increased significantly with increasing levels of phosphorus from 0-90 kg ha^{-1}. Maximum values of these characters were recorded at 90 kg P_2O_5 ha^{-1}.

Calcium and magnesium contents and uptake by soybean were significantly increased with phosphorus application up to 50 μg g^{-1}. Content of magnesium was higher in straw than in grain (Dwivedi *et al.*, 1998). Akbari *et al.* (2001) noticed that in soybean N and K content in grain and straw remained unaltered due to P application. Phosphorus content in grain and total uptake of NPK significantly increased due to phosphorus fertilization. Maximum P content in grain as well as total uptake of N (106.4 kg), P (8.22 kg), and K (45.1 kg) were recorded when phosphorus was applied @ 60 kg ha^{-1}. Majumdar *et al.* (2001) observed that P uptake of soybean seeds and straw increased significantly with the increase in doses. The uptake was higher in seed than in straw and was the highest at 60 kg P_2O_5 ha^{-1}.

Rather and Chahal (1977) found that in groundnut increased levels of phosphorus application resulted in a significant increase in its concentration in shoots and kernels. Concentration of P in shoot was higher at flowering stage than at maturity stage. In general kernels accumulated a higher amount of P as compared to the shoots. Phosphorus application significantly increased the N concentration in the plant parts but had no effect on K content. According to Singh *et al.* (1994), N and P uptake significantly increased with application of phosphorus and maximum uptake was observed at 30 kg P_2O_5 ha^{-1}. Teotia *et al.* (2001) reported that increase in application of P upto 60 µg g^{-1} increased the N and K contents in grain and straw of moong bean. Application of 60 kg P_2O_5 ha^{-1} in black gram resulted in an increased N and P uptake by grains to the extent of 58.82 and 97.34 per cent and by straw to the tune of 68.19 and 65.28 per cent (Tanwar *et al.*, 2003).

2.2.4. Quality

Chandran (1987) obtained highest protein content of 31.4% in pods when a combination of 30 kg N+ 60 kg P_2O_5 ha^{-1} was applied to vegetable cowpea. Gandhi *et al.* (1991) noticed that seed protein content of cowpea increased from 20.7 per cent in control to 22.2 and 22.7 per cent respectively with application of 50 and 75 kg P_2O_5 ha^{-1}.

Singh and Rajput (1985) recorded high protein and low crude fibre in cluster bean pods at 60 kg P_2O_5 ha^{-1}. Similar results have been reported by Ahmed *et al.* (1986) in mung bean and Rathi *et al.* (1993) in field pea. Kanaujia *et al.* (1999) obtained the same result with 80 kg P_2O_5 ha^{-1}. However, Akbari *et al.* (2001) observed that protein content of grain remained unaltered due to phosphorus application in soybean. Angayarkanni *et al.* (2001) observed that seed protein content increased from 18.8% in control to 23.4% with 60 kg P_2O_5 ha^{-1}.

2.3. POTASSIUM

Potassium plays an important role in enzyme activation, water relations, energy relation, translocation of assimilates, nitrogen uptake and protein synthesis. In legumes potassium enhances carbohydrate transport to nodules and utilization for synthesis of aminoacids (Tisdale *et al.*, 1993). Grain legumes in general require high quantities of potassium for normal growth and development compared to N and P (Yahiya *et al.*, 1996).

2.3.1. Growth characters

According to Chandran (1987), there was no influence for potassium application on vegetative characters of vegetable cowpea. Potassium application @ 20 kg K_20 ha^{-1} produced highest number of leaves per plant and leaf area index in cowpea (Geetha, 1999). Sangakara *et al.* (2001) reported that potassium increased root development of cowpea when applied @ 3.0 mM to pot plants. The same rate improved shoot growth in mungbean. The plant water relations and photosynthetic rates were improved by potassium. Potassium promoted overall growth of cowpea and mungbean when subjected to sub-optimal soil moisture. Application of potassium fertilizer could be considered as a significant factor in overcoming soil moisture stress in legumes. Swaroop *et al.* (2001) reported maximum root length for vegetable cowpea when potassium was applied at the rate of 120 kg K_20 ha^{-1}.

In green gram (Savithri, 1980) observed that higher levels of potash (20 and 30 kg ha^{-1}) improved plant height and number of leaves compared to 10 kg K_20 ha^{-1}. Yahiya *et al.* (1996) noted that application of potassium influenced favourably all the growth parameters in pigeon pea. Leaf area index was increased significantly up to 75 kg K_20 ha^{-1}. Kanaujia *et al.* (1999) observed that K application at 60 kg K_20 ha^{-1} registered significantly more plant height and number of branches per plant in French bean. There was considerable increase in total biomass production with K_20 application in comparison to control (Prasad *et al.*, 2000).

2.3.2. Yield and yield attributing characters

According to Sundaram *et al.* (1974) application of potassium did not show any significant effect on green and dry matter yield of cowpea up to 30 kg K_2O ha^{-1}. Chandran (1987) and Geetha and Varughese (2001) reported that in vegetable cowpea, response to potassium was positive up to 20 kg K_2O ha^{-1}. Nevertheless, its effect on yield contributing factors like number of pods per plant and days to 50 per cent flowering were not significant. However, Swaroop *et al.* (2001) reported that yield attributing factors viz. days to first flowering, days to first harvest, number of seeds per pod and length of pod were maximum at 120 kg K_2O ha^{-1} while yield and number of pods per plant were the highest at 60 kg K_2O ha^{-1}.

Singh *et al.* (1969) reported that there is no beneficial effect for application of K from 0 to 45 kg K_2O ha^{-1} on yield of pea grains. Similar results were reported by Chandra *et al.* (1983) in green gram. Prasad *et al.* (2000) opined that K has no significant effect on yield of mung bean.

In soils low in available potassium, application of 20 kg K_2O ha^{-1} increased seed yield up to 200 kg ha^{-1} (Kulkarni and Panwar, 1981). Kanaujia *et al.* (1999) observed that K application at 60 kg K_2O ha^{-1} registered significantly more pod length, number of pods per plant and green pod yield in French bean. Similar results were recorded in peas by Kanaujia and Rajnarayan (2000). According to Yakadri and Thatikunta (2002) application of potash at preflowering stage recorded higher yields compared to control. In blackgram response to potassium application was only up to 25 kg K_2O ha^{-1}.

2.3.3. Nutrient content and uptake

Kumar *et al.* (1979) reported maximum uptake in cowpea when K was applied at the rate of 20 kg K_20 ha^{-1}. Potassium application did not significantly influenced N and P uptake. Chandran (1987) also reported similar results. Maximum content of K in plant parts were noticed when a combination of 60 kg P_2O_5 + 30 kg K_2O ha^{-1} was applied. According to Singh and Varun (1989) application of K at 30 or 60 μg g^{-1} increased the uptake of potassium as well as iron in cowpea. Singh and Sharma (1995) noted that in cowpea magnesium uptake was lowered at higher K rates of 80 and 120 kg K_20 ha^{-1}. Optimum K: (Ca + Mg) ratio for cowpea was found to be 1.61. Potassium application significantly influenced the uptake of potassium at later stages of crop growth i.e. 90 DAS. Potassium application at the rate of 20 and 40 kg ha^{-1} resulted in maximum uptake (Geetha, 1999).

In groundnut, varying levels of potassium did not exert any influence on nitrogen content in dry matter, shell or the kernel. However, application of 75 kg K_20 ha^{-1} significantly influenced the P and K content in dry matter and kernel (Mathew, 1981). Kanaujia *et al.* (2000) reported that in French bean N and K contents of plant as well as in seed were higher at 90 kg K_20 ha^{-1}. Increase in K levels from 0 to 30 μg K g^{-1} soil resulted in significant increase in K uptake of mungbean (Prasad *et al.*, 2000).

2.3.4. Quality

Potassium application did not significantly influence the protein content of cowpea pods (Chandran, 1987). Kanaujia *et al.* (1999) reported highest protein content in green pods of French bean with K application @ 60 kg K_20 ha^{-1}.

2.4. COMBINATION EFFECTS

Application of 20 kg N + 60 kg P_2O_5 ha^{-1} gave a maximum yield of 1350 kg ha^{-1} in cowpea (Malik *et al.*, 1972). Chandran (1987) recommended a combined application of 30: 60: 30 kg N, P_2O_5 and K_2O ha^{-1} for getting maximum yield of pods in vegetable cowpea var. kurutholapayar. Syriac and Nair (1994) noted that green pod yield of vegetable cowpea increased upto 10: 20: 10 kg NPK ha^{-1} and further increase in NPK rates were not beneficial in Kumarokam soils. According to Fapohunda and Adekalu (1995), highest seed yield in cowpea (1.72 t ha^{-1}) was realized when N, P and K was applied at the rate of 100 kg ha^{-1}. Jyothi (1995) observed that marketable green pod yields of vegetable cowpea variety Malika was significantly influenced by N and P. The highest pod yield was obtained with 30: 45 kg NP ha^{-1} and was significantly superior to application of 20: 30 kg NP ha^{-1}. The increased pod yield was a reflection of the enhanced level of yield attributes viz. number of pods per plant, length of pods and number of seeds per pod. The NP ratios also markedly influenced the protein content of pods. Chowdhary *et al.* (1997) obtained highest yield of 1327 kg ha^{-1} in cowpea (211% increase over control) with NPK at 20: 60: 30 kg ha^{-1}. Fertilizer treatment significantly increased plant height, number of branches per plant, number of pods per plant and number of seeds per pod. In vegetable cowpea variety Arka Garima, combined application of 20 kg N, 80 kg P_2O_5, and 60 kg K_2O ha^{-1} with Rhizobium inoculation recorded highest average yield (114.08 q ha^{-1}) of green pods (Swaroop *et al.*, 2002).

Khamparia *et al.* (1981) reported that in mungbean maximum grain yields were recorded at 40: 60: 40 kg NPK ha^{-1}. The grain yield was 8.273 t ha^{-1} in control that rose to 11.394 t ha^{-1} with application of 40: 60: 40 kg NPK ha^{-1}. Plant height, number of primary branches, pods per plant, seeds per pod, seed weight and protein content were significantly increased. Highest yield of 18.52 q ha^{-1} was reported with

20: 40: 10 kg NPK ha^{-1} in gram (Chandra *et al.* 1983). Thirumalai and Khalak (1993) recommended 62.5 kg N + 100 kg P_2O_5 + 75 kg K_2O ha^{-1} for French bean for maximizing yields. For groundnut application of 20: 40: 20 kg NPK ha^{-1} recorded the highest pod and haulm yield and yield attributes than control (Mishra, 2000).

2.5. ECONOMICS OF CULTIVATION

George (1981) reported that a maximum net profit of Rs 1432 ha^{-1} when N alone was applied @ 30 kg ha^{-1}. A maximum net income of Rs. 11044.80 was realized when fertilizers were applied to vegetable cowpea at 20: 20: 10 kg NPK ha^{-1}. The treatment also recorded the highest return per rupee invested (2.37) (Chandran, 1987). According to Jyothi (1995), in vegetable cowpea maximum net returns (Rs 2538.22 ha^{-1}) and BCR (1.17: 1) were recorded with a combination of 30 kg N + 45 kg P_2O_5 ha^{-1}. Mini (1997) showed that highest net income (Rs 22519.20) and BCR (1.73: 1) with 45 kg P_2O_5 ha^{-1} and moderate spacing of 1 x 0.6 m. There was no significant influence for N and K rates on net returns and BCR. However, maximum net returns of Rs 65604.61 and BCR of 1.93 was obtained with N and K at 20 and 20 kgha^{-1} (Geetha, 1997). Mathew (1999) noted maximum net returns of Rs 15672.90 ha^{-1} and BCR of 1.54 with 30 kg P_2O_5 ha^{-1} in vegetable cowpea.

Thirumalai and Khalak (1993) found that application of 62.5 kg N + 100 kg P_2O_5 + 75 kg K_2O ha^{-1} gave a C: B ratio of 1: 4.12. The most economical treatment was 62.5 kg N + 100 kg P_2O5 + 0 kg K_2O ha^{-1} with a cost-benefit ratio of 1: 6.32. Doelankar and Mogal (1998) reported that the value of return per rupee invested for fertilizer increased with successive additional level of fertilizer and reached its maximum at 37.5 kg N and 75 kg P_2O_5 ha^{-1} in soybean. According to Mishra (2000), NPK application @ 10: 20: 10 kg ha^{-1} to groundnut recorded the highest B: C ratio of 1.2. In French bean N application increased net returns. With P application, highest net returns were obtained with 50 kg ha^{-1} (Singh, 2000). Akbari *et al.* (2001) were of the opinion that application of N @ 15 kg ha^{-1} recorded highest net benefit cost returns and nutrient use efficiency of 1: 6.97 and 4.27. Phosphorus at 15 kg ha^{-1} recorded a B: C ratio of 1: 1.87 and nutrient use efficiency of 1.97 compared to higher N and P levels.

2.6. SPLIT APPLICATION OF FERTILIZERS

Application of fertilizers in split doses are being practiced by farmers in vegetable crops like yard long bean and bitter gourd in Kerala. This results in an extended harvesting period and thereby better returns from the crop. But scientific study is lacking in this regard in yard long bean.

Lawn and Brun (1974) found that application of nitrogen at the fag end of flowering resulted in an increased seed and pod yield in soybean. Thimmegowda *et al.* (1975) reported that application of nutrients at 45 DAS significantly increased growth, yield components and pod yield in groundnut. Garcia and Hanway (1976) obtained increased seed yields in soybean due to nutrient spray application during seed filling, but spray application that contained nitrogen only, resulted in smaller increase in yield. According to Brevedan (1978) soybean plants that received higher nitrogen rates during flowering had significantly more number of pods. However, Robertson *et al.* (1977) reported that the yield of soybean was not affected by foliar applications either with nitrogen alone or in combination with P, K, and S. Increased grain yield as a result of additional nutrient application to soil during pod filling was reported by (Terman, 1977) and the higher grain yield was largely due to filling of more pods. Ghosal *et al.* (2000) reported that split application of nitrogen, if applied at the right stage to French bean improved the nitrogen use efficiency besides increased grain yield. Application of full dose of nutrients as basal led to considerable loss of nitrogen resulting in low yields as compared to split application. The demand for nitrogen in flowering stage is comparatively low. Singh *et al.* (2001a) found significant improvement in seed yield of soybean consequent to split application of N over full basal. They recommended application of nitrogen in three splits ½ at the time of sowing, ¼ at preflowering stage and remaining ¼ at pod formation stage as foliar spray.

2.7. ORGANIC FARMING

Organic farming is a practice which is gaining importance in the present day world. Organically grown vegetables are given more importance than any other food item by the quality conscious consumers. Work on organic farming in yard long bean is scanty in India. Hence research works on other related vegetables are included in the review.

Oliveira *et al.* (2000) reported maximum 3.0 t ha^{-1} seed yield in pulse cowpea when 21 t FYM ha^{-1} was applied along with mineral fertilizers, while a seed yield of 2.0 t ha^{-1} was recorded when 25 t cattle manure alone was applied. Economically, application of cattle manure @ 21 t ha^{-1} was viable for cowpea seed production. Oliviera *et al.* (2001) observed that the estimated maximum pod yield of cowpea (9.64 t ha^{-1}) was obtained with 25 t ha^{-1} of cattle manure in presence of mineral fertilizers, while in the absence of mineral fertilizer, pod yield increased by 49.3 kg ha^{-1} with increasing levels of cattle manure.

Plant height and root nodulation in vegetable pea improved with the application of FYM alone (Parmar *et al.*, 1998). Mishra (2000) observed that application of 20 t FYM ha^{-1} recorded significantly high pod and haulm yields of 1237 and 1883 kg ha^{-1} in groundnut than lower levels of FYM application. The same treatment also affected the yield attributes like number of pods per plant. Application of 20 t FYM ha^{-1} also obtained highest net profit of Rs 8552 ha^{-1} with a BCR of 1.90. Ramasamy *et al.* (2000) reported that applying FYM resulted in a significant increase in plant height, root length and number of branches per plant in soybean. It increased available P content of soil due to production of organic acids. Application of enriched FYM produced highest number of pods per plant and higher grain yield of 1499 kg ha^{-1} in summer. Saxena *et al.* (2001) noted that in soybean growth characters like plant height, number of trifoliates, plant dry matter, and leaf area index were significantly increased due to application of organic manures combined with inorganic sources of nutrients. These were maximum with 50 kg N and 1 t neemcake ha^{-1}. Significant increase in growth characters, yield components, and yield of green gram was obtained following combined use of vermicompost and fertilizer (Rajkhowa *et al.*, 2002).

In oriental pickling melon, treatment that received NPK in the organic form alone recorded relatively low yield and the lowest yield was recorded in the treatment that received standard dose of NPK completely as organic manure (Joseph, 1985). Growth of brinjal was highest in plants treated with either poultry manure alone (155 kg N ha^{-1}) or in combination with mineral fertilizers. It also gave highest crop duration and maximum number of harvests. Maximum starch content and reducing sugars of fruits were recorded with 38.5 t FYM ha^{-1}. There was no significant difference in moisture content of fruits between treatments (Prasanna, 1998). Reddy *et al.* (2002) found that application of organic manure alone reduced the yields of tomato by 29.19%. They also reported that fifty percent of recommended dose of N could be substituted with FYM without significant reduction in yield when compared to recommended dose of fertilizers.

Organic fertilization increased leaf calcium content in vegetable crops (Luzzati *et al.* 1975). Wilson (1979) compared the effect of organic and inorganic fertilizers in carrot, cabbage and leek and found that organic fertilizers increased the content of P and Ca in the dry matter, whereas content of K and Mg was dependent on the kind of fertilizer applied. According to Vityakom and Seripong (1988), cattle manure significantly increased the uptake of P and K but not calcium.

Singh *et al.* (1970) studied the effect of poultry manure on cauliflower and found that moisture, vitamin C and protein contents of the curd increased with higher doses of poultry manure, whereas carbohydrate content decreased. A favourable influence of organic fertilization on ascorbic acid content of sweet pepper fruits was observed by Valsikova (1983). Nandini (1998) observed that protein content of okra in general was higher in treatments supplied with FYM than other sources of organic manure.

2.8. STORAGE STUDY

Mani and Ramanathan (1981) reported that, in okra, application of nitrogen lowered the shelf life of fruits significantly. The shelf life observed was 14 days when N was applied @ 35 kg ha^{-1} compared to 11 days for higher N levels. Higher levels of N adversely influenced the storage behaviour of onion both under ordinary conditions and cold store (Madan and Sandhu, 1983). Rotting increased with N levels higher than 80 kg ha^{-1}. On the other hand, higher doses of P and K had a positive influence on storage. Increasing the levels of P and K to 60 kg ha^{-1}without N resulted in an improvement in storage quality. Inclusion of P or K with N alleviated the adverse influence of N on storage behaviour of onion. In okra the number of unmarketable fruits increased at higher levels of manures irrespective of whether organic or inorganic (100 kg N ha^{-1}) (Nandini, 1998).

Joseph (1985) observed the highest rotting percentage in treatments that received the highest dose of NPK completely in the inorganic form in oriental pickling melon. The lowest rotting was recorded by the organic treatment, which received farmyard manure and woodash (standard NPK completely in organic form) alone. During storage moisture content of fruits showed a steady decline irrespective of treatments. The storage life of harvested produce was more in the case of fruits from plots supplied with organic manures alone. Rapid rotting of harvested produce was seen in the case of fruits supplied with inorganic fertilizers in bitter gourd in a week (Veenakumari, 1992) and brinjal (Prasanna, 1998). Narayanankutty *et al.* (2002) reported that 60-75% of mature fruits obtained from treatments where both organic and inorganic sources were used decayed with in six months compared to 25% where organic manures alone was applied in oriental pickling melon. The corresponding figures were 90% and 45% respectively in the case of ash gourd.

2.9. PALATABILITY

Meirproeger *et al.* (1989) observed that compost from biogenic waste gave superior organoleptic quality, storability, and nutrient contents in tomato, beetroot and cabbage. Nandini (1998) reported that organoleptic quality of bhindi fruits did not differ significantly with source of N. However, FYM equivalent to 50 and 75 kg N ha^{-1} recorded better acceptance among consumers. Organoleptic test of fruits showed significant differences between sources of nutrients and doses of nitrogen given to the crop. The lowest dose of N in the form of poultry manure (80 kg N ha^{-1}) recorded the highest score for flavour, texture and taste in brinjal (Prasanna, 1998).

2.10. SPACING

Not much work has been done in yard long bean with regard to spacing. Majority of scientific works available are with respect to bush and semi trailing type cowpea. Mini (1997) noted that a spacing of 1 x 0.6 m is ideal for vegetable cowpea with regard to plant growth, days to flowering and harvest, yield attributing characters like pods per plant, total pod yield and uptake of nutrients. The high density treatments recorded minimum values for uptake of nutrients.

Kwapata and Hall (1990) reported that pod yield of vegetable cowpea variety (UCR 206) was not influenced by plant density. At the same time some varieties like UCR 193 responded positively to plant density. In UCR 193 total yields progressively increased with increasing plant density upto 400000 plants ha^{-1}, but the difference in yield was not significant. The *Vigna unguiculata* cv. Cowpea 263 gave the highest mean green pod yield at a spacing of 30 x 15 cm and plant density of 220000 plants ha^{-1} (Singh *et al.*, 1992). A higher grain yield of 1.69 t ha^{-1} was obtained in cowpea when a wider inter row spacing of 45 cm was given along with 15 kg N + 30 kg P2O5 ha^{-1} (Angne *et al.*, 1993). Kumar *et al.* (1997) observed highest seed yield and harvest index in cowpea with 45 cm inter row spacing. Spacing did not affect seed crude protein content.

In French bean differences in intra row spacing (40 x 10 cm, 40 x 15 cm and 40 x 20 cm) did not affect plant height and whole plant weight significantly, but maximum weight of plants was recorded with widest spacing. The length, diameter and weight of pods remained unaltered. The number and yield of pods per plant showed progressive increase with increasing intra row spacing, but differences were not significant. The highest pod yield was recorded with closest spacing, which was significantly more than the yield observed in the case of widest spacing. Similar trend was noticed for net returns. This was due to higher plant population in closer spacing that contributed to pod yield, raising returns with little expenditure on seed. Similarly, closest spacing recorded maximum net profit, which was 42% higher than the rate of net profit in widest spacing (Singh, 2000).

Materials and Methods

3. MATRERIAL AND METHODS

The present investigation was carried out to standardize the optimum spacing and nutrient requirement of yard long bean and to assess the feasibility of organic farming in the crop. The field experiment was conducted during December to April of 2003-2004. The materials used and the methods adopted for the study are briefly summarized below.

3.1. MATERIALS

3.1.1. Experimental site

The field experiment was conducted in the rice fallows of Agricultural Research Station, Mannuthy. The experimental site is situated at 12^0 32' N latitude and 74^0 20' E longitude at an altitude of 22.5 m above mean sea level. The area experiences a typical warm humid tropical climate.

3.1.2. Cropping history of the field

A continuous bulk rice crop with uniform package of practices was cultivated during the previous season.

3.1.3. Soil

The soil of the experimental site was sandy clay loam in texture. The important chemical properties of the soil are summarized in Table 3.1.

Table 3.1. Chemical properties of the soil before the experiment

Constituent	Content in soil
Organic carbon (%)	0.454
Available P_2O_5 (kg ha^{-1})	82.6
Available K_2O (kg ha^{-1})	133.65
Available Ca (µg g^{-1})	328.67
Available Mg (µg g^{-1})	564.4
Available Fe (kg ha^{-1})	128.24
pH	4.62
EC (dS m^{-1})	0.117

3.1.4. Season

The crop was raised during the rabi season of 2003-2004 from December to April.

3.1.5. Weather conditions

The monthly averages of temperature and relative humidity during the cropping period were collected from Agro-meteorological observatory attached to the College of Horticulture, Vellanikkara and the data are given in Appendix 1.

3.1.6. Yard long bean variety

The adaptable high yielding yard long bean variety Lola developed in the Department of Olericulture, College of Horticulture, Vellanikkara was selected for the study.

3.1.7. *Manures and Fertilizers*

Well-decomposed and dried farmyard manure (FYM) obtained from University farm was used. Chemical fertilizers of the following analytical grade were used as sources of nitrogen, phosphorus, and potassium.

Urea - 46 per cent N

Rajphos - 18 per cent P_2O_5

Muriate of potash- 60 per cent K_2O

3.2. DESIGN AND LAYOUT

The field experiment was laid out in split plot design with three replications. The layout plan is presented in figure 3.1.

3.3. TREATMENT DETAILS

Main plots – Spacing

M1- 1.5m x 0.25m
M2- 1.5m x 0.50m
M3- 1.5m x 0.75m

Sub-plots – Fertilizer combinations

Nine fertilizer treatments were fixed by altering levels, sources and frequencies of application of nutrients. The levels are fixed as 0%, 50% and 100% increase over package of practices recommendation (POP). A basal dose of 20 t FYM ha^{-1} was applied uniformly to all the plots.

T_1- POP recommendation (20: 30: 10 kg NPK ha^{-1} – half N, full P and full K as basal and half N 20 days after sowing (DAS))

T_2- 50% increase over POP (30: 45: 15 kg NPK ha^{-1} in 2 splits as in T1)

T_3- 100% increase over POP (40: 60: 20 kg NPK ha^{-1} in 2 splits as in T1)

T_4- 20: 30: 10 kg NPK ha^{-1} – N and K in 5 equal splits – basal, 20, 40, 60, and 80 DAS and full P as basal

T_5- 30: 45: 15 kg NPK ha^{-1} in 5 splits as in T4

T_6- 40: 60: 20 kg NPK ha^{-1} in 5 splits as in T4

T_7- 4 t ha^{-1} cow dung (equivalent to 20 kg N ha^{-1}) as slurry application in 4 equal splits- 20, 40, 60, and 80 DAS

T_8- 6 t ha^{-1} cow dung (equivalent to 30 kg N ha^{-1}) as slurry application in 4 equal splits- 20, 40, 60, and 80 DAS

T_9- 8 t ha^{-1} cow dung (equivalent to 40 kg N ha^{-1}) as slurry application in 4 equal splits- 20, 40, 60, and 80 DAS

A basal dose of 20 t FYM ha^{-1} was applied uniformly to all the plots.

3.4. FIELD CULTURE

3.4.1. Land preparation and sowing

The field was prepared by ploughing twice and the field was divided into plots of size 4.5 m x 4.35 m. In each plot, three trenches of dimension 4.2m x 0.3m x 0.15m were taken 1.5 m apart. Farmyard manure was applied @ 13.5 kg per trench (20 t ha^{-1}) uniformly to all the trenches and incorporated well. Basal dose of fertilizers were applied as per treatment and yard long bean seeds were dibbled at a depth of 5 cm at 0.25m, 0.5m, and 0.75m spacing according to the treatment. The field was irrigated immediately after sowing.

3.4.2. After cultivation

The seeds germinated within 5 days of sowing and after a week gap filling was done. Irrigation was given thrice a week. As the yard long bean plants started vining, the plants were trailed on small twigs. After a month trellis were erected for each trench. For this, two poles of 2 m height were erected at both ends of the trench and two wires were tied horizontally across them. Ropes were tied connecting the wires at regular intervals in order to trail the plants.

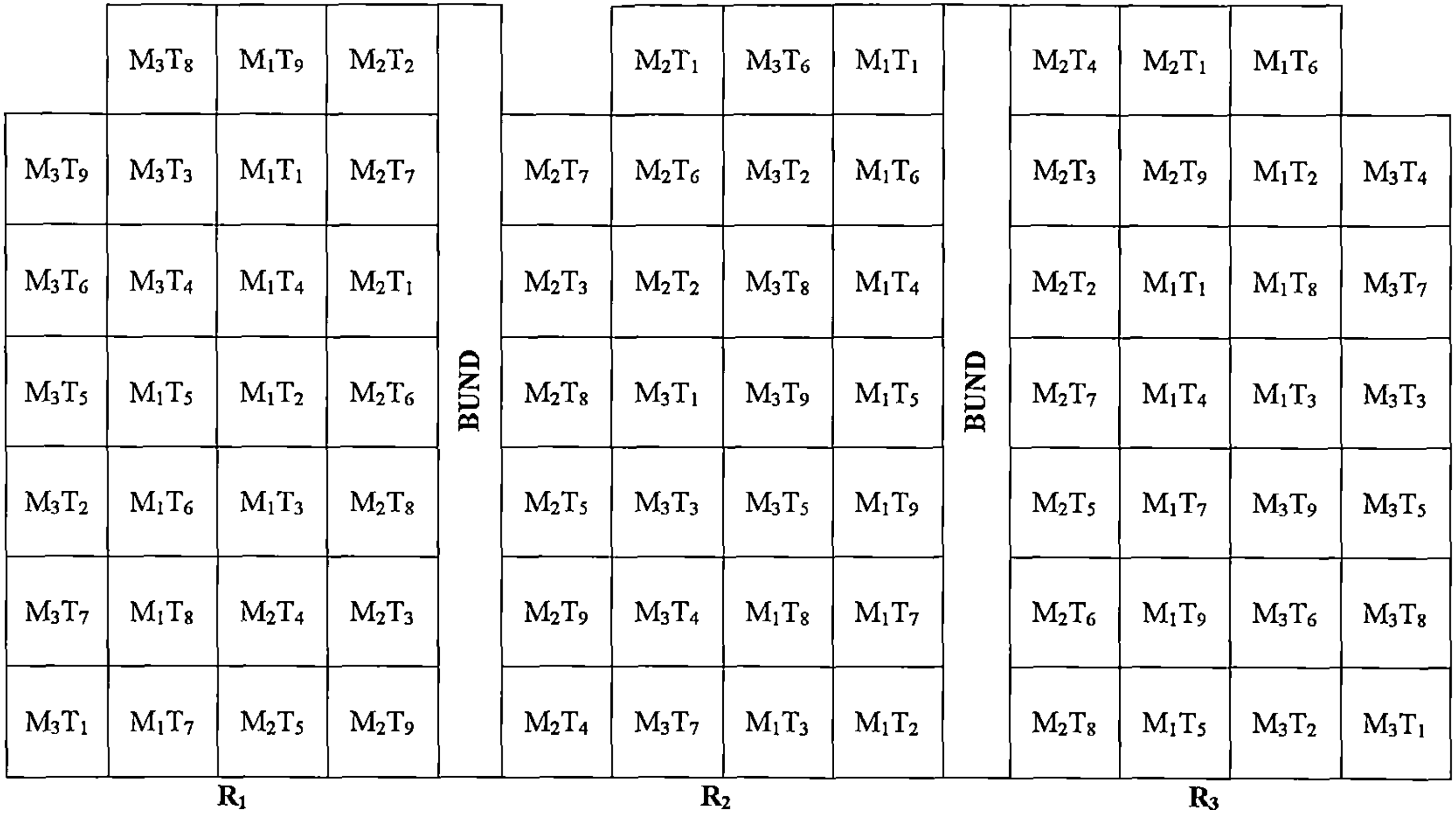

Figure 3.1. Layout of the field

Plate 1. General view of the field

The field was kept weed free throughout the cropping season by regular weeding. Top-dressing of fertilizers was given as per treatment.

3.4.3. Plant protection

Dust application of Sevin was done against ants soon after sowing. Two rounds of spraying with Acephate was carried out during seedling stage to control sucking pests and miners. After pod formation spraying of neem oil emulsion was done thrice to check aphids.

3.4.4. Harvesting

Harvesting of green pods started on 45th day after sowing. The pods were harvested thrice a week and weight of pods obtained from each trench were taken separately and recorded.

3.5. BIOMETRIC OBSERVATIONS

The following biometrical observations were taken at three stages of crop growth viz. 30, 60, and 90 days after sowing. Five observational plants were selected from each treatment randomly and tagged.

3.5.1. Number of primary branches per plant

The mean value of number of primary branches per plant were computed from the five observational plants and recorded.

3.5.2. Internodal length

The distance between 5^{th} and 6^{th} node from tip of the vine was measured from the observational plants, mean value calculated and recorded as the internodal length.

3.5.3. Leaf length

The length of ten recently matured leaves were taken from the five observational plants and the mean value was taken as leaf length.

3.5.4. Leaf width

The leaves that were used to measure leaf length were also used to compute leaf width.

3.5.5. Leaf area index

Leaf area index was calculated using the formula

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

Leaf area was calculated using the standard formula given by Sharma *et al.* (1987)

$$\text{Leaf area} = \text{length} \times \text{breadth} \times 0.6654$$

The same leaves taken for leaf length and width measurement were used to compute leaf area.

3.5.6. Days to first flowering

The dates of flowering of the five observational plants were recorded separately and the number of days taken from sowing to first flowering was calculated.

3.5.7. Days to first harvest

The dates of first harvest of the five observational plants were recorded separately and the number of days taken from sowing to first harvest was calculated.

3.5.8. Green pod yield

Yield of vegetable cowpea obtained from each plot was recorded separately, totalled up at the end of the cropping season, and expressed in kg ha^{-1}.

3.5.9. Number of pods per plant

Pods obtained from each treatment were counted during each harvest, totalled up at the end and divided by number of plants per treatment to get number of pods per plant.

3.5.10. Length of pods

Lengths of five pods were taken during each harvest per treatment and the average is worked out as the length of pods.

3.5.11. Pod weight

Weights of five pods were taken during each harvest per treatment and the average is worked out as the pod weight.

3.5.12. Root: shoot ratio

The dry weights of root and shoot portions were taken of each destructive sample (vegetative, flowering and after harvest) and their ratio worked out.

3.6. ANALYTICAL PROCEDURES

3.6.1. Determination of chemical properties of soil samples

Soil samples were taken from the experimental area before and after the experiment. Air-dried samples were used for analysis. Soil fertility parameters covering various electrochemical and chemical constituents of the soil, were analysed as per standard procedures.

3.6.1.1. Soil pH

The pH of the soil was determined in a 1:2.5 soil water suspension potentiometrically using a pH meter (Jackson, 1958).

3.6.1.2. Electrical conductivity

Electrical conductivity was determined in the supernatant liquid of the soil water suspension (1:2.5) with the help of a conductivity meter (Jackson, 1958).

3.6.1.3. Organic carbon

Organic carbon of the soil was determined by wet digestion method of Walkley and Black (Walkley and Black, 1934).

3.6.1.4. Available phosphorus

Available phosphorus in the soil samples were determined by extracting with Bray No. 1 reagent (Bray and Kurtz, 1945) and estimated colorimetrically by reduced molybdate ascorbic acid blue colour method using Spectronic 20 (Genesys) spectrophotometer (Watanabe and Olsen, 1965).

3.6.1.5. Neutral normal ammonium acetate extractable cations

Available potassium was extracted with neutral normal ammonium acetate solution and its content in the extract was determined by flame photometry (Jackson, 1958). Available calcium and magnesium from the ammonium acetate extract were estimated by versanate titration method (Hesse, 1971).

3.6.1.6. Available iron

Available iron in the soil samples was estimated colorimetrically using Spectronic 20 (Genesys) spectrophotometer. The available iron was extracted in 0.1N HCl (2: 20) (Sims and Johnson, 1991). To 1 ml of the extract, 5ml of 10% hydroxylammoniumchloride and 4 ml of 2.5% orthophenanthroline were added and a red colour was developed. The intensity of the red colour was then read at 515 nm in the spectrophotometer (Olson and Ellis, 1982).

3.7.2. Determination of nutrient elements in plant samples

Plant samples were taken during three stages of crop growth viz. vegetative, flowering and after harvest. The root portion was removed and the remaining plant parts were chopped and dried in an oven at 80-85°C. The dried samples were powdered, sieved and used for analysis. The samples were analysed for N, P, K, Ca, Mg, and Fe. Pods were collected from the five observational plants during each harvest and composite samples were used for analysis of the above mentioned nutrients.

Nitrogen was estimated by the modified Kjeldahl's method described by Jackson (1958). For this the monoacid digestion using sulfuric acid and digestion mixture was done and the digested samples were distilled using Microkjeldahl's distillation apparatus.

Determination of all other nutrients was carried out after digestion of the powdered plant samples with 2:1 nitric acid – perchloric acid mixture (Jackson, 1958).

Phosphorus in the digest was determined by the vanadomolybdate yellow colour method (Koenig and Johnson, 1942) and readings were taken in Spectronic 20 (Genesys) spectrophotometer. Potassium in the digest was estimated by flame photometry. Calcium and magnesium were determined using the versanate titration method (Hesse, 1971). Iron content in the plant samples was determined colourimetrically using Spectro Genesys spectrophotometer (Olson and Ellis, 1982).

3.8.3. Biochemical analysis of pods

3.8.3.1. Moisture content of pods

Moisture content was determined gravimetrically by drying the samples in a hot air oven at 80°C until the samples attained constant weights. The moisture content was expressed in percentage (Sadasivam and Manickam, 1992).

3.8.3.2. Crude protein content

Nitrogen content in the pods was estimated by modified Kjeldahl's method as described by Jackson (1958). To obtain protein content, the nitrogen content was multiplied by a constant 6.25 (Sadasivam and Manickam, 1992).

3.8.3.3. Carbohydrate

The total carbohydrate content of the pods was estimated using anthrone method, where the content was estimated colourimetrically using Spectro Genesys spectrophotometer. The hydrolysed extract of sample with 2.5 N HCl was used for analysis (Sadasivam and Manickam, 1992).

3.8.3.4. Minerals

Important minerals estimated were Ca, P, K, and Fe. The same procedure used for plant samples were followed here also.

3.8.3.5. Crude fibre

Fat free pod samples were first boiled with acid and subsequently with alkali. The residue obtained after final filtration was weighed, incinerated, cooled and weighed again. The crude fibre content was given by the loss in weight and expressed as percentage (Sadasivam and Manickam, 1992).

3.7. STORAGE STUDY

Twenty pods of uniform maturity were harvested from each treatment. Ten pods each were kept in zero energy cool chamber and the remaining pods under ambient conditions. Observations were taken daily on moisture loss and at alternate days on marketable number of pods.

3.8. PALATABILITY STUDY

Immature pods were cut into pieces, cooked by adding oil and salt and given to a panel of five judges to taste and score. The hedonic scale (Appendix 2) suggested by Swaminathan (1974) was used for organoleptic evaluation .

The judges opinion were recorded separately.

3.9. ECONOMIC ANALYSIS

Cost: benefit analysis for different treatments were carried out. B:C ratio for each treatment was worked out using the formula

$$BCR = \frac{\text{Total returns}}{\text{Total cost of cultivation}}$$

3.10. STATISTICAL ANALYSIS

The data on each observation were analysed statistically using Analysis of Variance (ANOVA) and Duncans Multiple Range Test (DMRT) techniques using MSTAT Package.

Results

4. RESULTS

The field experiment was conducted in the rice fallows of Agricultural Research Station, Mannuthy during December - April of 2003-2004. The results of the same are summarized below.

4.1. GROWTH CHARACTERS

Growth characters of yard long bean were measured in terms of number of primary branches, internodal length, leaf length, leaf width, leaf area index and root: shoot ratio.

4.1.1. Number of primary branches

There was significant difference between different spacing treatments for the number of primary branches at 30 DAS. The treatments M_2 and M_3 recorded the maximum number of branches (2.96 and 2.82) and were significantly superior to M_1 (2.50). At 60 and 90 DAS, there was no significant difference in number of primary branches (Table 4.1.1).

The different fertilizer treatments were found to exert no significant influence on number of primary branches during the three stages of crop growth. However, the treatment T_3 recorded the maximum value (3.11, 5.00, and 6.67) at 30, 60, and 90 DAS respectively.

The interaction effects of spacing and fertilizers on number of primary branches were also not significant (Table 4.1.2).

4.1.2. Internodal length

At 60 and 90 DAS, the main effect of spacing were found to have significant effect on internodal length whereas it was non significant at 30 DAS. The lowest spacing M_1 showed the highest internodal length at both stages (7.21 cm and 8.19 cm respectively) and was significantly superior to M_2 (6.92 cm and 7.92 cm) and M_3 (6.90 cm and 7.92 cm). The treatments M_2 and M_3 were found to be on par (Table 4.1.1).

Increasing doses of nutrients given did not significantly affect the internodal length of yard long bean. Internodal length at 30 DAS ranged from 1.64 cm (T_3) to 2.03 cm (T_7), whereas at 60 DAS, it ranged from 6.83 cm (T_1) to 7.17 cm (T_8). At 90 DAS, maximum internodal length was shown by T_8 (8.17) and the lowest value was recorded for T_5 (8.07 cm).

The interaction effects were also non-significant at all stages of crop growth (Table 4.1.2).

4.1.3. Leaf length

Spacing had significant influence on leaf length only at 90 DAS. The effect was non-significant during vegetative and flowering stages. At 90 DAS, significantly higher value was recorded for the wider spacing M_3 (10.95 cm) was superior to the other two treatments. The treatments M_2 and M_3 were similar (Table 4.1.3).

Fertilizer treatments had no significant effect on leaf length at 30 DAS in yard long bean. The observations for leaf length fell in the range of 9.39 cm (T_4) to 10.03

Table. 4.1.1. Number of branches and internodal length of yard long bean as influenced by spacing and fertilizers

Treatment	Number of branches			Internodal length (cm)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Spacing						
M_1	2.50^b	4.75^a	6.44^a	1.93^a	7.21^a	8.19^a
M_2	2.96^a	4.73^a	6.33^a	1.78^a	6.92^b	7.92^b
M_3	2.82^a	4.87^a	6.64^a	1.88^a	6.90^b	7.92^b
Mean	2.76	4.78	6.47	1.86	7.01	8.01
Fertilizer						
T_1	2.58^a	4.64^a	6.27^a	1.83^a	6.83^a	7.81^a
T_2	2.78^a	4.93^a	6.44^a	1.93^a	7.06^a	8.13^a
T_3	3.11^a	5.00^a	6.67^a	1.64^a	6.93^a	7.92^a
T_4	2.91^a	4.84^a	6.49^a	1.91^a	7.10^a	8.10^a
T_5	2.87^a	4.71^a	6.51^a	1.90^a	7.07^a	8.07^a
T_6	2.89^a	4.91^a	6.56^a	1.75^a	6.88^a	7.87^a
T_7	2.56^a	4.60^a	6.38^a	2.03^a	7.08^a	8.08^a
T_8	2.44^a	4.67^a	6.44^a	1.96^a	7.17^a	8.17^a
T_9	2.73^a	4.73^a	6.49^a	1.82^a	6.98^a	7.98^a
Mean	2.76	4.78	6.47	1.86	7.01	8.01

Treatments having alphabets in common belong to one homogenous group

Table. 4.1.2. Number of branches and internodal length of yard long bean as influenced by interaction of spacing and fertilizers

Treatment	Number of branches			Internodal length (cm)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
M_1T_1	2.53^{a}	4.47^{a}	6.07^{a}	1.75^{a}	6.89^{a}	7.81^{a}
M_1T_2	2.47^{a}	4.73^{a}	6.40^{a}	2.22^{a}	7.27^{a}	8.27^{a}
M_1T_3	2.80^{a}	5.00^{a}	6.93^{a}	1.83^{a}	7.22^{a}	8.22^{a}
M_1T_4	2.33^{a}	4.93^{a}	6.73^{a}	1.84^{a}	7.35^{a}	8.35^{a}
M_1T_5	2.53^{a}	5.00^{a}	6.60^{a}	1.81^{a}	7.29^{a}	8.29^{a}
M_1T_6	2.87^{a}	5.20^{a}	6.53^{a}	1.80^{a}	7.13^{a}	8.10^{a}
M_1T_7	2.20^{a}	4.27^{a}	6.13^{a}	2.17^{a}	7.35^{a}	8.35^{a}
M_1T_8	2.20^{a}	4.53^{a}	6.13^{a}	2.09^{a}	7.31^{a}	8.31^{a}
M_1T_9	2.60^{a}	4.60^{a}	6.47^{a}	1.85^{a}	7.04^{a}	8.04^{a}
M_2T_1	2.87^{a}	4.87^{a}	6.33^{a}	1.73^{a}	6.80^{a}	7.80^{a}
M_2T_2	3.00^{a}	4.87^{a}	6.40^{a}	1.57^{a}	6.87^{a}	7.87^{a}
M_2T_3	3.07^{a}	4.73^{a}	6.47^{a}	1.42^{a}	6.83^{a}	7.83^{a}
M_2T_4	3.73^{a}	4.87^{a}	6.33^{a}	2.01^{a}	7.02^{a}	8.02^{a}
M_2T_5	2.87^{a}	4.47^{a}	6.33^{a}	2.08^{a}	7.25^{a}	8.25^{a}
M_2T_6	3.20^{a}	4.87^{a}	6.40^{a}	1.68^{a}	6.86^{a}	7.86^{a}
M_2T_7	3.13^{a}	4.80^{a}	6.20^{a}	1.89^{a}	6.77^{a}	7.77^{a}
M_2T_8	2.20^{a}	4.27^{a}	6.27^{a}	1.79^{a}	6.99^{a}	7.99^{a}
M_2T_9	2.60^{a}	4.80^{a}	6.27^{a}	1.86^{a}	6.93^{a}	7.93^{a}
M_3T_1	2.33^{a}	4.60^{a}	6.40^{a}	2.01^{a}	6.81^{a}	7.81^{a}
M_3T_2	2.87^{a}	5.20^{a}	6.73^{a}	2.00^{a}	7.03^{a}	8.25^{a}
M_3T_3	3.27^{a}	5.20^{a}	6.93^{a}	1.65^{a}	6.74^{a}	7.71^{a}
M_3T_4	2.87^{a}	4.67^{a}	6.47^{a}	1.88^{a}	6.95^{a}	7.95^{a}
M_3T_5	2.60^{a}	4.80^{a}	6.73^{a}	1.82^{a}	6.67^{a}	7.67^{a}
M_3T_6	3.20^{a}	5.20^{a}	6.73^{a}	1.78^{a}	6.64^{a}	7.64^{a}
M_3T_7	2.33^{a}	4.73^{a}	6.60^{a}	2.04^{a}	7.12^{a}	8.12^{a}
M_3T_8	2.93^{a}	4.67^{a}	6.53^{a}	1.99^{a}	7.20^{a}	8.20^{a}
M_3T_9	3.00^{a}	4.80^{a}	6.60^{a}	1.77^{a}	6.96^{a}	7.96^{a}
Mean	2.76	4.78	6.47	1.86	7.01	8.01

Treatments having alphabets in common belong to one homogenous group

cm (T_3). However, their effects were significant at 60 and 90 DAS. At 60 DAS, the treatment T_3 (11.14 cm) recorded the highest value for leaf length, but was on par with T_2 (10.89 cm), T_6 (10.84 cm), T_1 (10.81 cm), T_5 (10.77 cm) and T_8 (10.70 cm). At 90 DAS, the treatment T_3 recorded the maximum value (10.97 cm), which was on par with T_5 (10.88 cm), T_2 (10.88 cm), T_6 (10.84 cm), T_1 (10.71 cm), T_4 (10.63 cm) and T_8 (10.58 cm). The lowest values were recorded for T_6 (10.43 cm) and T_1 (10.28 cm).

The interaction effects were found to be insignificant at 30 and 60 DAS, but were significant at 90 DAS (Table 4.1.4). The treatment combination M_1T_3 (11.52 cm) recorded the highest value. It was on par with M_1T_4 (11.39 cm), M_1T_5 (11.00 cm), M_2T_5 (10.99 cm), M_2T_4 (10.90 cm), M_2T_7 (10.89 cm), M_3T_9 (10.88 cm), M_3T_7 (10.85 cm) and M_3T_3 (10.82 cm). The treatment M_3T_1 registered the lowest value (9.75 cm) .

4.1.4. Leaf width

Different spacing treatments did not influence leaf width at 30 DAS (Table 4.1.3). The mean values ranged from 5.34 cm (M_2) to 5.54 cm (M_3). At 60 DAS, also the same trend was noticed. However, at 90 DAS, spacing was found to exert significant influence on leaf width. The treatment M_3 recorded the highest value for the parameter (6.86 cm), which was superior to both M_2 (6.44 cm) and M_1 (6.42 cm).

During all the three stages of crop growth, main effects of fertilizers on leaf width were found to be significant (Table 4.1.3). At 30 DAS, the treatment T_2 recorded the maximum leaf width of (5.76 cm), which was on par with T_3 (5.75 cm),

T_5 (5.57 cm), and T_6 (5.44 cm). The treatments T_8 (5.38 cm), T_4 (5.37 cm), T_9 (5.34 cm) T_7 (5.28 cm) and T_1 (5.23 cm) were found to be at par and were inferior to all other treatments. At 60 DAS, T_3 recorded the highest value (6.86 cm). It was on par with T_5 (6.72 cm), T_2 (6.68 cm) and T_4 (6.55 cm). The least value was recorded for T_6 (6.31 cm). At 90 DAS, also a similar trend was noticed. The highest value was exhibited by T_3 (6.96 cm) and the least value by T_6 (6.40 cm). The treatments T_2, T_3, T_4, and T_5 were found to be better than all other treatments at all stages of crop growth.

The interaction effects of fertilizer and spacing on leaf width were also found to be significant at all stages of crop growth (Table 4.1.4). The treatment combination M_1T_2 (6.53 cm) was found to be superior to all other treatments. The lowest value was recorded by M_2T_7 (5.00 cm). At 60 DAS also, M_1T_2 (7.33 cm) and M_2T_7 (6.15 cm) recorded the maximum and minimum values. At 90 DAS, the treatments M_1T_3 (7.76 cm) and M_1T_2 (7.63 cm) were found to be at par but were superior to all other treatments. The treatment combination M_3T_2 (6.13 cm) recorded the minimum value.

4.1.5. Leaf area index

Spacing exerted a significant influence on leaf area index (Table 4.1.5). At 30 DAS, M_1 recorded the maximum value for leaf area index (0.69) followed by M_2 (0.33) and M_3 (0.22). At 60 and 90 DAS also, the lowest spacing M_1 recorded the highest value for leaf area index. The mean values were 2.27 (M_1), 1.12 (M_2) and 0.74 (M_3) and 3.15 (M_1), 1.45 (M_2) and 0.96 (M_3) at 60 and 90 DAS respectively.

Table. 4.1.3. Leaf length and leaf width of yard long bean as influenced by spacing and fertilizers

Treatment	Leaf length (cm)			Leaf width (cm)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Spacing						
M_1	9.69[a]	10.59[a]	10.54[b]	5.49[a]	6.73[a]	6.86[a]
M_2	9.67[a]	10.69[a]	10.58[b]	5.34[a]	6.46[a]	6.42[b]
M_3	9.71[a]	10.92[a]	10.95[a]	5.54[a]	6.46[a]	6.44[b]
Mean	9.69	10.73	10.69	5.46	6.55	6.57
Fertilizer						
T_1	9.71[a]	10.81[abc]	10.71[ab]	5.22[b]	6.39[bc]	6.47[b]
T_2	9.85[a]	10.89[ab]	10.88[a]	5.76[a]	6.69[ab]	6.74[ab]
T_3	10.03[a]	11.14[a]	10.97[a]	5.75[a]	6.86[a]	6.96[a]
T_4	9.39[a]	10.63[bc]	10.63[abc]	5.37[b]	6.55[abc]	6.60[ab]
T_5	9.78[a]	10.77[abc]	10.88[a]	5.57[ab]	6.72[ab]	6.67[ab]
T_6	9.77[a]	10.84[ab]	10.84[a]	5.44[ab]	6.31[c]	6.40[b]
T_7	9.56[a]	10.37[c]	10.28[c]	5.28[b]	6.47[bc]	6.48[b]
T_8	9.44[a]	10.70[abc]	10.58[abc]	5.38[b]	6.48[bc]	6.43[b]
T_9	9.66[a]	10.46[bc]	10.43[bc]	5.34[b]	6.49[bc]	6.42[b]
Mean	9.69	10.73	10.69	5.46	6.55	6.57

Treatments having alphabets in common belong to one homogenous group

Table. 4.1.4. Leaf length and leaf width of yard long bean as influenced by interaction of spacing and fertilizers

Treatment	Leaf length cm)			Leaf width (cm)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
M_1T_1	9.78[a]	10.54[a]	10.61[cde]	5.10[de]	6.04[g]	6.17[cd]
M_1T_2	10.00[a]	11.08[a]	11.16[abc]	6.53[a]	7.33[a]	7.63[a]
M_1T_3	10.25[a]	11.38[a]	11.52[a]	5.83[bc]	7.20[ab]	7.75[a]
M_1T_4	9.64[a]	10.72[a]	11.38[ab]	5.28[bcde]	6.68[bcdefg]	6.92[b]
M_1T_5	9.72[a]	10.82[a]	11.00[abcd]	5.52[bcde]	6.82[abcde]	6.91[bc]
M_1T_6	9.79[a]	11.22[a]	10.62[cde]	5.32[bcde]	6.40[cdefg]	6.48[bcd]
M_1T_7	9.15[a]	10.98[a]	10.90[abcd]	5.24[cde]	6.93[abcd]	6.80[bcd]
M_1T_8	9.53[a]	10.68[a]	10.64[cde]	5.45[bcde]	6.70[abcdefg]	6.64[bcd]
M_1T_9	9.55[a]	10.85[a]	10.71[bcde]	5.17[de]	6.49[cdefg]	6.42[bcd]
M_2T_1	9.55[a]	10.84[a]	10.48[cde]	5.09[de]	6.33[cdefg]	6.37[bcd]
M_2T_2	9.48[a]	11.05[a]	10.32[def]	5.53[bcde]	6.60[bcdefg]	6.46[bcd]
M_2T_3	10.17[a]	11.08[a]	10.29[def]	5.86[bc]	6.98[abc]	6.71[bcd]
M_2T_4	9.48[a]	10.44[a]	10.90[abcd]	5.15[de]	6.26[defg]	6.22[bcd]
M_2T_5	10.05[a]	10.41[a]	10.99[abcd]	5.28[bcde]	6.57[bcdefg]	6.44[bcd]
M_2T_6	9.96[a]	10.07[a]	10.12[ef]	5.37[bcde]	6.15[fg]	6.39[bcd]
M_2T_7	9.31[a]	10.55[a]	10.88[abcd]	5.00[e]	6.33[cdefg]	6.44[bcd]
M_2T_8	8.96[a]	10.96[a]	10.71[bcde]	5.41[bcde]	6.49[cdefg]	6.31[bcd]
M_2T_9	9.83[a]	10.83[a]	10.54[cde]	5.33[bcde]	6.47[cdefg]	6.44[bcd]
M_3T_1	9.23[a]	9.74[a]	9.75[f]	5.48[bcde]	6.81[abcdef]	6.86[bcd]
M_3T_2	9.83[a]	10.39[a]	10.42[def]	5.22[cde]	6.17[efg]	6.13[d]
M_3T_3	9.92[a]	11.00[a]	10.82[abcde]	5.57[bcde]	6.41[cdefg]	6.41[bcd]
M_3T_4	9.86[a]	10.95[a]	10.61[cde]	5.68[bcd]	6.71[abcdefg]	6.66[bcd]
M_3T_5	9.73[a]	10.45[a]	10.53[cde]	5.91[b]	6.75[abcdef]	6.65[bcd]
M_3T_6	9.81[a]	10.58[a]	10.56[cde]	5.63[bcde]	6.37[cdefg]	6.34[bcd]
M_3T_7	9.59[a]	10.89[a]	10.85[abcd]	5.58[bcde]	6.17[efg]	6.21[bcd]
M_3T_8	9.62[a]	10.45[a]	10.38[def]	5.28[bcde]	6.25[defg]	6.35[bcd]
M_3T_9	9.78[a]	10.93[a]	10.88[abcd]	5.51[bcde]	6.51[cdefg]	6.40[bcd]
Mean	9.69	10.73	10.69	5.46	6.55	6.57

Treatments having alphabets in common belong to one homogenous group

Increasing doses of nutrients significantly improved leaf area index. The treatment T_3 (0.72) was superior to all other treatments. The least value was recorded for T_7 (0.28) at 30 DAS. At 60 DAS also, T_3 recorded the highest value (1.69) and the lowest value was obtained for T_1 (1.07). At 90 DAS also, the same trend was noticed. The highest and lowest values were 2.20 and 1.56 for T_3 and T_1 respectively (Table 4.1.5).

There was significant influence for spacing x nutrient interaction on leaf area index of yard long bean at all stages of crop growth (Table 4.1.6). At 30 DAS, the treatment combinations M_1T_2 and M_1T_3 (1.23 and 1.22) were found to be superior to all other treatments. The least value was recorded for M_3T_7 (0.17). At 60 DAS, the maximum value for leaf area index was recorded for the treatment combination M_1T_3 (2.81), which were on par with M_1T_2 (2.61) and M_1T_6 (2.37). The lowest value was recorded for M_3T_1 (0.66). At 90 DAS also, almost similar trend was noticed. The treatment M_1T_3 (4.13) was found to be superior to all other treatments. The lowest value was recorded for M_3T_2 (0.91). For the lowest spacing M_1, the fertilizer treatment T_3 was found to give better leaf area index. Similarly, for M_2, the treatment T_5 was found to be ideal and for M_3, T_4 was better.

4.1.6. Root: shoot ratio

There was no significant influence for spacing on root: shoot ratio at 30 and 90 DAS (Table 4.1.5). The mean values ranged from 0.15 (M_3) to 0.17 (M_2) and 0.06 (M_2) to 0.07 (M_1) at 30 and 90 DAS respectively. At 60 DAS, the main effects of spacing were found to be significant. The maximum value was registered for M_3 (0.12), but was on par with M_2 (0.11). The least value was recorded for M_1 (0.08).

Fertilizer treatments did not exert any significant influence on root: shoot ratio of yard long bean (Table 4.1.5). At 30 DAS, the mean values for fertilizer treatments ranged from 0.12 (T_2) to 0.20 (T_4). At 60 DAS, the values ranged from 0.09 (T_2) to 0.12 (T_6). At maturity stage, the highest value for root: shoot ratio was recorded for T_4 (0.08) and lowest value for T_9 (0.06).

The interaction effects were insignificant at 30 and 90 DAS, while it was significant at 60 DAS (Table 4.1.6). At 60 DAS, the maximum value was recorded for M_3T_6 and M_3T_1 (0.17). These were on par with M_3T_4 (0.17), M_2T_3, M_2T_5, M_2T_6 (0.14), M_3T_5 (0.12) and M_1T_1 (0.11). The least value was recorded for M_2T_4 (0.04).

4.2. EARLINESS

4.2.1. Days to first flowering

Main effects of spacing significantly affected the days to first flowering in yard long bean (Table 4.2.1). Minimum number of days was taken by M_1 (41.92) followed by M_2 (42.58) and M_3 (42.66).

There was significant influence of nutrient levels on days to first flowering in yard long bean (Table 4.2.1). Earliest flowering was noticed in T_7 (39.53), which was on par with T_9 (39.67) followed by T_8 (40.20) and T_4 (40.22). Maximum number of days was taken by T_3 (48.04).

The interaction effect was also significant for days to first flowering (Table 4.2.1). The treatment combinations M_1T_7 and M_1T_8 showed early flowering (38.87). Maximum number of days was taken by M_3T_3 (48.67) and M_2T_3 (48.07).

Table. 4.1.5. Leaf area index and root:shoot ratio of yard long bean as influenced by spacing and fertilizers

Treatment	Leaf area index			Root:shoot ratio		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Spacing						
M_1	0.69^{a}	2.27^{a}	3.15^{a}	0.16^{a}	0.08^{b}	0.07^{a}
M_2	0.32^{b}	1.13^{b}	1.45^{b}	0.17^{a}	0.11^{a}	0.06^{a}
M_3	0.22^{c}	0.74^{c}	0.96^{c}	0.15^{a}	0.12^{a}	0.07^{a}
Mean	0.41	1.38	1.85	0.16	0.100	0.06
Fertilizer						
T_1	0.35^{cd}	1.07^{d}	1.56^{e}	0.13^{a}	0.11^{a}	0.06^{a}
T_2	0.65^{b}	1.50^{b}	2.01^{b}	0.12^{a}	0.09^{a}	0.07^{a}
T_3	0.72^{a}	1.69^{a}	2.20^{a}	0.17^{a}	0.10^{a}	0.06^{a}
T_4	0.33^{cde}	1.38^{bc}	1.91^{bc}	0.20^{a}	0.10^{a}	0.08^{a}
T_5	0.38^{c}	1.41^{bc}	1.91^{bc}	0.20^{a}	0.12^{a}	0.06^{a}
T_6	0.36^{cd}	1.37^{bc}	1.83^{cd}	0.18^{a}	0.12^{a}	0.06^{a}
T_7	0.28^{f}	1.36^{bc}	1.81^{cd}	0.15^{a}	0.09^{a}	0.06^{a}
T_8	0.30^{ef}	1.31^{c}	1.72^{d}	0.15^{a}	0.09^{a}	0.07^{a}
T_9	0.32^{def}	1.31^{c}	1.73^{d}	0.17^{a}	0.11^{a}	0.06^{a}
Mean	0.41	1.38	1.85	0.16	0.100	0.06

Treatments having alphabets in common belong to one homogenous group

Table. 4.1.6. Leaf area index and root:shoot ratio of yard long bean as influenced by interaction of spacing and fertilizers

Treatment	Leaf area index			Root: shoot ratio		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
M_1T_1	0.58^{b}	1.56^{e}	2.43^{f}	0.08^{a}	0.14^{abcdef}	0.05^{a}
M_1T_2	1.23^{a}	2.07^{ab}	3.64^{b}	0.12^{a}	0.08^{cdefg}	0.06^{a}
M_1T_3	1.22^{a}	2.81^{a}	4.13^{a}	0.23^{a}	0.05^{fg}	0.09^{a}
M_1T_4	0.48^{c}	2.23^{cd}	3.27^{c}	0.19^{a}	0.08^{cdefg}	0.10^{a}
M_1T_5	0.62^{b}	2.28^{cd}	3.16^{c}	0.25^{a}	0.09^{cdefg}	0.07^{a}
M_1T_6	0.62^{b}	2.37^{bc}	3.11^{c}	0.19^{a}	0.06^{fg}	0.06^{a}
M_1T_7	0.48^{c}	2.31^{cd}	3.04^{cd}	0.14^{a}	0.07^{defg}	0.07^{a}
M_1T_8	0.47^{c}	2.15^{cd}	2.82^{de}	0.07^{a}	0.07^{efg}	0.06^{a}
M_1T_9	0.49^{c}	2.09^{d}	2.75^{e}	0.22^{a}	0.07^{defg}	0.06^{a}
M_2T_1	0.31^{de}	0.99^{ghijk}	1.32^{g}	0.15^{a}	0.06^{fg}	0.05^{a}
M_2T_2	0.43^{c}	1.16^{g}	1.49^{g}	0.14^{a}	0.08^{cdefg}	0.07^{a}
M_2T_3	0.60^{b}	1.42^{ef}	1.52^{g}	0.14^{a}	0.14^{abc}	0.05^{a}
M_2T_4	0.31^{de}	1.09^{gh}	1.45^{g}	0.25^{a}	0.04^{g}	0.05^{a}
M_2T_5	0.30^{de}	1.20^{fg}	1.56^{g}	0.20^{a}	0.14^{abc}	0.05^{a}
M_2T_6	0.25^{efgh}	1.01^{ghij}	1.42^{g}	0.20^{a}	0.14^{abc}	0.05^{a}
M_2T_7	0.21^{fgh}	1.08^{ghi}	1.45^{g}	0.15^{a}	0.11^{abcdef}	0.06^{a}
M_2T_8	0.25^{efg}	1.10^{gh}	1.40^{g}	0.20^{a}	0.16^{ab}	0.07^{a}
M_2T_9	0.26^{ef}	1.08^{ghi}	1.43^{g}	0.15^{a}	0.13^{abcde}	0.06^{a}
M_3T_1	0.17^{gh}	0.66^{l}	0.93^{h}	0.15^{a}	0.17^{a}	0.07^{a}
M_3T_2	0.29^{de}	0.74^{kl}	0.91^{h}	0.11^{a}	0.10^{bcdefg}	0.09^{a}
M_3T_3	0.35^{d}	0.83^{hijkl}	0.96^{h}	0.15^{a}	0.09^{cdefg}	0.05^{a}
M_3T_4	0.21^{fgh}	0.81^{ijkl}	1.01^{h}	0.18^{a}	0.17^{a}	0.08^{a}
M_3T_5	0.20^{fgh}	0.74^{kl}	1.00^{h}	0.15^{a}	0.12^{abcde}	0.06^{a}
M_3T_6	0.21^{fgh}	0.73^{kl}	0.97^{h}	0.16^{a}	0.17^{a}	0.06^{a}
M_3T_7	0.17^{h}	0.69^{l}	0.95^{h}	0.16^{a}	0.08^{cdefg}	0.06^{a}
M_3T_8	0.17^{gh}	0.69^{l}	0.93^{h}	0.19^{a}	$0.05f^{g}$	0.08^{a}
M_3T_9	0.20^{fgh}	0.77^{jkl}	1.01^{h}	0.14^{a}	0.13^{abcd}	0.05^{a}
Mean	0.41	1.38	1.85	0.16	0.100	0.06

Treatments having alphabets in common belong to one homogenous group

4.2.2. Days to first harvest

Days to first harvest also exhibited a trend similar to days to first flowering (Table 4.2.1). The closest spacing M_1 had the earliest harvest (48.57 days). It was superior to other two spacings M_2 (49.28) and M_3 (49.35), which were at par.

The fertilizer treatments T_9 (46.31), T_7 (46.38), T_8 (46.93) and T_4 (47.07) were found to be at par and were early to harvest compared to T_3 (54.69) and T_2 (52.33) (Table 4.2.1).

Spacing x nutrient interaction also profoundly influenced the days to harvest (Table 4.2.2). The treatment combination M_1T_8 (45.20) took the minimum days to harvest and was on par with all other treatments except M_1T_3 (53.93) and M_3T_3 (55.13), which were late to harvest.

4.3. YIELD AND YIELD ATTRIBUTING CHARACTERS

Yield attributes of yard long bean viz. number of pods per plant, length of pods and pod weight were significantly influenced by spacing, fertilizers and their interactions (Tables 4.3.1 and 4.3.2).

4.3.1. Number of pods per plant

Maximum number of pods per plant was obtained for the spacing M_2 (34.16) and minimum in M_1 (28.05). The differences were significant.

Table. 4.2.1. Earliness of yard long bean as influenced by spacing and fertilizers

Treatment	Days to 1st flowering	Days to 1st harvest
Spacing		
M_1	41.92[c]	48.03[b]
M_2	42.38[b]	49.28[a]
M_3	42.66[a]	49.35[a]
Mean	42.32	48.89
Fertilizer		
T_1	42.40[d]	49.27[cd]
T_2	45.58[b]	52.33[b]
T_3	48.04[a]	54.69[a]
T_4	40.22[f]	47.07[e]
T_5	41.62[e]	48.44[d]
T_6	43.60[c]	50.18[c]
T_7	39.53[g]	46.38[e]
T_8	40.20[f]	46.93[e]
T_9	39.67[g]	46.31[e]
Mean	42.32	48.89

Treatments having alphabets in common belong to one homogenous group

Table. 4.2.2. Earliness of yard long bean as influenced by interaction of spacing and fertilizers

Treatment	Days to 1st flowering	Days to 1st harvest
M_1T_1	42.13^{gh}	49.13^{abcd}
M_1T_2	44.93^{de}	51.93^{abcd}
M_1T_3	47.40^{b}	53.93^{abc}
M_1T_4	39.87^{ijk}	46.33^{bcd}
M_1T_5	41.40^{h}	48.00^{abcd}
M_1T_6	44.33^{e}	50.67^{abcd}
M_1T_7	38.87^{l}	45.60^{cd}
M_1T_8	38.87^{l}	45.20^{d}
M_1T_9	39.47^{jkl}	46.33^{bcd}
M_2T_1	42.87^{fg}	49.73^{abcd}
M_2T_2	45.40^{d}	52.33^{abcd}
M_2T_3	48.07^{ab}	55.00^{ab}
M_2T_4	40.33^{ij}	47.40^{abcd}
M_2T_5	41.87^{h}	48.93^{abcd}
M_2T_6	43.53^{f}	50.27^{abcd}
M_2T_7	39.73^{ijk}	46.73^{abcd}
M_2T_8	40.27^{ij}	47.07^{abcd}
M_2T_9	39.33^{kl}	46.07^{cd}
M_3T_1	42.20^{gh}	48.93^{abcd}
M_3T_2	46.40^{c}	52.73^{abcd}
M_3T_3	48.67^{a}	55.13^{a}
M_3T_4	40.47^{i}	47.47^{abcd}
M_3T_5	41.60^{h}	48.40^{abcd}
M_3T_6	42.93^{fg}	49.60^{abcd}
M_3T_7	40.00^{ijk}	46.80^{abcd}
M_3T_8	41.47^{h}	48.53^{abcd}
M_3T_9	40.20^{ij}	46.53^{abcd}
Mean	42.32	48.89

Treatments having alphabets in common belong to one homogenous group

The fertilizer treatment T_3 recorded maximum number of pods per plant (35.04) and was superior to all other treatments. The least value was recorded for treatments T_7 (28.23) and T_8 (29.44).

The interaction effects were also significant. The best treatment combination M_2T_3 (40.27) was found to be superior to all other treatments. The lowest values were recorded for M_1T_7 (24.35), M_1T_8 (25.12) and M_1T_9 (26.25).

4.3.2. Length of pods

The main effects of spacing profoundly influenced the length of cowpea pods. Highest value was obtained for widest spacing M_3 (51.30 cm), but it was on par with M_2 (51.19 cm). Both the treatments were superior to M_1 (50.76 cm).

There was significant influence for fertilizer treatments on the pod length of yard long bean. Among the fertilizer treatments, the treatment T_6 showed maximum length of pods (51.35 cm). It was on par with T_8, T_1, T_5, T_7 and T_2.

There were significant differences for interaction effects also. The treatment combination M_3T_6 produced the longest pods (51.98 cm). The lowest value was recorded for M_1T_3 (49.81 cm).

4.3.3. Pod weight

The spacing treatment M_1 produced pods with maximum pod weight (19.19 g). It was superior to M_3 (18.81 g) and M_2 (18.62 g), but the treatments M_3 and M_2 were at par.

Table. 4.3.1. Yield attributes of yard long bean as influenced by spacing and fertilizers

Treatment	No. of pods per plant	Pod length (cm)	Pod weight (g)
Spacing			
M_1	28.05[c]	50.76[b]	19.19[a]
M_2	34.16[a]	51.19[a]	18.62[b]
M_3	31.03[b]	51.30[a]	18.81[b]
Mean	31.08	51.08	18.87
Fertilizer			
T_1	30.74[cde]	51.26[abc]	19.13[a]
T_2	32.63[b]	50.93[abc]	18.89[a]
T_3	35.04[a]	50.91[bc]	18.72[ab]
T_4	30.10[de]	50.90[bc]	19.10[a]
T_5	30.62[cde]	51.23[abc]	19.14[a]
T_6	31.85[bc]	51.35[a]	18.91[a]
T_7	28.22[f]	50.98[abc]	18.81[ab]
T_8	29.44[ef]	51.34[ab]	18.29[b]
T_9	31.08[cd]	50.86[c]	18.88[a]
Mean	31.08	51.08	18.87

Treatments having alphabets in common belong to one homogenous group

Table. 4.3.2. Yield attributes of yard bean as influenced by interaction of spacing and fertilizers

Treatment	No. of pods per plant	Pod length (cm)	Pod weight (g)
M_1T_1	27.97^{jk}	50.89^{cde}	19.21^{a}
M_1T_2	30.46^{ghi}	50.61^{e}	18.65^{a}
M_1T_3	30.54^{ghi}	49.81^{f}	19.19^{a}
M_1T_4	28.42^{hijk}	50.69^{e}	19.82^{a}
M_1T_5	28.94^{hij}	51.16^{bcde}	19.74^{a}
M_1T_6	30.41^{ghij}	50.91^{bcde}	19.48^{a}
M_1T_7	24.35^{l}	50.79^{de}	19.06^{a}
M_1T_8	25.12^{l}	51.11^{bcde}	18.40^{a}
M_1T_9	26.25^{kl}	50.89^{bcde}	19.14^{a}
M_2T_1	34.22^{bcde}	51.21^{bcde}	19.36^{a}
M_2T_2	33.91^{bcde}	51.06^{bcde}	18.29^{a}
M_2T_3	40.27^{a}	51.38^{abcde}	18.42^{a}
M_2T_4	31.85^{defg}	50.95^{bcde}	18.71^{a}
M_2T_5	32.02^{defg}	51.39^{abcde}	18.67^{a}
M_2T_6	34.57^{bc}	51.17^{bcde}	18.39^{a}
M_2T_7	32.20^{cdefg}	51.10^{bcde}	18.73^{a}
M_2T_8	33.20^{bcdef}	51.71^{ab}	18.26^{a}
M_2T_9	35.20^{b}	50.73^{de}	18.77^{a}
M_3T_1	30.02^{ghij}	51.69^{abc}	18.80^{a}
M_3T_2	33.52^{bcde}	51.11^{bcde}	19.74^{a}
M_3T_3	34.30^{bcd}	51.52^{abcd}	18.54^{a}
M_3T_4	30.02^{ghij}	51.07^{bcde}	18.77^{a}
M_3T_5	30.90^{fgh}	51.13^{bcde}	19.01^{a}
M_3T_6	30.59^{ghi}	51.98^{a}	18.87^{a}
M_3T_7	28.11^{ijk}	51.06^{bcde}	18.63^{a}
M_3T_8	29.99^{ghij}	51.19^{bcde}	18.22^{a}
M_3T_9	31.80^{efg}	50.97^{bcde}	18.72^{a}
Mean	31.08	51.08	18.87

Treatments having alphabets in common belong to one homogenous group

Fertilizer treatments also significantly influenced pod weight. Maximum value was recorded for T_5 (19.14 g), but it was on par with all other treatments except T_8 (18.29 g).

The interaction effects were not significant.

4.3.4. Yield per plant

There was significant influence for the main effects of spacing, fertilizers and their interactions on yield per plant (Tables 4.3.3 and 4.3.4). The spacing treatment M_3 recorded maximum yield per plant (435.66 g) followed by M_2 (341.63g) and M_1 (252.50 g).

The fertilizer treatment T_3 produced maximum pod yield per plant (385.96 g) followed by T_2 (364.65 g). The least value was for T_7 (311.65 g). The remaining treatments were found to be at par.

The treatment combination M_3T_2 produced maximum pod yield of 480.68 gram per plant, but was on par with M_3T_3 (480.27 g). The lowest value was recorded with M_1T_7 (219.32 g).

4.3.5. Productivity

Maximum productivity was obtained in M_1 (6.73 t ha^{-1}) followed by M_2 (4.55 t ha^{-1}) and M_3 (3.87 t ha^{-1}).

The fertilizer treatment T_3 recorded the maximum productivity (5.66 t ha^{-1}) followed by T_2 (5.37 t ha^{-1}) and T_6 (5.24 t ha^{-1}). The treatments T_2 and T_6 were at par. The lowest value was recorded for T_7 (4.55 t ha^{-1}).

Table 4.3.3. Yield of yard long bean as influenced by spacing and fertilizers

Treatment	Yield per plant (g)	Productivity (t ha^{-1})
Spacing		
M_1	252.5^{c}	6.73^{a}
M_2	341.63^{b}	4.55^{b}
M_3	435.66^{a}	3.87^{c}
Mean	343.26	5.05
Fertilizer		
T_1	338.21^{cde}	5.00^{c}
T_2	364.65^{b}	5.37^{b}
T_3	385.96^{a}	5.66^{a}
T_4	331.53^{de}	4.93^{c}
T_5	337.75^{cde}	5.02^{c}
T_6	349.19^{c}	5.24^{b}
T_7	311.65^{f}	4.55^{d}
T_8	326.01^{e}	4.73^{d}
T_9	344.45^{cd}	4.98^{c}
Mean	343.26	5.05

Treatments having alphabets in common belong to one homogenous group

Table. 4.3.4. Yield of yard long bean as influenced by interaction of spacing and fertilizers

Treatment	Yield per plant (g)	Productivity (t ha^{-1})
M_1T_1	251.71^{gh}	6.71^{b}
M_1T_2	274.34^{g}	7.31^{a}
M_1T_3	274.82^{g}	7.33^{a}
M_1T_4	255.82^{gh}	6.82^{b}
M_1T_5	260.44^{gh}	6.94^{b}
M_1T_6	273.71^{g}	7.30^{a}
M_1T_7	219.32^{i}	5.85^{d}
M_1T_8	226.12^{i}	6.03^{cd}
M_1T_9	236.21^{hi}	6.30^{c}
M_2T_1	342.56^{ef}	4.57^{fg}
M_2T_2	338.93^{ef}	4.52^{fg}
M_2T_3	402.79^{cd}	5.37^{e}
M_2T_4	318.53^{f}	4.25^{gh}
M_2T_5	320.22^{f}	4.27^{gh}
M_2T_6	345.66^{ef}	4.61^{fg}
M_2T_7	322.03^{f}	4.29^{gh}
M_2T_8	332.04^{ef}	4.43^{fg}
M_2T_9	351.96^{e}	4.69^{f}
M_3T_1	420.36^{bcd}	3.74^{ij}
M_3T_2	480.68^{a}	4.27^{gh}
M_3T_3	480.27^{a}	4.27^{gh}
M_3T_4	420.24^{bcd}	3.73^{ij}
M_3T_5	432.58^{b}	3.84^{ij}
M_3T_6	428.19^{bc}	3.81^{ij}
M_3T_7	393.60^{d}	3.50^{j}
M_3T_8	419.86^{bcd}	3.73^{ij}
M_3T_9	445.18^{b}	3.96^{hi}
Mean	343.26	5.05

Treatments having alphabets in common belong to one homogenous group

The combination M_1T_3 produced maximum productivity (7.33 t ha^{-1}), but was on par with M_1T_2 (7.31 t ha^{-1}) and M_1T_6 (7.30 t ha^{-1}). The lowest value was recorded for M_3T_7 (3.50 t ha^{-1}). For the spacing treatments M_1 and M_2 the fertilizer treatment T_3 was found to be the best. For M_3, T_2 and T_3 were found to be equally good.

4.4. QUALITY OF PODS

Quality of pods was measured in terms of their moisture, carbohydrate, crude protein, minerals and crude fibre contents. The results are shown in tables 4.4.1 and 4.4.2

4.4.1. Moisture content of pods

Spacing did not significantly influence the moisture content of pods. The highest moisture percentage was observed in M_1 (94.34%).

Fertilizer treatments profoundly influenced the moisture content of pods. The highest moisture content was seen for pods from organically treated pods. But the rate of cowdung application seemed to be ineffective in altering the moisture content of pods as the moisture percentage for T_7 (95.76 %), T_8 (95.52 %) and T_9 (95.55 %) did not differ significantly from one another. The least value was reported for T_3 (92.52 %).

The interaction effects were non-significant.

4.4.2. Crude protein

Crude protein content of pods was unaltered by different spacing and fertilizer treatments or their interactions. Nevertheless, the highest value was recorded for the spacing M_1 (30.85%), fertilizer treatment T_6 (31.50%) and their combination M_1T_6 (32.67%) respectively.

4.4.3. Carbohydrate

Varying levels of spacing did not alter the carbohydrate content of pods significantly.

Fertilizers had significant influence on the carbohydrate content of pods. Highest carbohydrate content was noticed for T_9 (4.22%), which was on par with T_6 (4.17%).

Fertilizer- spacing interactions also significantly influenced the carbohydrate content of pods. The best combination noticed was M_1T_6 (4.29%), which was similar to M_3T_9, M_2T_9, M_3T_6, M_1T_9, M_1T_3, M_2T_3, M_2T_6 and M_3T_8.

4.4.4. Minerals

The contents of minerals viz. Ca, P, K, and Fe were also significantly affected by different spacing and fertilizer treatments and their interactions.

In the case of P, the spacing effect was significant. Highest P content of pods was seen for the treatment M_1 (4.84) and M_3 (4.65%). For other minerals Ca, K, and Fe, spacing effect was insignificant.

The effect of fertilizers was significant for all the minerals. The Ca content of pods was found to highest in the fertilizer treatment T_9 (0.57%) and T_6 (0.50%) and the least value was recorded for T_4 (0.41%). For P, it was noticed that T_8 (5.08%), which was on par with T_7 (5.01%) and T_2 (4.78%). In the case of K, the highest contents were recorded for T_6 (2.32%), T_9 (2.22%), T_7 (2.08%) and T_5 (2.04%). For iron, T_9 (0.32%) was superior to all other treatments.

Spacing x fertilizer interaction was also significant in all the cases. The best treatment combinations for Ca content of pods were M_2T_9 and M_1T_2 (0.61%). For P, the best treatment combination was M_1T_7 (5.41%). In the case of K, it was noticed that the combinations M_2T_6 (2.95%) and M_2T_5 92.63%) recorded the maximum value. The, treatment M_3T_9 (0.47%) was superior to all other treatments for Fe content of the pods.

4.4.5. Crude fibre

There was significant influence for spacing, fertilizers and their interaction on crude fibre content of cowpea pods. A low fibre content is preferred in cowpea. The treatment M_1 recorded the lowest crude fibre content (3.02%). Highest fibre was observed for M_3 (3.51%).

Organic manures were found to be superior to fertilizers as far as crude fibre content of pods was considered as they registered the lowest fibre contents of 2.26%, 2.32%, and 2.36% respectively compared to a higher value for T_3 (4.50%).

The interaction effects were also significant. The best treatment combinations obtained were M_1T_8 (1.99%), M_1T_9 (1.99%) and M_1T_7 (2.00%), which were also similar to M_2T_9, M_2T_6, M_2T_9, M_3T_8, and M_3T_7.

Table. 4.4.1. Quality of yard long bean pods as influenced by spacing and fertilizers (percentage)

Treatment	Moisture	Crude protein	Carbohydrate	Minerals				Crude fibre
				Ca	P	K	Fe	
Spacing								
M_1	94.40^{a}	30.85^{a}	3.87^{a}	0.48^{a}	0.48^{a}	2.17^{a}	0.16^{a}	3.02^{b}
M_2	94.16^{a}	29.30^{a}	3.85^{a}	0.48^{a}	0.45^{b}	2.11^{a}	0.22^{a}	3.13^{b}
M_3	94.19^{a}	28.39^{a}	3.82^{a}	0.47^{a}	0.46^{ab}	1.98^{a}	0.21^{a}	3.51^{a}
Mean	94.25	29.51	3.84	0.476	0.465	2.09	0.20	3.22
Fertilizer								
T_1	93.88^{b}	28.00^{a}	3.43^{d}	0.41^{d}	0.42^{d}	1.84^{d}	0.15^{c}	3.02^{c}
T_2	93.52^{b}	28.39^{a}	3.73^{c}	0.54^{ab}	0.50^{ab}	2.28^{ab}	0.21^{bc}	3.78^{b}
T_3	92.52^{c}	29.94^{a}	4.04^{b}	0.47^{bcd}	0.51^{a}	2.32^{a}	0.18^{bc}	4.50^{a}
T_4	93.85^{b}	29.94^{a}	3.49^{d}	0.43^{cd}	0.44^{cd}	2.04^{bcd}	0.17^{bc}	3.02^{c}
T_5	94.02^{b}	29.17^{a}	3.77^{c}	0.41^{d}	0.43^{d}	1.94^{cd}	0.18^{bc}	3.93^{b}
T_6	93.62^{b}	31.50^{a}	4.19^{a}	0.50^{abc}	0.47^{bc}	1.94^{cd}	0.23^{b}	3.77^{b}
T_7	95.76^{a}	28.78^{a}	3.79^{c}	0.49^{bcd}	0.48^{abc}	2.08^{abcd}	0.18^{bc}	2.32^{d}
T_8	95.52^{a}	29.56^{a}	3.94^{b}	0.46^{cd}	0.47^{bc}	2.06^{bcd}	0.15^{c}	2.26^{d}
T_9	95.55^{a}	30.33^{a}	4.22^{a}	0.57^{a}	0.45^{cd}	2.22^{abc}	0.32^{a}	2.36^{d}
Mean	94.25	29.51	3.84	0.476	0.465	2.09	0.20	3.22

Treatments having alphabets in common belong to one homogenous group

Table. 4.4.2. Quality of yard long bean pods as influenced by interaction of spacing and fertilizers (percentage)

Treatment	Moisture	Crude protein	Carbohydrate	Minerals				Crude fibre
				Ca	P	K	Fe	
M_1T_1	93.94^{a}	25.67^{a}	3.47^{ghij}	0.40^{cde}	0.44^{efghi}	2.18^{bcdefg}	0.10^{f}	2.93^{cd}
M_1T_2	94.05^{a}	31.50^{a}	3.74^{efg}	0.61a	0.53^{ab}	1.85^{fghij}	0.17^{cdef}	3.13^{c}
M_1T_3	92.98^{a}	33.83^{a}	4.12^{abc}	0.39^{de}	0.45^{defgh}	2.12^{cdefghi}	0.15^{cdef}	4.20^{b}
M_1T_4	94.13^{a}	31.50^{a}	3.64^{efghi}	0.41^{cde}	0.43^{ghi}	2.45^{bcd}	0.20^{bcdef}	2.97^{cd}
M_1T_5	94.26^{a}	31.50^{a}	3.91^{bcde}	0.45^{bcde}	0.46^{cdefgh}	2.13^{cdefgh}	0.15^{cdef}	3.97^{b}
M_1T_6	93.76^{a}	32.67^{a}	4.29^{a}	0.50^{abcd}	0.49^{abcdefg}	1.93^{efghij}	0.14^{def}	3.99^{b}
M_1T_7	95.38^{a}	29.17^{a}	3.67^{efgh}	0.51^{abcd}	0.54^{a}	2.03^{cdefghi}	0.13^{ef}	2.00^{f}
M_1T_8	95.62^{a}	30.33^{a}	3.85^{cdef}	0.54^{abc}	0.60^{abcd}	2.38^{bcde}	0.14^{cdef}	1.99^{f}
M_1T_9	95.46^{a}	31.50^{a}	4.15^{ab}	0.51^{abcd}	0.49^{abcde}	2.45^{bcd}	0.24^{bcde}	1.99^{f}
M_2T_1	94.50^{a}	28.00^{a}	3.48^{ghij}	0.32^{e}	0.43^{ghi}	1.52^{j}	0.24^{bcde}	2.98^{cd}
M_2T_2	92.75^{a}	26.83^{a}	3.87^{cde}	0.48^{abcd}	0.43^{ghi}	1.88^{fghij}	0.15^{cdef}	3.98^{b}
M_2T_3	92.11^{a}	30.33^{a}	4.11^{abc}	0.54^{abc}	0.43^{fghi}	1.98^{defghij}	0.14^{cdef}	5.12^{a}
M_2T_4	93.79^{a}	29.17^{a}	3.37^{ij}	0.50^{abcd}	0.54^{ab}	2.03^{cdefghi}	0.23^{bcde}	2.96^{cd}
M_2T_5	93.90^{a}	29.17^{a}	3.65^{efgh}	0.39^{de}	0.42^{hij}	2.63^{ab}	0.27^{bc}	3.71^{b}
M_2T_6	93.68^{a}	31.50^{a}	4.06^{abcd}	0.50^{abcd}	0.43^{fghi}	2.95^{a}	0.25^{bcde}	2.32^{ef}
M_2T_7	95.88^{a}	28.00^{a}	3.91^{bcde}	0.48^{abcd}	0.44^{efghi}	1.72^{ghij}	0.23^{bcde}	2.59^{de}
M_2T_8	95.19^{a}	30.33^{a}	3.91^{bcde}	0.46^{abcde}	0.53^{ab}	2.13^{cdefgh}	0.24^{bcde}	2.45^{ef}
M_2T_9	95.67^{a}	30.33^{a}	4.25^{a}	0.61^{a}	0.37^{j}	2.17^{bcdefg}	0.25^{bcde}	2.08^{ef}
M_3T_1	93.22^{a}	30.33^{a}	3.35^{j}	0.53^{abcd}	0.39^{ij}	1.82^{fghij}	0.09^{f}	3.16^{c}
M_3T_2	93.76^{a}	26.83^{a}	3.58^{ghij}	0.55^{abc}	0.48^{bcdefgh}	2.25^{bcdef}	0.31^{b}	4.22^{b}
M_3T_3	92.46^{a}	25.67^{a}	3.88^{bcde}	0.48^{abcd}	0.53^{ab}	1.73^{ghij}	0.26^{bcd}	4.19^{b}
M_3T_4	93.62^{a}	29.17^{a}	3.46^{hij}	0.39^{de}	0.37^{j}	1.63^{ij}	0.08^{f}	3.12^{c}
M_3T_5	93.89^{a}	26.83^{a}	3.76^{ef}	0.38^{de}	0.43^{fghi}	2.08^{cdefghi}	0.13^{def}	4.12^{b}
M_3T_6	93.42^{a}	30.33^{a}	4.20^{a}	0.51^{abcd}	0.49^{abcdef}	2.07^{cdefghi}	0.31^{b}	5.00^{a}
M_3T_7	96.02^{a}	29.17^{a}	3.80^{def}	0.47^{abcde}	0.52^{ab}	2.50^{bc}	0.17^{cdef}	2.37^{ef}
M_3T_8	95.75^{a}	28.00^{a}	4.04^{abcd}	0.38^{de}	0.48^{abcdefg}	1.65^{hij}	0.08^{f}	2.36^{ef}
M_3T_9	95.53^{a}	29.17^{a}	4.27^{a}	0.59^{a}	0.48^{abcdefg}	2.05^{cdefghi}	0.47^{a}	3.01^{cd}
Mean	94.25	29.51	3.84	0.476	0.465	2.09	0.20	3.22

Treatments having alphabets in common belong to one homogenous group

4.5. SOIL NUTRIENT STATUS AFTER THE EXPERIMENT

The nutrient status of the soil after the experiment is shown in tables 4.5.1 and 4.5.2.

4.5.1. pH of the soil

There was no significant effect for spacing on the pH of the soil after the experiment.

Various fertilizer treatments significantly changed the pH of the soil. The highest pH was registered by the treatment T_8 (5.64), but was on par with T_5, T_2, T_7, and T_9, whereas T_3 showed the lowest value (5.28).

The treatment combinations also significantly altered the pH of the soil after the experiment. The highest value was recorded for M_2T_8 (5.91).

4.5.2. EC of the soil

The different spacing and fertilizer treatments and their combinations significantly affected the electrical conductivity of the soil after the experiment.

The spacing treatment M_2 measured the maximum EC of (0.14 dS m^{-1}), followed by M_1 (0.13 dS m^{-1}) and M_3 (0.11 dS m^{-1}).

The fertilizer treatment T_9 recorded the maximum EC value (0.17 dS m^{-1}), which was on par with T_2 (0.15) and T_8 (0.15).

The interaction effects were also significant and the combination M_1T_9 (0.22 dS m^{-1}) recorded the highest value compared to all other treatments.

4.5.3. Organic carbon

Spacing did not alter the organic carbon content of the soil after the experiment. However, the highest value was recorded by M_1 (0.73%).

Nutrients supplied to the soil in the form of fertilizers significantly altered the organic carbon content of the soil. The fertilizer treatment T_7 recorded the maximum value of 0.81 per cent that was on par with T_2, T_3, and T_1. The least value was recorded by T_6 (0.62%).

The interaction effects of spacing and fertilizers on organic carbon content of the soil were non-significant.

4.5.4. Available Phosphorus

Main effects of spacing significantly affected the available phosphorus content of the soil after the experiment. Maximum P content was recorded for M_1 (167.36 kg ha^{-1}), and it was superior to other two levels of spacing.

The fertilizer treatment effects were also significant. The treatment T_9 recorded the maximum level of P in the soil (169.04 kg ha^{-1}), which was on par with T_1, T_5, T_8, T_3, and T_2.

The interaction effects were also significant. The treatment combination M_1T_9 (191.90 kg ha^{-1}) recorded the highest value, which was statistically on par with M_2T_8, M_1T_7, M_1T_8, M_3T_1, M_3T_5, M_1T_1, M_1T_5, M_1T_3, M_2T_1, M_2T_5, M_2T_9, and M_2T_3.

4.5.5. Available Potassium

Spacing did not significantly change the available K content of the soil after the experiment. The maximum available K content was noticed for M_1 (195.00 kg ha^{-1}).

The effect of fertilizers was significant on available K content of the soil. The fertilizer treatment T_9 recorded maximum value for available potassium content (202.17 kg ha^{-1}). It possessed negligible difference with the treatments T_5 (195.88 kg ha^{-1}), T_1 (191.14 kg ha^{-1}), and T_8 (190.56 kg ha^{-1}).

The interaction effects did not significantly influence the available nutrient status of the soil.

4.5.6. Available Calcium

Spacing profoundly influenced the available calcium content of the soil after the crop. Highest value was obtained for M_1 (615.67 $\mu g\ g^{-1}$), followed by M_3 (506.85 $\mu g\ g^{-1}$) and M_2 (500.70 $\mu g\ g^{-1}$), which were at par.

As far as fertilizer treatments were concerned, the treatment T_5 showed maximum value for available calcium content of the soil (771.56 $\mu g\ g^{-1}$). It was superior to all other treatments in this regard. The least value was recorded for T_8 (420.67 $\mu g\ g^{-1}$).

There were significant differences for interaction effects also. The best treatment combination M_1T_5 (1125.00 µg g^{-1}) was superior to all other treatments.

4.5.7. Available Magnesium

The spacing treatments did not have any significant influence on the available magnesium status of the soil after the experiment. The highest value was recorded for M_1 (522.41 µg g^{-1}).

There was significant influence for fertilizer treatments on soil magnesium content. Maximum value was recorded for T_5 (645.09 µg g^{-1}), but it was on par with T_2 (545.03 µg g^{-1}).

The interaction effects were significant in altering the available magnesium content of the soil. The treatment combination M_1T_5 was found to be better than all other combinations with an available Mg content of 939.33 µg g^{-1}. The least value was obtained for M_2T_7 (242.33 µg g^{-1}).

4.5.8. Available Iron

Spacing was found not to affect the available iron content of the soil after the experiment significantly.

The fertilizer treatment T_7 had the maximum iron content in the soil (212.74 kg ha^{-1}), which was on par with T_8 (212.43 kg ha^{-1}), T_2 (210.57 kg ha^{-1}), and T_9 (203.47 kg ha^{-1}).

Table. 4.5.1. Soil nutrient status after the experiment as influenced by spacing and fertilizers

Treatment	pH	EC (dS m^{-1})	Organic C (%)	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available Ca (µg g^{-1})	Available Mg (µg g^{-1})	Available Fe (kg ha^{-1})
Spacing								
M_1	5.41^{a}	0.13^{b}	0.73^{a}	167.36^{a}	195.00^{a}	615.67^{a}	522.41^{a}	195.94^{a}
M_2	5.43^{a}	0.14^{a}	0.69^{a}	146.17^{b}	192.62^{a}	500.70^{b}	469.59^{a}	191.93^{a}
M_3	5.58^{a}	0.11^{c}	0.67^{a}	144.62^{b}	170.97^{a}	506.85^{b}	486.93^{a}	192.20^{a}
Mean	5.48	0.13	0.69	152.72	186.95	541.07	492.97	193.36
Fertilizer								
T_1	5.35^{bc}	0.11^{cd}	0.70^{abc}	167.29^{a}	191.14^{abc}	562.56^{bcd}	498.00^{bc}	175.35^{e}
T_2	5.63^{a}	0.15^{ab}	0.75^{ab}	151.53^{abc}	187.82^{bc}	460.00^{cd}	545.03^{ab}	210.57^{a}
T_3	5.28^{c}	0.13^{bc}	0.71^{abc}	158.02^{ab}	182.23^{cd}	423.33^{cd}	423.02^{cd}	156.60^{f}
T_4	5.35^{bc}	0.09^{d}	0.66^{bc}	127.59^{d}	174.64^{de}	525.67^{bcd}	454.82^{bcd}	197.04^{bc}
T_5	5.62^{a}	0.13^{bc}	0.64^{bc}	163.87^{a}	195.88^{ab}	771.56^{a}	645.09^{a}	212.74^{a}
T_6	5.33^{bc}	0.13^{bc}	0.62^{c}	134.21^{cd}	166.20^{e}	488.78^{cd}	522.90^{bc}	187.05^{cd}
T_7	5.60^{a}	0.10^{cd}	0.82^{a}	142.35^{bcd}	185.12^{bcd}	571.78^{bc}	432.14^{bcd}	184.99^{de}
T_8	5.64^{a}	0.15^{ab}	0.67^{bc}	160.53^{a}	190.56^{abc}	420.67^{d}	533.97^{bc}	212.43^{a}
T_9	5.51^{ab}	0.17^{a}	0.69^{bc}	169.04^{a}	202.17^{a}	636.33^{b}	381.80^{d}	203.47^{a}
Mean	5.48	0.13	0.69	152.72	186.95	541.07	492.97	193.36

Treatments having alphabets in common belong to one homogenous group

Table. 4.5.2. Soil nutrient status after the experiment as influenced by interaction of spacing and fertilizers

Treatment	pH	EC (dS m^{-1})	Organic C (%)	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available Ca (µg g^{-1})	Available Mg(µg g^{-1})	Available Fe(kg ha^{-1})
M_1T_1	5.020^{h}	0.108^{bc}	0.670^{a}	165.550^{abcd}	190.433^{a}	581.000^{bcde}	498.000^{bcd}	184.953^{fgh}
M_1T_2	5.890^{a}	0.162^{b}	0.787^{a}	153.650^{bcde}	197.253^{a}	581.000^{bcde}	522.900^{bc}	180.697^{fgh}
M_1T_3	5.260^{defgh}	0.127^{bc}	0.715^{a}	163.480^{abcd}	189.433^{a}	489.000^{bcde}	306.270^{de}	172.333^{ghi}
M_1T_4	5.105^{gh}	0.117^{bc}	0.796^{a}	141.433^{cdef}	186.100^{a}	498.000^{bcde}	368.467^{cde}	181.740^{fgh}
M_1T_5	5.670^{abc}	0.159^{b}	0.718^{a}	163.853^{abcd}	201.710^{a}	1125.000^{a}	939.333^{a}	186.927^{fgh}
M_1T_6	5.227^{fgh}	0.123^{bc}	0.651^{a}	155.367^{bcde}	183.517^{a}	553.333^{bcde}	655.700^{b}	200.897^{ef}
M_1T_7	5.420^{cdefg}	0.107^{bc}	0.850^{a}	191.217^{a}	197.037^{a}	636.333^{bcd}	506.300^{bcd}	209.377^{de}
M_1T_8	5.470^{bcdefg}	0.070^{c}	0.667^{a}	179.813^{ab}	194.077^{a}	321.333^{e}	522.900^{bc}	229.685^{abcd}
M_1T_9	5.660^{abc}	0.217^{a}	0.748^{a}	191.900^{a}	215.450^{a}	747.000^{b}	381.800^{cde}	216.833^{bcde}
M_2T_1	5.413^{cdefg}	0.113^{bc}	0.676^{a}	160.867^{abcd}	197.810^{a}	525.667^{bcde}	514.600^{bcd}	129.343^{j}
M_2T_2	5.360^{cdefgh}	0.160^{b}	0.758^{a}	149.747^{bcde}	189.250^{a}	332.000^{e}	564.400^{bc}	233.560^{ab}
M_2T_3	5.107^{gh}	0.154^{b}	0.824^{a}	158.200^{abcd}	192.237^{a}	384.000^{de}	464.800^{bcd}	169.417^{ghi}
M_2T_4	5.573^{abcdef}	0.072^{c}	0.600^{a}	104.167^{h}	175.467^{a}	581.000^{bcde}	531.200^{bcd}	166.037^{hi}
M_2T_5	5.583^{abcdef}	0.123^{bc}	0.593^{a}	160.767^{abcd}	217.600^{a}	691.667^{bc}	531.133^{bcd}	218.460^{bcde}
M_2T_6	5.143^{gh}	0.113^{bc}	0.583^{a}	108.200^{gh}	173.973^{a}	470.333^{cde}	431.600^{cde}	221.307^{bcde}
M_2T_7	5.537^{abcdef}	0.120^{bc}	0.896^{a}	121.733^{efgh}	191.490^{a}	498.000^{bcde}	242.333^{e}	159.487^{i}
M_2T_8	5.910^{a}	0.259^{a}	0.673^{a}	191.800^{a}	190.400^{a}	498.000^{bcde}	581.000^{bc}	219.813^{bcde}
M_2T_9	5.243^{efgh}	0.161^{b}	0.566^{a}	160.067^{abcd}	205.333^{a}	525.667^{bcde}	365.200^{cde}	209.963^{de}
M_3T_1	5.650^{abc}	0.105^{bc}	0.766^{a}	175.467^{abc}	185.173^{a}	581.000^{bcde}	481.400^{bcd}	211.760^{cde}
M_3T_2	5.643^{abcd}	0.123^{bc}	0.709^{a}	151.200^{bcde}	176.960^{a}	467.000^{cde}	547.800^{bc}	217.460^{bcde}
M_3T_3	5.473^{bcdefg}	0.107^{bc}	0.593^{a}	152.367^{bcde}	165.013^{a}	415.000^{de}	498.000^{bcd}	128.047^{j}
M_3T_4	5.357^{cdefgh}	0.079^{c}	0.583^{a}	137.167^{defg}	162.350^{a}	498.000^{bcde}	464.800^{bcd}	243.347^{a}
M_3T_5	5.643^{abcd}	0.100^{bc}	0.615^{a}	167.067^{abcd}	168.323^{a}	498.000^{bcde}	464.800^{bcd}	232.830^{ab}
M_3T_6	5.620^{abcde}	0.147^{b}	0.631^{a}	139.067^{defg}	141.120^{a}	442.667^{cde}	481.400^{bcd}	138.960^{j}
M_3T_7	5.827^{ab}	0.081^{c}	0.698^{a}	114.100^{fgh}	166.830^{a}	581.00^{bcde}	547.800^{bc}	185.980^{fgh}
M_3T_8	5.547^{abcdef}	0.108^{bc}	0.662^{a}	109.967^{fgh}	187.213^{a}	442.667^{cde}	498.000^{bcd}	187.803^{fgh}
M_3T_9	5.633^{abcd}	0.122^{bc}	0.759^{a}	155.167^{bcde}	185.720^{a}	636.333^{bcd}	398.400^{cde}	183.623^{fgh}
Mean	5.48	0.13	0.69	152.72	186.95	541.07	492.97	193.36

Treatments having alphabets in common belong to one homogenous group

Among the treatment combinations, M_3T_4 (243.35 kg ha^{-1}) registered maximum iron content in soil, which was statistically on par with M_2T_2 (233.56 kg ha^{-1}), M_3T_5 (232.83 kg ha^{-1}), and M_1T_8 (229.68 kg ha^{-1}).

4.6. NUTRIENT CONTENT OF THE CROP

4.6.1. Nitrogen

There was no significant difference between different spacing treatments nitrogen content in the plant during the three stages of crop growth (Table 4.6.1). The treatment M_3 (2.28%) recorded the maximum nitrogen content during vegetative stage. At mid flowering and after harvest stages also, a similar trend was noticed where the N content was 3.40% and 4.52% respectively.

The different fertilizer treatments were found to exert significant influence on nitrogen content of cowpea crop during the three stages of plant growth (Table 4.6.1). During vegetative stage, T_3 showed the highest plant N content (2.61%), but it was similar to other treatments viz. T_6 (2.43%), T_2 (2.36%), T_4 (2.36%), and T_5 (2.30%). A similar trend was noticed at mid flowering and after harvest stages also where the highest N content obtained was 3.73% and 4.85% for the treatment T_3.

The interaction effects of spacing and fertilizers were found to be insignificant during the three crop growth stages (Table 4.6.2).

Table. 4.6.1. Plant nitrogen content of yard long bean as influenced by spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
Spacing			
M_1	2.24^{a}	3.36^{a}	4.48^{a}
M_2	2.18^{a}	3.30^{a}	4.42^{a}
M_3	2.28^{a}	3.40^{a}	4.52^{a}
Mean	2.23	3.35	4.47
Fertilizer			
T_1	2.24^{bc}	3.36^{bc}	4.48^{bc}
T_2	2.36^{abc}	3.48^{abc}	4.60^{abc}
T_3	2.61^{a}	3.73^{a}	4.85^{a}
T_4	2.36^{abc}	3.48^{abc}	4.60^{abc}
T_5	2.30^{abc}	3.42^{abc}	4.54^{abc}
T_6	2.43^{ab}	3.55^{ab}	4.67^{ab}
T_7	1.80^{d}	2.92^{d}	4.04^{d}
T_8	1.93^{d}	3.05^{d}	4.17^{d}
T_9	2.05^{cd}	3.17^{cd}	4.29^{cd}
Mean	2.23	3.35	4.47

Treatments having alphabets in common belong to one homogenous group

Table. 4.6.2. Plant nitrogen content of yard long bean as influenced by interaction of spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
M_1T_1	2.05[a]	3.17[a]	4.29[a]
M_1T_2	2.43[a]	3.55[a]	4.67[a]
M_1T_3	2.61[a]	3.73[a]	4.85[a]
M_1T_4	2.24[a]	3.36[a]	4.48[a]
M_1T_5	2.24[a]	3.36[a]	4.48[a]
M_1T_6	2.43[a]	3.55[a]	4.67[a]
M_1T_7	1.87[a]	2.99[a]	4.11[a]
M_1T_8	2.05[a]	3.17[a]	4.29[a]
M_1T_9	2.24[a]	3.36[a]	4.48[a]
M_2T_1	2.24[a]	3.36[a]	4.48[a]
M_2T_2	2.05[a]	3.17[a]	4.29[a]
M_2T_3	2.43[a]	3.55[a]	4.67[a]
M_2T_4	2.43[a]	3.55[a]	4.67[a]
M_2T_5	2.43[a]	3.55[a]	4.67[a]
M_2T_6	2.24[a]	3.36[a]	4.48[a]
M_2T_7	1.68[a]	2.80[a]	3.92[a]
M_2T_8	2.05[a]	3.17[a]	4.29[a]
M_2T_9	2.05[a]	3.17[a]	4.29[a]
M_3T_1	2.43[a]	3.55[a]	4.67[a]
M_3T_2	2.61[a]	3.73[a]	4.85[a]
M_3T_3	2.80[a]	3.92[a]	5.04[a]
M_3T_4	2.43[a]	3.55[a]	4.67[a]
M_3T_5	2.24[a]	3.36[a]	4.48[a]
M_3T_6	2.61[a]	3.73[a]	4.85[a]
M_3T_7	1.87[a]	2.99[a]	4.11[a]
M_3T_8	1.68[a]	2.80[a]	3.92[a]
M_3T_9	1.87[a]	2.99[a]	4.11[a]
Mean	2.23	3.35	4.47

Treatments having alphabets in common belong to one homogenous group

4.6.2. Phosphorus

During vegetative stage, P content of cowpea was found to be unaffected by the different spacing treatments given (Table 4.6.3). Highest content of P was recorded for M_2 (0.36%). At mid flowering and after harvest stages, the main effects of spacing were found to be significant. The treatment M_2 had the highest value of 0.32%, which was on par with that of M_3 (0.31%) during flowering stage. At pod formation stage the spacing treatment M_1 registered the maximum P content (0.30%) followed by M_2 (0.25%) and M_3 (0.23%).

Incremental doses of nutrients affected the phosphorus content of yard long bean (Table 4.6.3). During vegetative stage P content was highest for T_5 (0.40%), which was statistically similar to the treatments T_6 (0.36%) and T_3 (0.36%). At mid flowering stage, the treatment T_6 (0.34%) recorded the highest value for P content in plant. The lowest value was recorded by T_7 (0.26%). At reproductive stage, the treatment T_2 (0.30%) was found to be superior to all other treatments for P content.

The interaction effects were also significant at flowering and pod formation stages of crop growth (Table 4.6.4). However, the effect was insignificant at vegetative stage. At that time, the phosphorus content of cowpea plants ranged from 0.28% to 0.42%. At 60 DAS the treatment, combinations M_2T_6 (0.38%), M_2T_5 (0.38%), and M_2T_4 (0.38%) were found to be superior. During maturity stage of the crop, the treatment combination M_1T_4 (0.40%) was superior to all other treatments, while the least value was obtained for M_3T_7 (0.22%).

Table. 4.6.3. Plant phosphorus content of yard long bean as influenced by spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
Spacing			
M_1	0.33[a]	0.26[b]	0.23[c]
M_2	0.34[a]	0.31[a]	0.25[b]
M_3	0.36[a]	0.32[a]	0.30[a]
Mean	0.34	0.30	0.26
Fertilizer			
T_1	0.34[bc]	0.28[e]	0.27[cd]
T_2	0.34[bc]	0.30[d]	0.30[a]
T_3	0.36[ab]	0.32[c]	0.27[c]
T_4	0.34[bc]	0.34[ab]	0.29[b]
T_5	0.39[a]	0.33[bc]	0.23[f]
T_6	0.36[ab]	0.34[a]	0.24[f]
T_7	0.31[c]	0.26[f]	0.24[f]
T_8	0.31[c]	0.26[f]	0.26[de]
T_9	0.34[bc]	0.29[f]	0.25[e]
Mean	0.34	0.30	0.26

Treatments having alphabets in common belong to one homogenous group

Table 4.6.4. Plant phosphorus content of yard long bean as influenced by interaction of spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
M_1T_1	0.37^{a}	0.24^{h}	0.28^{e}
M_1T_2	0.35^{a}	0.26^{g}	0.23^{ijkl}
M_1T_3	0.36^{a}	0.29^{de}	0.26^{fg}
M_1T_4	0.35^{a}	0.28^{def}	0.23^{jkl}
M_1T_5	0.40^{a}	0.26^{gh}	0.25^{fgh}
M_1T_6	0.35^{a}	0.29^{d}	0.23^{jkl}
M_1T_7	0.30^{a}	0.24^{h}	0.25^{fgh}
M_1T_8	0.28^{a}	0.27^{efg}	0.27^{ef}
M_1T_9	0.34^{a}	0.26^{g}	0.24^{hijk}
M_2T_1	0.35^{a}	0.29^{d}	0.24^{ghij}
M_2T_2	0.35^{a}	0.32^{c}	0.26^{fg}
M_2T_3	0.35^{a}	0.36^{b}	0.23^{ijkl}
M_2T_4	0.35^{a}	0.38^{a}	0.22^{kl}
M_2T_5	0.42^{a}	0.38^{a}	0.23^{jkl}
M_2T_6	0.36^{a}	0.38^{a}	0.24^{hijk}
M_2T_7	0.34^{a}	0.26^{g}	0.25^{ghi}
M_2T_8	0.34^{a}	0.26^{gh}	0.28^{e}
M_2T_9	0.36^{a}	0.29^{d}	0.32^{d}
M_3T_1	0.31^{a}	0.30^{d}	0.38^{b}
M_3T_2	0.31^{a}	0.32^{c}	0.36^{c}
M_3T_3	0.37^{a}	0.32^{c}	0.40^{a}
M_3T_4	0.32^{a}	0.35^{b}	0.240^{hijk}
M_3T_5	0.34^{a}	0.35^{b}	0.22^{l}
M_3T_6	0.37^{a}	$0. 35^{b}$	0.24^{ghij}
M_3T_7	0.30^{a}	0.27^{fg}	0.22^{l}
M_3T_8	0.31^{a}	0.26^{gh}	0.23^{jkl}
M_3T_9	0.32^{a}	0.32^{c}	0.24^{hijk}
Mean	0.34	0.30	0.26

Treatments having alphabets in common belong to one homogenous group

4.6.3. Potassium

During vegetative stage, there was no significant influence for different spacing treatments on plant potassium content (Table 4.6.5). The values ranged from 0.85% (M_3) to 0.96% (M_2). At mid flowering stage, the effects were significant, where the treatment M_3 (2.28%) was superior to M_2 (1.92%) and M_1 (1.87%). The treatments M_2 and M_3 were found to be similar. During pod formation stage, M_1 (1.18%) and M_3 (1.11%) were found to be at par and superior to M_2 (1.02%).

Main effects of fertilizers were found to be significant at three stages of crop growth of yard long bean (Table 4.6.5). During vegetative stage, the better treatments were T_5 (3.29%), T_4 (3.03%), T_2 (2.99%), T_9 (2.97%). At flowering stage, the treatment T_6 (2.63%) was superior to all other treatments, whereas the treatment T_5 (1.52%) was better at pod formation stage. The least values were recorded by T_8 (2.73%), T_7 (1.41%), and T_7 (0.76%) respectively during vegetative, mid flowering and after harvest stages.

The interaction effect was found to be insignificant at vegetative stage (Table 4.6.6). The treatment combination M_1T_2 (3.07%) recorded the highest value at mid flowering stage. It was superior to all other treatments. The treatment M_1T_7 registered the lowest value (1.07%). During pod formation stage, the differences between the treatments M_1T_2, M_1T_3, M_1T_4, M_1T_5, M_1T_6, M_2T_5, and M_3T_5 were found to be negligible even though the highest value was for M_2T_5 (1.57%).

Table. 4.6.5. Plant potassium content of yard long bean as influenced by spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
Spacing			
M_1	2.92^{a}	1.87^{b}	1.18^{a}
M_2	2.96^{a}	1.92^{b}	1.02^{b}
M_3	2.85^{a}	2.28^{a}	1.11^{ab}
Mean	2.91	2.02	1.10
Fertilizer			
T_1	2.83^{b}	1.48^{f}	1.09^{c}
T_2	3.03^{ab}	2.33^{b}	1.11^{c}
T_3	3.29^{a}	2.12^{cd}	1.16^{c}
T_4	2.67^{b}	2.21^{bc}	1.29^{b}
T_5	2.99^{ab}	2.21^{bc}	1.52^{a}
T_6	2.81^{b}	2.63^{a}	1.28^{b}
T_7	2.88^{b}	1.41^{f}	0.76^{e}
T_8	2.73^{b}	1.81^{e}	0.84^{de}
T_9	2.97^{ab}	2.00^{d}	0.91^{d}
Mean	2.91	2.02	1.10

Treatments having alphabets in common belong to one homogenous group

Table. 4.6.6. Plant potassium content of yard long bean as influenced by interaction of spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
M_1T_1	2.57[a]	1.18[k]	1.10[cde]
M_1T_2	3.17[a]	3.07[a]	1.45[ab]
M_1T_3	2.33[a]	1.72[fghij]	1.48[a]
M_1T_4	2.53[a]	1.72[fghij]	1.42[ab]
M_1T_5	2.78[a]	1.83[efgh]	1.45[ab]
M_1T_6	2.97[a]	2.80[b]	1.45[ab]
M_1T_7	3.28[a]	1.07[k]	0.67[i]
M_1T_8	3.18[a]	1.67[ghij]	0.67[i]
M_1T_9	2.95[a]	1.78[efghi]	0.95[defg]
M_2T_1	3.02[a]	1.62[hij]	1.08[cdef]
M_2T_2	3.02[a]	1.95[cdef]	0.70[hi]
M_2T_3	3.17[a]	2.70[b]	0.83[ghi]
M_2T_4	2.95[a]	2.20[cd]	1.18[c]
M_2T_5	2.87[a]	2.00[cde]	1.57[a]
M_2T_6	2.52[a]	2.15[cd]	1.12[cd]
M_2T_7	3.00[a]	1.60[hij]	0.88[fgh]
M_2T_8	2.75[a]	1.55[ij]	0.95[defg]
M_2T_9	2.87[a]	1.48[j]	0.88[fgh]
M_3T_1	2.65[a]	1.65[hij]	1.08[cdef]
M_3T_2	3.05[a]	1.97[cdef]	1.17[c]
M_3T_3	3.60[a]	1.93[defg]	1.15[cd]
M_3T_4	3.02[a]	2.70[b]	1.27[bc]
M_3T_5	3.12[a]	2.80[b]	1.53[a]
M_3T_6	2.93[a]	2.95[ab]	1.27[bc]
M_3T_7	3.00[a]	1.55[ij]	0.73[hi]
M_3T_8	2.70[a]	2.22[c]	0.90[efgh]
M_3T_9	2.62[a]	2.73[b]	0.88[fgh]
Mean	2.91	2.02	1.10

Treatments having alphabets in common belong to one homogenous group

4.6.4. Calcium

Different spacing treatments influenced the calcium content of yard long bean at the three stages (Table 4.6.7). At vegetative, mid flowering stages, the treatment M_1 (1.47% and 2.42%) and M_2 (1.50% and 2.38%) was found to be par and superior to M_3 (1.28% and 2.31%). The treatment M_2 (2.62%) was found to be superior to M_3 (2.48%) and M_1 (2.40%) at after harvest stage.

During all the three stages of crop growth, main effects of fertilizers were found to be significant (Table 4.6.7). At vegetative stage, the treatment T_5 recorded the maximum value (1.79%), which was superior to all other treatments and T_9 recorded the minimum value (1.20%). At mid flowering stage, the best result was obtained for the treatments T_5 and T_4 (2.63%). The least value was recorded for T_2 (2.08%). At after harvest stage, the treatment T_5 (2.78%) showed the best result, but was on par with T_7 and T_8 (2.66%). The treatments T_2, T_3, T_4, and T_5 were found to be better than other treatments at all stages of crop growth.

The interaction effects were also found to be significant at all stages of crop growth (Table 4.6.8). The treatment combinations M_1T_5 (2.54%) and M_2T_7 (2.43%) were found to be superior to all other treatments. The lowest value was recorded by M_3T_9 (1.00%). At mid flowering stage, M_3T_9, M_2T_4 (3.04%), M_1T_5, M_2T_5 (2.96%) were the treatments that recorded the better values. At after harvest stage also, a similar trend was noticed.

4.6.5. Magnesium

There was significant influence for spacing on magnesium content of plants (Table 4.6.9). At vegetative stage, M_1 recorded the maximum value for magnesium content (0.62%) followed by M_2 (0.55%) and M_3 (0.53%). At mid flowering and after harvest stages, the highest mean values were 0.82% and 2.32% for the treatment M_2.

Increasing doses of nutrients significantly affected plant magnesium contents (Table 4.6.9). At vegetative stage, the treatment T_2 (0.75%) was superior to all other treatments. At mid flowering stage also, the treatment T_2 (1.00%) was superior to all other treatments except T_9 (0.97%). The least value was recorded for T_5 (0.61%) at mid flowering stage. At after harvest stage, T_6 recorded the highest value (2.95%) and the lowest value was obtained for T_7 (2.13%).

There was significant influence for spacing x nutrient interaction on magnesium content of yard long bean at all stages of crop growth (Table 4.6.10). At vegetative stage, the treatment combinations M_1T_6 (1.19%) was found to be superior to all other treatments. The least value was recorded for M_1T_8 (0.27%). At mid flowering stage, the maximum value for magnesium content was recorded for the treatment combination M_1T_9 (1.29%). At after harvest stage, M_1T_6 and M_3T_6 (3.12%) were the better treatment combinations. The treatment combinations M_1T_8 (0.38%) and M_3T_8 (1.94%) were found to be show the least values at flowering and after harvest stages respectively.

4.6.6. Iron

There was significant influence for spacing on iron content of plants at 30 and 90 DAS (Table 4.6.11). The highest mean value for vegetative stage was 0.11% for the treatment M_1, which was followed by M_3 (0.09%) and M_2 (0.07%). At mid flowering stage, the main effects of spacing were found to be insignificant. The maximum value was registered for M_1 (0.18%), followed by M_3 (0.15%) and M_2 (0.12%) at after harvest stage.

Fertilizer treatments also exerted significant influence on iron content of yard long bean (Table 4.6.11). At vegetative stage, the highest mean values for fertilizer treatments obtained were 0.10% (T_3, T_4 and T_7). At mid flowering stage, T_7 (0.16%) was found to be good, but was on par with T_9 and T_4 (0.13%). At after harvest stage also, a similar trend was noticed.

The interaction effects were significant at all the three stages of crop growth (Table 4.6.12). At vegetative stage, the treatments M_1T_6 (0.15%) and M_3T_7 (0.14%) were found to be equally good, whereas the treatments M_3T_9 (0.28%) and M_1T_7 (0.25%) were found to be better at mid flowering stage. During pod formation stage, the treatment combinations M_1T_7 (0.31%), M_1T_6 (0.27%), and M_1T_1 (0.26%) recorded the maximum values.

Correlation studies have shown that P and K content at mid flowering stage had high positive correlation with yield of yard long bean (0.4732** and 0.3923** respectively). Iron content during vegetative stage had significant negative correlation with yield (-0.2605*). The correlation between soil and plant nutrient contents was also worked out. The correlation between soil P and plant Ca (-0.2679*) and soil K and plant Mg (-0.2965*) was significant.

4.7. STORAGE STUDY

There was significant difference between moisture loss of yard long bean pods under ambient conditions and zero energy cool chamber (Tables 4.7.1, 4.7.2, 4.7.4 and 4.7.5). Maximum moisture loss was registered under ambient conditions than in zero energy cool chamber.

Table. 4.6.7. Plant calcium content of yard long bean as influenced by spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
Spacing			
M_1	1.50^{a}	2.42^{a}	2.62^{a}
M_2	1.47^{a}	2.38^{a}	2.40^{c}
M_3	1.28^{b}	2.31^{b}	2.48^{b}
Mean	1.42	2.37	2.5
Fertilizer			
T_1	1.38^{c}	2.16^{c}	2.31^{c}
T_2	1.40^{c}	2.08^{c}	1.99^{d}
T_3	1.30^{d}	2.16^{c}	2.31^{c}
T_4	1.39^{c}	2.63^{a}	2.60^{b}
T_5	1.80^{a}	2.66^{a}	2.78^{a}
T_6	1.27^{d}	2.38^{b}	2.62^{b}
T_7	1.60^{b}	2.42^{b}	2.66^{ab}
T_8	1.43^{c}	2.45b	2.66^{ab}
T_9	1.20^{e}	2.38^{b}	2.60^{b}
Mean	1.42	2.37	2.5

Treatments having alphabets in common belong to one homogenous group

Table. 4.6.8. Plant calcium content of yard long bean as influenced by interaction of spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
M_1T_1	1.24^{efg}	1.99^{ghi}	2.05^{j}
M_1T_2	1.47^{d}	2.43^{ef}	1.59^{k}
M_1T_3	1.15^{fgh}	2.66^{bc}	2.41^{fghi}
M_1T_4	1.59^{bcd}	2.71^{b}	2.30^{ghij}
M_1T_5	2.54^{a}	2.96^{a}	3.13^{a}
M_1T_6	1.24^{ghi}	2.57^{bcde}	2.77^{cde}
M_1T_7	1.33^{b}	2.13^{gh}	2.52^{efg}
M_1T_8	1.60^{bcd}	2.16^{g}	2.41^{fghi}
M_1T_9	1.12^{ghi}	2.13^{gh}	2.46^{fgh}
M_2T_1	1.63^{b}	2.35^{f}	2.57^{def}
M_2T_2	1.60^{bc}	1.85^{ij}	2.30^{ghij}
M_2T_3	1.63^{b}	1.71^{j}	2.30^{ghij}
M_2T_4	1.08^{hi}	3.04^{a}	3.13^{a}
M_2T_5	1.24^{ef}	2.96^{a}	3.04^{ab}
M_2T_6	1.33^{e}	2.49^{cdef}	2.63^{def}
M_2T_7	2.43^{a}	2.63^{bcd}	2.82^{bcd}
M_2T_8	1.05^{hi}	2.46^{def}	2.60^{def}
M_2T_9	1.49^{cd}	1.96^{hi}	2.24^{hij}
M_3T_1	1.26^{ef}	2.13^{gh}	2.30^{ghij}
M_3T_2	1.12^{ghi}	1.96^{hi}	2.10^{j}
M_3T_3	1.12^{ghi}	2.10^{gh}	2.24^{hij}
M_3T_4	1.49^{cd}	2.13^{gh}	2.38^{fghi}
M_3T_5	1.58^{bcd}	2.05^{gh}	2.16^{ij}
M_3T_6	1.25^{ef}	2.07^{gh}	2.46^{fgh}
M_3T_7	1.03^{hi}	2.52^{cdef}	2.67^{def}
M_3T_8	1.63^{b}	2.74^{b}	2.96^{abc}
M_3T_9	1.00^{i}	3.04^{a}	3.10^{a}
Mean	1.42	2.37	2.5

Treatments having alphabets in common belong to one homogenous group

Table. 4.6.9. Plant magnesium content of yard long bean as influenced by spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
Spacing			
M_1	0.62^{a}	0.76^{b}	2.45^{a}
M_2	0.55^{b}	0.82^{a}	2.32^{b}
M_3	0.53^{c}	0.75^{b}	2.44^{a}
Mean	0.56	0.78	2.40
Fertilizer			
T_1	0.42^{f}	0.79^{b}	2.32^{d}
T_2	0.75^{a}	1.00^{a}	2.33^{d}
T_3	0.68^{b}	0.72^{bc}	2.40^{cd}
T_4	0.56^{d}	0.76^{bc}	2.50^{bc}
T_5	0.44^{f}	0.61^{d}	2.61^{b}
T_6	0.65^{bc}	0.70^{c}	2.95^{a}
T_7	0.44^{f}	0.74^{bc}	2.13^{f}
T_8	0.62^{c}	0.70^{c}	2.17^{ef}
T_9	0.51^{e}	0.97^{a}	2.28^{de}
Mean	0.56	0.78	2.40

Treatments having alphabets in common belong to one homogenous group

Table. 4.6.10. Plant magnesium content of yard long bean as influenced by interaction of spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
M_1T_1	0.39^{h}	1.05^{cd}	2.26^{efg}
M_1T_2	1.10^{b}	0.98^{de}	2.39^{cdef}
M_1T_3	0.64^{e}	0.67^{jk}	2.27^{efg}
M_1T_4	0.64^{e}	0.76^{ghij}	2.41^{cdef}
M_1T_5	0.40^{h}	0.39^{lm}	2.54^{bcd}
M_1T_6	1.19^{a}	0.50^{l}	3.12^{a}
M_1T_7	0.38^{h}	0.86^{fgh}	2.26^{efg}
M_1T_8	0.27^{i}	0.38^{m}	2.49^{cde}
M_1T_9	0.58^{f}	1.29^{a}	2.46^{cdef}
M_2T_1	0.38^{h}	0.44^{lm}	2.22^{fg}
M_2T_2	0.46^{g}	1.16^{b}	2.39^{cdef}
M_2T_3	0.75^{d}	0.78^{ghij}	2.42^{cdef}
M_2T_4	0.58^{f}	0.75^{hij}	2.47^{cdef}
M_2T_5	0.56^{f}	0.76^{ghij}	2.51^{cde}
M_2T_6	0.38^{h}	0.95^{def}	2.61^{bc}
M_2T_7	0.48^{g}	0.74^{ijk}	2.06^{gh}
M_2T_8	0.85^{c}	0.69^{jk}	2.09^{gh}
M_2T_9	0.48^{g}	1.11^{bc}	2.07^{gh}
M_3T_1	0.50^{g}	0.88^{efg}	2.47^{cdef}
M_3T_2	0.68^{e}	0.85^{fghi}	2.22^{fg}
M_3T_3	0.66^{e}	0.72^{jk}	2.49^{cde}
M_3T_4	0.46^{g}	0.78^{ghij}	2.61^{bc}
M_3T_5	0.36^{h}	0.69^{jk}	2.77^{b}
M_3T_6	0.38^{h}	0.66^{jk}	3.12^{a}
M_3T_7	0.47^{g}	0.62^{k}	2.07^{gh}
M_3T_8	0.76^{d}	1.05^{cd}	1.94^{h}
M_3T_9	0.46^{g}	0.50^{l}	2.31^{defg}
Mean	0.56	0.78	2.40

Treatments having alphabets in common belong to one homogenous group

Table. 4.6.11. Plant iron content of yard long bean as influenced by spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
Spacing			
M_1	0.11^{a}	0.11^{a}	0.18^{a}
M_2	0.07^{c}	0.13^{a}	0.12^{c}
M_3	0.09^{b}	0.09^{a}	0.15^{b}
Mean	0.09	0.11	0.15
Fertilizer			
T_1	0.08^{bc}	0.09^{bcd}	0.19^{ab}
T_2	0.08^{bc}	0.11^{bcd}	0.12^{d}
T_3	0.10^{a}	0.12^{bcd}	0.11^{d}
T_4	0.10^{a}	0.13^{abc}	0.14^{cd}
T_5	0.09^{bc}	0.08^{cd}	0.13^{d}
T_6	0.09^{b}	0.08^{d}	0.18^{ab}
T_7	0.10^{a}	0.16^{a}	0.20^{a}
T_8	0.07^{d}	0.09^{bcd}	0.11^{d}
T_9	0.08^{c}	0.13^{ab}	0.16^{bc}
Mean	0.09	0.11	0.15

Treatments having alphabets in common belong to one homogenous group

Table. 4.6.12. Plant iron content of yard long bean as influenced by interaction of spacing and fertilizers (percentage)

Treatment	Vegetative stage	Flowering stage	After harvest
M_1T_1	0.08^{gh}	0.10^{bcdefg}	0.26^{ab}
M_1T_2	0.13^{bc}	0.14^{bcdef}	0.17^{cdef}
M_1T_3	0.12^{c}	0.15^{bcd}	0.08^{ghij}
M_1T_4	0.10^{def}	0.12^{bcdefg}	0.13^{defghi}
M_1T_5	0.11^{cde}	0.04^{g}	0.19^{cd}
M_1T_6	0.15^{a}	0.07^{defg}	0.27^{ab}
M_1T_7	0.07^{ghi}	0.25^{a}	0.31^{a}
M_1T_8	0.09^{fg}	0.05^{g}	0.06^{j}
M_1T_9	0.12^{cd}	0.07^{cdefg}	0.14^{defg}
M_2T_1	0.08^{fg}	0.11^{bcdefg}	0.18^{cde}
M_2T_2	0.06^{hi}	0.15^{bcde}	0.07^{ij}
M_2T_3	0.07^{ghi}	0.11^{bcdefg}	0.12^{efghij}
M_2T_4	0.10^{def}	0.16^{bc}	0.14^{defg}
M_2T_5	0.08^{gh}	0.15^{bcde}	0.08^{hij}
M_2T_6	0.04^{k}	0.10^{bcdefg}	0.12^{efghij}
M_2T_7	0.09^{fg}	0.17^{b}	0.14^{defg}
M_2T_8	0.04^{jk}	0.17^{b}	0.12^{fghij}
M_2T_9	0.07^{ghi}	0.05^{g}	0.13^{efghij}
M_3T_1	0.09^{fg}	0.05^{fg}	0.14^{defg}
M_3T_2	0.06^{ij}	0.04^{g}	0.13^{fghij}
M_3T_3	0.12^{c}	0.08^{cdefg}	0.13^{defgh}
M_3T_4	0.10^{ef}	0.10^{bcdefg}	0.15^{defg}
M_3T_5	0.07^{ghi}	0.07^{defg}	0.13^{defgh}
M_3T_6	0.09^{fg}	0.07^{defg}	0.14^{defg}
M_3T_7	0.14^{ab}	0.06^{defg}	0.15^{def}
M_3T_8	0.07^{ghi}	0.06^{efg}	0.14^{defg}
M_3T_9	0.04^{jk}	0.28^{a}	0.22^{bc}
Mean	0.09	0.11	0.15

Treatments having alphabets in common belong to one homogenous group

There was no significant influence for spacing on moisture loss of pods either in ambient conditions or in zero energy cool chamber during the entire storage period of 5 days under ambient conditions and 3 days in zero energy cool chamber.

Fertilizer treatments exerted significant influence on moisture loss of yard long bean pods only on first day of storage under both conditions. During the rest of the storage period fertilizers had no influence on the moisture loss from the pods. On first day of storage, the fertilizer treatment T_7 (8.26%) recorded the minimum moisture loss under ordinary conditions of storage. It was on par with T_4 (8.46%), T_8 (8.77%) and T_5 (9.39%). In zero energy cool chamber the treatment T_7 registered minimum loss of moisture (1.36%), which was significantly superior to all other treatments. Maximum moisture loss was obtained for T_3 (5.46%).

The interaction effects were significant under zero energy cool chamber conditions during the entire storage period of three days whereas, it was non-significant under ambient conditions. On first day of storage, minimum moisture loss was recorded for M_2T_7 (1.35%), which was on par with M_3T_7 (1.36%) and M_1T_7 (1.37%). The highest value was recorded for M_1T_3 (5.78%). On second day, M_3T_6 (7.39%) recorded the minimum moisture loss, which was on par with all other treatment combinations except M_1T_2, M_1T_3, M_1T_5, M_2T_6, M_2T_9 and M_3T_9. On third day, M_3T_6 (9.85%) recorded the minimum moisture loss, which was on par with all other treatment combinations except M_1T_2, M_1T_3, M_1T_5, M_2T_6, M_2T_9 and M_3T_9.

The percentage of unmarketable pods increased progressively with the storage period. A maximum storage period of 5 days was obtained under ambient conditions and 3 days in zero energy cool chamber irrespective of the treatments given. However the percentage of unmarketable pods was significantly decreased with increase in fertilizers, while it was unaffected by the various spacing treatments (Tables 4.7.3 and 4.7.6).

On third day of storage under ambient conditions minimum percentage of unmarketable fruits was recorded for T_9 (34.44%), which was on par with T_7 and T_8 (35.56%). On fifth day also, a similar trend was noticed. The treatments T_7 and T_8 registered minimum percentage of marketable fruits in zero energy cool chamber also on third day of storage (15.56%).

The interaction effect of spacing and fertilizer remained non significant during the entire period of storage under both conditions.

4.8. PALATABILITY STUDY

The palatability of cooked pods were measured in terms of appearance, flavour, taste and texture (Tables 4.8.1 and 4.8.2). Spacing, fertilizer and their interactions were significant in the case of organoleptic quality of the pods. For all the four characters studied, the spacings M_1 and M_3 were found to be at par and superior to M_2. M_1 recorded the highest values of 4.00, 4.00, 4.00 and 3.99 respectively for the four organoleptic characters studied.

The organic treatments T_7, T_8 and T_9 were found to be at par and superior to inorganic treatments for organoleptic quality. The highest values were reported for T_8 (4.82, 4.87, 4.87 and 4.82). The lowest values were recorded for T_3.

The combination M_3T_7 and M_3T_9 recorded the highest values (4.93) for appearance, taste and texture and were on par with M_1T_7, M_1T_8, M_1T_9, M_2T_8, M_2T_9

Table. 4.7.1. Moisture loss (percentage) of yard long bean under ambient conditions as influenced by spacing and fertilizers

Treatment	1st day	2nd day	3rd day	4th day	5th day
Spacing					
M_1	9.60[a]	15.25[a]	19.40[a]	24.95[a]	30.49[a]
M_2	9.76[a]	15.56[a]	19.80[a]	25.46[a]	31.12[a]
M_3	9.66[a]	15.41[a]	19.61[a]	25.21[a]	30.81[a]
Mean	9.67	15.40	19.60	25.21	30.81
Fertilizer					
T_1	9.55[bcd]	15.93[a]	20.27[a]	26.06[a]	31.85[a]
T_2	10.40[ab]	15.88[a]	20.21[a]	25.99[a]	31.78[a]
T_3	11.01[a]	15.14[a]	19.27[a]	24.77[a]	30.28[a]
T_4	8.55[de]	14.69[a]	18.69[a]	24.04[a]	29.38[a]
T_5	9.39[bcde]	14.75[a]	18.77[a]	24.14[a]	29.50[a]
T_6	11.08[a]	15.24[a]	19.39[a]	24.93[a]	30.47[a]
T_7	8.26[e]	15.67[a]	19.95[a]	25.65[a]	31.34[a]
T_8	8.77[cde]	15.55[a]	19.80[a]	25.45[a]	31.11[a]
T_9	10.04[ab]	15.78[a]	20.08[a]	25.82[a]	31.56[a]
Mean	9.67	15.40	19.60	25.21	30.81

Treatments having alphabets in common belong to one homogenous group

Table. 4.7.2. Moisture loss (percentage) of yard long bean in village model cool chamber as influenced by spacing and fertilizers

Treatment	1st day	2nd day	3rd day
Spacing			
M_1	3.01^a	8.22^a	10.96^a
M_2	3.02^a	8.20^a	10.94^a
M_3	3.01^a	8.00^a	10.67^a
Mean	3.02	8.14	10.86
Fertilizer			
T_1	2.15^f	8.05^a	10.74^a
T_2	3.28^c	8.21^a	10.94^a
T_3	5.46^a	8.19^a	10.91^a
T_4	1.84^g	7.87^a	10.49^a
T_5	2.93^d	8.25^a	11.00^a
T_6	4.98^b	8.30^a	11.07^a
T_7	1.36^h	8.15^a	10.87^a
T_8	2.39^e	7.98^a	10.64^a
T_9	2.76^d	8.30^a	11.06^a
Mean	3.02	8.14	10.86

Treatments having alphabets in common belong to one homogenous group

Table. 4.7.3. Percentage of unmarketable pods under both conditions of storage as influenced by spacing and fertilizers

Treatment	Ambient conditions		Zero energy cool chamber
	3rd day	5th day	3rd day
Spacing			
M_1	46.67[a]	71.85[a]	27.41[a]
M_2	42.96[a]	73.70[a]	22.96[a]
M_3	42.96[a]	74.81[a]	22.96[a]
Mean	44.20	73.46	24.44
Fertilizer			
T_1	46.67[a]	75.56[ab]	26.67[ab]
T_2	48.89[a]	76.67[ab]	28.89[ab]
T_3	51.11[a]	81.11[a]	31.11[ab]
T_4	45.56[a]	73.33[b]	25.56[b]
T_5	47.78[a]	77.78[ab]	27.78[ab]
T_6	52.22[a]	80.00[a]	32.22[a]
T_7	35.56[b]	65.56[c]	15.56[c]
T_8	35.56[b]	67.78[c]	15.56[c]
T_9	34.44[b]	63.33[c]	16.67[c]
Mean	44.20	73.46	24.44

Treatments having alphabets in common belong to one homogenous group

Table. 4.7.4. Percentage of moisture loss under ambient conditions of storage as influenced by interaction of spacing and fertilizers

Treatment	1st day	2nd day	3rd day	4th day	5th day
M_1T_1	9.03^{a}	15.06^{a}	19.17^{a}	24.64^{a}	30.12^{a}
M_1T_2	11.16^{a}	17.05^{a}	21.70^{a}	27.90^{a}	34.11^{a}
M_1T_3	11.77^{a}	16.18^{a}	20.60^{a}	26.48^{a}	32.36^{a}
M_1T_4	8.69^{a}	14.93^{a}	19.00^{a}	24.43^{a}	29.86^{a}
M_1T_5	9.22^{a}	14.48^{a}	18.43^{a}	23.70^{a}	28.96^{a}
M_1T_6	10.99^{a}	15.11^{a}	19.24^{a}	24.73^{a}	30.23^{a}
M_1T_7	8.21^{a}	15.56^{a}	19.81^{a}	25.47^{a}	31.12^{a}
M_1T_8	8.19^{a}	14.52^{a}	18.48^{a}	23.76^{a}	29.05^{a}
M_1T_9	9.11^{a}	14.31^{a}	18.21^{a}	23.42^{a}	28.62^{a}
M_2T_1	10.08^{a}	16.79^{a}	21.37^{a}	27.48^{a}	33.59^{a}
M_2T_2	10.06^{a}	15.37^{a}	19.57^{a}	25.16^{a}	30.75^{a}
M_2T_3	10.65^{a}	14.65^{a}	18.64^{a}	23.97^{a}	29.29^{a}
M_2T_4	8.55^{a}	14.70^{a}	18.71^{a}	24.05^{a}	29.39^{a}
M_2T_5	9.43^{a}	14.82^{a}	18.87^{a}	24.26^{a}	29.65^{a}
M_2T_6	11.23^{a}	15.44^{a}	19.65^{a}	25.26^{a}	30.87^{a}
M_2T_7	8.03^{a}	15.22^{a}	19.38^{a}	24.91^{a}	30.45^{a}
M_2T_8	9.57^{a}	16.99^{a}	21.62^{a}	27.80^{a}	33.98^{a}
M_2T_9	10.20^{a}	16.03^{a}	20.41^{a}	26.24^{a}	32.07^{a}
M_3T_1	9.55^{a}	15.92^{a}	20.27^{a}	26.06^{a}	31:85^{a}
M_3T_2	9.96^{a}	15.22^{a}	19.37^{a}	24.91^{a}	30.44^{a}
M_3T_3	10.61^{a}	14.59^{a}	18.57^{a}	23.88^{a}	29.18^{a}
M_3T_4	8.40^{a}	14.44^{a}	18.38^{a}	23.63^{a}	28.88^{a}
M_3T_5	9.51^{a}	14.95^{a}	19.02^{a}	24.46^{a}	29.89^{a}
M_3T_6	11.02^{a}	15.16^{a}	19.29^{a}	24.80^{a}	30.32^{a}
M_3T_7	8.56^{a}	16.23^{a}	20.66^{a}	26.56^{a}	32.46^{a}
M_3T_8	8.54^{a}	15.15^{a}	19.28^{a}	24.79^{a}	30.30^{a}
M_3T_9	10.82^{a}	17.00^{a}	21.63^{a}	27.82^{a}	34.00^{a}
Mean	9.67	15.40	19.60	25.21	30.81

Treatments having alphabets in common belong to one homogenous group

Table. 4.7.5. Percentage of moisture loss of pods in village model cool chamber as influenced by interaction of spacing and fertilizers

Treatment	1st day	2nd day	3rd day
M_1T_1	2.17^{jkl}	8.31^{cde}	10.84^{cde}
M_1T_2	3.62^{d}	9.05^{ab}	12.06^{ab}
M_1T_3	5.79^{a}	8.68^{abc}	11.57^{abc}
M_1T_4	1.86^{lm}	7.96^{cde}	10.61^{cde}
M_1T_5	2.52^{hi}	8.39^{bcd}	11.18^{bcd}
M_1T_6	4.94^{b}	8.24^{bcde}	10.99^{bcde}
M_1T_7	1.37^{n}	8.22^{bcde}	10.96^{bcde}
M_1T_8	2.23^{ijk}	7.44^{e}	9.923^{e}
M_1T_9	2.63^{gh}	7.90^{cde}	10.54^{cde}
M_2T_1	2.17^{jkl}	8.16^{cde}	10.88^{cde}
M_2T_2	3.07^{ef}	7.67^{de}	10.22^{de}
M_2T_3	5.11^{b}	7.66^{de}	10.21^{de}
M_2T_4	1.83^{m}	7.85^{cde}	10.47^{cde}
M_2T_5	2.74^{gh}	8.22^{bcde}	10.96^{bcde}
M_2T_6	5.56^{a}	9.27^{a}	12.37^{a}
M_2T_7	1.35^{n}	8.09^{cde}	10.78^{cde}
M_2T_8	2.49^{hij}	8.29^{bcde}	11.06^{bcde}
M_2T_9	2.88^{efg}	8.63^{abc}	11.51^{abc}
M_3T_1	2.10^{klm}	7.87^{cde}	10.49^{cde}
M_3T_2	3.16^{e}	7.91^{cde}	10.55^{cde}
M_3T_3	5.48^{a}	8.22^{bcde}	10.96^{bcde}
M_3T_4	1.82^{m}	7.80^{cde}	10.40^{cde}
M_3T_5	3.53^{d}	8.14^{cde}	10.85^{cde}
M_3T_6	4.43^{c}	7.39^{e}	9.849^{e}
M_3T_7	1.36^{n}	8.14^{cde}	10.86^{cde}
M_3T_8	2.46^{hij}	8.21^{bcde}	10.94^{bcde}
M_3T_9	2.78^{fgh}	8.35^{bcd}	11.14^{bcd}
Mean	3.02	8.14	10.86

Treatments having alphabets in common belong to one homogenous group

Table. 4.7.6. Percentage of unmarketable pods under both conditions of storage as influenced by interaction of spacing and fertilizers

Treatment	Ambient conditions		Zero energy cool chamber
	3rd day	5th day	3rd day
M_1T_1	46.67[a]	73.33[a]	26.67[a]
M_1T_2	50.00[a]	73.33[a]	30.00[a]
M_1T_3	53.33[a]	76.67[a]	33.33[a]
M_1T_4	46.67[a]	73.33[a]	26.67[a]
M_1T_5	50.00[a]	76.67[a]	30.00[a]
M_1T_6	53.33[a]	76.67[a]	33.33[a]
M_1T_7	40.00[a]	63.33[a]	20.00[a]
M_1T_8	40.00[a]	70.00[a]	20.00[a]
M_1T_9	40.00[a]	63.33[a]	26.67[a]
M_2T_1	46.67[a]	73.33[a]	26.67[a]
M_2T_2	46.67[a]	76.67[a]	26.67[a]
M_2T_3	46.67[a]	80.00[a]	26.67[a]
M_2T_4	46.67[a]	73.33[a]	26.67[a]
M_2T_5	46.67[a]	76.67[a]	26.67[a]
M_2T_6	53.33[a]	83.33[a]	33.33[a]
M_2T_7	33.33[a]	63.33[a]	13.33[a]
M_2T_8	33.33[a]	70.00[a]	13.33[a]
M_2T_9	33.33[a]	66.67[a]	13.33[a]
M_3T_1	46.67[a]	80.00[a]	26.67[a]
M_3T_2	50.00[a]	80.00[a]	30.00[a]
M_3T_3	53.33[a]	86.67[a]	33.33[a]
M_3T_4	33.33[a]	73.33[a]	23.33[a]
M_3T_5	46.67[a]	80.00[a]	26.67[a]
M_3T_6	50.00[a]	80.00[a]	30.00[a]
M_3T_7	33.33[a]	70.00[a]	13.33[a]
M_3T_8	33.33[a]	63.33[a]	13.33[a]
M_3T_9	30.00[a]	60.00[a]	10.00[a]
Mean	44.20	73.46	24.44

Treatments having alphabets in common belong to one homogenous group

and M_3T_8. For flavour, M_3T_8 recorded the highest value of 5.00. It was on par with M_1T_7, M_1T_8, M_2T_8, M_3T_7 and M_3T_9.

4.9.ECONOMIC ANALYSIS

Economics of cultivation was analysed based on net returns and benefit:cost ratio (B:C ratio). The results are shown in tables 4.9.1 and 4.9.2.

4.9.1. Net Returns

There was significant influence for spacing, fertilizer and their interactions on the net returns of yard long bean cultivation. The highest net returns was recorded for the closer spacing M_1 (Rs. 26130 ha^{-1}), which was significantly superior to M_2 and M_3. For the wider spacing M_3, the net returns was negative (-1128 Rs ha^{-1}) indicating a loss in cultivation.

The fertilizer treatment T_3 recorded the maximum net returns (16790 Rs ha^{-1}), which was significantly superior to all other treatments. The lowest return was for T_7 (4710 Rs ha^{-1}).

The treatment combination M_1T_2 (33030 Rs ha^{-1}) obtained the maximum net returns, which was on par with M_1T_3 (32720 Rs ha^{-1}) and M_1T_6 (31520 Rs ha^{-1}). The treatment combination M_3T_7 was the least in this regard (-5223 Rs ha^{-1}).

Table. 4.8.1. Organoleptic quality of yard long bean pods as influenced by spacing and fertilizers (1-5 hedonic scale)

Treatment	Appearance	Flavour	Taste	Texture
Spacing				
M_1	4.00[a]	4.00[a]	4.00[a]	3.99[a]
M_2	3.84[b]	3.834[b]	3.84[b]	3.84[b]
M_3	3.99[a]	3.98[a]	3.98[a]	3.96[a]
Mean	3.94	3.94	3.94	3.93
Fertilizer				
T_1	3.89[b]	3.89[b]	3.89[b]	3.89[b]
T_2	3.37[c]	3.47[c]	3.47[c]	3.47[c]
T_3	3.27[d]	3.27[d]	3.27[d]	3.27[d]
T_4	3.58[c]	3.58[c]	3.58[c]	3.58[c]
T_5	3.49[c]	3.47[c]	3.47[c]	3.49[c]
T_6	3.51[c]	3.51[c]	3.51[c]	3.49[c]
T_7	4.76[a]	4.71[a]	4.71[a]	4.76[a]
T_8	4.82[a]	4.87[a]	4.87[a]	4.82[a]
T_9	4.71[a]	4.71[a]	4.71[a]	4.71[a]
Mean	3.94	3.94	3.94	3.93

Treatments having alphabets in common belong to one homogenous group

Table. 4.8.2. Organoleptic quality of yard long bean pods as influenced by interaction of spacing and fertilizers (1-5 hedonic scale)

Treatment	Appearance	Flavour	Taste	Texture
M_1T_1	4.27^{c}	4.27^{d}	4.27^{c}	4.27^{c}
M_1T_2	3.60^{de}	3.60^{ef}	3.60^{de}	3.60^{de}
M_1T_3	3.20^{f}	3.20^{g}	3.20^{f}	3.20^{f}
M_1T_4	3.60^{de}	3.60^{ef}	3.60^{de}	3.60^{de}
M_1T_5	3.47^{def}	3.47^{efg}	3.47^{def}	3.47^{def}
M_1T_6	3.60^{de}	3.60^{ef}	3.60^{de}	3.53^{def}
M_1T_7	4.80^{ab}	4.80^{abc}	4.80^{ab}	4.80^{ab}
M_1T_8	4.87^{ab}	4.87^{ab}	4.87^{ab}	4.87^{ab}
M_1T_9	4.60^{ab}	4.60^{bc}	4.60^{ab}	4.60^{ab}
M_2T_1	3.60^{de}	3.60^{ef}	3.60^{de}	3.60^{de}
M_2T_2	3.33^{ef}	3.33^{fg}	3.33^{ef}	3.33^{ef}
M_2T_3	3.33^{ef}	3.33^{fg}	3.33^{ef}	3.33^{ef}
M_2T_4	3.60^{de}	3.60^{ef}	3.60^{de}	3.60^{de}
M_2T_5	3.47^{def}	3.47^{efg}	3.47^{def}	3.47^{def}
M_2T_6	3.33^{ef}	3.33^{fg}	3.33^{ef}	3.33^{ef}
M_2T_7	4.53^{bc}	4.53^{cd}	4.53^{bc}	4.53^{bc}
M_2T_8	4.73^{ab}	4.73^{abc}	4.73^{ab}	4.73^{ab}
M_2T_9	4.60^{ab}	4.60^{bc}	4.60^{ab}	4.60^{ab}
M_3T_1	3.80^{d}	3.80^{e}	3.80^{d}	3.80^{d}
M_3T_2	3.47^{def}	3.47^{fg}	3.47^{def}	3.47^{def}
M_3T_3	3.27^{ef}	3.27^{fg}	3.27^{ef}	3.27^{ef}
M_3T_4	3.53^{def}	3.53^{efg}	3.53^{def}	3.53^{def}
M_3T_5	3.53^{def}	3.47^{fg}	3.53^{def}	3.53^{def}
M_3T_6	3.60^{de}	3.60^{ef}	3.53^{def}	3.47^{def}
M_3T_7	4.93^{a}	4.80^{abc}	4.93^{a}	4.93^{a}
M_3T_8	4.87^{ab}	5.00^{a}	4.87^{ab}	4.733^{ab}
M_3T_9	4.93^{a}	4.93^{a}	4.93^{a}	4.933^{a}
Mean	3.94	3.94	3.94	3.93

Treatments having alphabets in common belong to one homogenous group

4.9.2. Benefit: Cost Ratio

Spacing, fertilizer and their combinations significantly changed the benefit: cost ratio of yard long bean cultivation. The trend was similar to that of net returns. The closer spacing M_1 (1.64) was significantly superior to M_2 (1.13) and M_3 (0.97).

Among the different fertilizer treatments, T_3 (1.42) was superior to all other treatments. The lowest value was shown by T_7 (1.11).

The spacing-fertilizer combination M_1T_2 produced the highest B:C ratio of 1.82. It was statistically similar to M_1T_3 (1.81) and M_1T_6 (1.76). The combination M_3T_7 (0.87) was the inferior one.

4.9. PEST AND DISEASE INCIDENCE

Incidence of mosaic was noticed during the crop growth period. The affected plants were uprooted and destroyed. Minor incidence of *Colletotrichum* leaf spot (*Colletotrichum lindemuthianum*) was also seen, which was controlled by timely sprayings. There was no correlation between disease incidence and different treatments.

Pests like stem fly and leaf miner (*Liriomyza trifolii*) were seen during the initial stages of crop growth which were kept under control by prophylatic and control measures adopted. Aphids (*Aphis craccivora*) and pod borer (*Adisura atkinsonii*) attack were seen during later stages of crop growth. The pest attack was also not correlated with the different treatments given.

Table. 4.9.1. Economics of yard long bean cultivation as influenced by spacing and fertilizers

Treatment	Net returns (Rs ha^{-1})	B: C ratio
Spacing		
M_1	26130[a]	1.637[a]
M_2	5400[b]	1.135[b]
M_3	-1128[c]	0.97[c]
Mean	10134	1.25
Fertilizer		
T_1	11170[cd]	1.283[c]
T_2	14370[b]	1.361[b]
T_3	16790[a]	1.418[a]
T_4	9565[d]	1.236[c]
T_5	9974[cd]	1.243[c]
T_6	11710[c]	1.283[c]
T_7	4710[f]	1.112[e]
T_8	5637[ef]	1.132[de]
T_9	7270[e]	1.168[d]
Mean	10134	1.25

Treatments having alphabets in common belong to one homogenous group

Table. 4.9.2. Economics of yard long bean cultivation as influenced by interaction of spacing and fertilizers

Treatment	Net returns (Rs ha^{-1})	B: C ratio
M_1T_1	27440^{c}	1.691^{b}
M_1T_2	33030^{a}	1.823^{a}
M_1T_3	32720^{a}	1.806^{a}
M_1T_4	27640^{c}	1.681^{b}
M_1T_5	28430^{bc}	1.693^{b}
M_1T_6	31520^{ab}	1.760^{ab}
M_1T_7	16930^{de}	1.407^{c}
M_1T_8	17840^{d}	1.420^{c}
M_1T_9	19630^{d}	1.453^{c}
M_2T_1	7041^{f}	1.182^{d}
M_2T_2	6141^{fg}	1.157^{de}
M_2T_3	14190^{e}	1.359^{c}
M_2T_4	2938^{g}	1.074^{ef}
M_2T_5	2720^{g}	1.068^{ef}
M_2T_6	5669^{fg}	1.140^{de}
M_2T_7	2427^{g}	1.060^{efg}
M_2T_8	2862^{g}	1.069^{ef}
M_2T_9	4618^{fg}	1.109^{de}
M_3T_1	-968^{h}	0.97^{fgh}
M_3T_2	3951^{fg}	1.102^{de}
M_3T_3	3472^{fg}	1.089^{de}
M_3T_4	-1878^{hi}	0.95^{hi}
M_3T_5	-1224^{h}	0.97^{ghi}
M_3T_6	-2057^{hi}	0.95^{hi}
M_3T_7	-5223^{i}	0.87^{i}
M_3T_8	-3789^{hi}	0.91^{hi}
M_3T_9	-2438^{hi}	0.94^{hi}
Mean	10134	1.25

Treatments having alphabets in common belong to one homogenous group

Discussion

5. DISCUSSION

Yard long bean (*Vigna unguiculata* var. *sesquipedalis*) occupies a prime position among the vegetables grown in Kerala. The crop can be cultivated throughout the year in the state. During the rainy season it is mainly cultivated as an upland crop either in open as a pure crop or as an intercrop in coconut gardens. In summer season, it is cultivated as an irrigated crop in summer rice fallows. It is a highly remunerative crop due to its high productivity and long pods especially during festival seasons compared to bush type vegetable cowpea.

Yard long bean is a trailing crop with indeterminate growth habit, protracted growth period and higher productivity. Naturally it demands a wider spacing and higher doses of fertilizers than the bush types. The production potential of pulse varieties is 4 t ha^{-1} and that of bush type vegetable varieties is 6 t ha^{-1}. Yard long bean types can give a yield of 10-12 t ha^{-1}. But only a general recommendation for grain and bush type cowpea is available (KAU, 1996). Since the vegetative growth and harvesting of the crop is continuous split application of fertilizers will be advantageous. This will result in prolonged harvesting period and consequently higher yield from the crop. Earlier works at College of Agriculture, Vellayani also proved that yard long bean responds to higher doses of fertilizers. So the present study was undertaken to standardize the spacing and nutrient requirements of the crop.

Organic farming is an emerging trend in today's quality conscious world. Organically grown vegetables have export potential and fetch more price in the local market than intensively grown vegetables. It is also well known that organically grown vegetables have better palatability and taste. So, an effort was made in the present study to standardize the organic farming practices of the crop considering the yield, economics, storability and palatability aspects. The results obtained in the experiment are discussed in this chapter.

5.1. GROWTH CHARACTERS

The growth characters of yard long bean were measured in terms of number of primary branches, internodal length, leaf length, leaf width, leaf area index and root: shoot ratio. There was progressive increase in the above growth characters up to 90 DAS except for root:shoot ratio which decreased with the age of the plant.

The effects of spacing, fertilizers or their interaction were not significant on the number of primary branches and root: shoot ratio of yard long bean during the different stages of crop growth (Tables 4.1.1, 4.1.2, 4.1.5 and 4.1.6). Similar results have been reported by Chandran (1987), Jain *et al.* (1993) and Swaroop *et al.* (2001) in vegetable cowpea.

There was significant positive influence for spacing on the internodal length of yard long bean (Tables 4.1.1 and 4.1.2). The closest spacing or high-density treatment M_1 1.5 m x 0.25 m (7.21 cm and 8.19 cm) recorded maximum value for internodal length at 60 and 90 DAS compared to the wider spacing treatment M_3 (1.5 m x 0.75 m). This may be due to higher level of competition for light in the closely spaced plants that resulted in an increased internodal length. Fertilizers failed to exert any significant influence on internodal length of the crop in the present study at all the three stages of crop growth. These results are in conformity with the findings of Chandran (1987) and Mini (1997) in vegetable cowpea.

Leaf length and leaf width of yard long bean were significantly affected by varying spacing treatments at maturity stage of the crop (Tables 4.1.3 and 4.1.4). The maximum value was observed for the wider spacing treatment of 1.5 m x 0.75 m (10.95 cm). During the initial stages of crop growth, there is no competition for resources like space, light, nutrients, and water among the various spacing treatments. As the plant grows, the area occupied by single plant varies and there is competition for resources in closely spaced plants, which might have resulted in lesser leaf length and width compared to the widely spaced plants. Similar results have been reported by Mini (1997) in vegetable cowpea.

Fertilizers also significantly increased leaf length and width of yard long bean at all the three stages of crop growth. The fertilizer treatment T_3 where 100% increase over POP was given recorded the maximum value at all the stages. The findings are in agreement with those of Yahiya *et al.* (1996). Application of fertilizers in more than two splits did not have any significant influence as compared to standard application on leaf length and width of yard long bean.

The treatment combination M_1T_3 recorded significantly higher value for leaf length (11.52 cm) at 90 DAS. For leaf width, the combination M_1T_2 showed the maximum value (6.53 cm and 7.33 cm) at 30 and 60 DAS and M_3T_2 (6.13 cm) at 90 DAS which was significantly superior.

Leaf area index of yard long bean was significantly increased by spacing, fertilizer and their interaction at all the three stages of crop growth (Figure 5.1 and 5.2). Maximum leaf area index was seen for the closer spacing M_1 (0.69, 2.27 and 3.15) at all the three stages compared to wider spacing M_3 (Tables 4.1.5 and 4.1.6). Even though, widely spaced plants showed better performance for leaf area, the increase was not proportional to the increase in land area occupied by the crop. This might have resulted in a reduction in the leaf area index of widely spaced plants. Mini (1997) also reported similar results in vegetable cowpea.

Increase in fertilizer doses significantly increased the leaf area index of the crop. Highest value was recorded by the fertilizer treatment T_3 (0.72, 1.69 and 2.20), which received the maximum amount of fertilizers (0.72, 1.69 and 2.20). Similar results were obtained by George (1981) in pulse cowpea, Chandran (1987) and Geetha (1999) in vegetable cowpea.

The interaction effect of spacing and fertilizer was also significant on leaf area index of yard long bean. The combination M_1T_3 with 1.5 m x 0.25 m spacing and 100% increase over POP was found to be the best at all the three stages of crop growth (1.219, 2.810 and 4.132).

Application of fertilizers in split doses resulted in a decreased leaf area index compared to application at two splits as per package of practices recommendation.

In general root:shoot ratio decreased with age of the crop (Tables 4..1.5 and 4.1.6). Root:shoot ratio was found to be unaffected by different fertilizer and spacing treatments at all stages of crop growth. There was increase in root and shoot weight with increase in levels of fertilizers, but the ratio remained the same.

In general, the growth characters of yard long bean increased with increase in levels of fertilizers and spacing. The plant nutrient contents at the vegetative stage were also found to be high in the treatments that received higher amounts of fertilizers in inorganic form. The improved plant growth can be directly attributed to increase in plant nutrient content. Low nutrient content was observed in plants receiving cow dung slurry alone especially during vegetative stage. This may be due to low rate of mineralisation from cow dung slurry, which might have resulted in reduced availability of nutrients in these treatments. This might have affected the

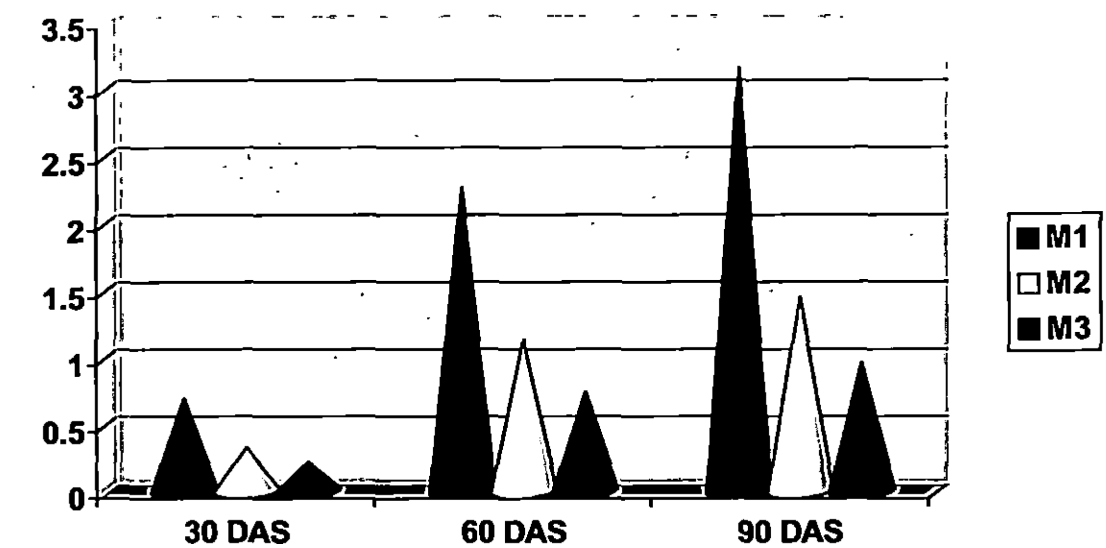

Figure 5.1. Leaf area index of yard long bean as influenced by different spacings

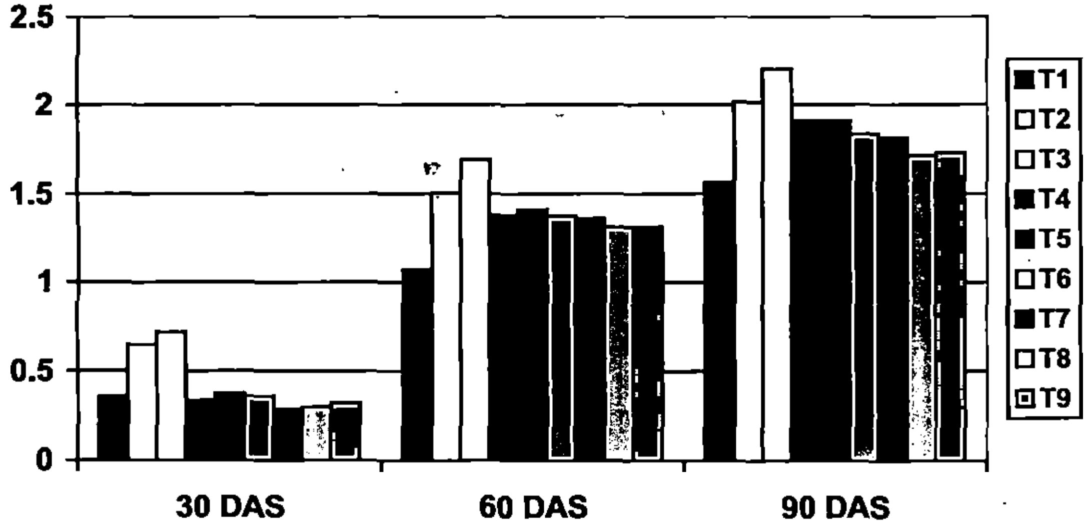

Figure 5.2. Leaf area index of yard long bean as influenced by fertilizer

growth characters of these plants. Reduction in plant growth by applying FYM alone was also reported by Joseph (1985) in oriental pickling melon and Reddy *et al.* (2002) in tomato. Split application of fertilizers was not found to be beneficial regarding growth characters of yard long bean. In general, standard recommendation was found to be inferior to increased doses of chemical fertilizers (50% and 100%), but superior to treatments that received FYM alone.

5.2. EARLINESS

Days to first flowering and first harvest were significantly influenced by spacing and fertilizer treatments (Tables 4.2.1 and 4.2.2). Early flowering and harvest was noticed in high-density treatments compared to low-density treatment. This is in agreement with the observations of Mini (1997). Due to competition for resources, the plants grown under closer spacing might have experienced a stress because of which they have switched to reproductive phase earlier than those grown under wider spacing.

Significantly early flowering and harvest was noticed in treatments that received FYM alone and chemical fertilizers in lower doses (8.51and 8.31 days). Similar results have been reported by Tewari and Singh (2000) in French bean and Swaroop *et al.* (2001) in cowpea.

5.3. YIELD ATTRIBUTES

Yield contributing characters of yard long bean viz. length of pods, pod weight and number of pods per plant were significantly increased with increase in spacing and fertilizers (Figure 5.3 and 5.4). Wider spacing in general favoured these characters except for pod weight. Better vegetative growth and consequent photosynthetic rate might have positively reflected on the yield attributes in the case of widely spaced plants. The results are in agreement with that of Ramamurthy *et al.* (1990) in grain cowpea, Mini (1997) in vegetable cowpea and Singh (2000) in French bean.

The increase in yield attributes might be a direct consequence of growth characters and better uptake of nutrients due to increased dose of fertilizer application. Highest value for number of pods per plant, pod length and pod weight was recorded for 100% increase over POP applied in 2 splits (35.04), 100% increase over POP applied in 5 splits (51.35 cm) and 50% increase over POP applied in 5 splits (19.14 g) respectively (Tables 4.3.1 and 4.3.2). Similar results were also reported by Chandran (1987), Jyothi (1995) and Swaroop *et al.* (2002) in cowpea.

The decrease in yield attributès in organic treatments may be due to decreased availability and consequent low uptake of nutrients thereby resulting in a reduced initial growth. The low mineralisation of nutrients from FYM might have resulted in a decreased availability of nutrients and consequently a lower uptake. The results are supported by the findings of Joseph (1985) in oriental pickling melon and Reddy *et al.* (2002) in tomato.

5.4. YIELD

Green pod yield per plant and productivity was significantly increased by different spacing and fertilizer treatments and their interactions (Tables 4.2.1 and 4.2.2 and Figures 5.5 and 5.6). Wider spacing M_3 (1.5 m x 0.75 m) produced more pod yield per plant (435.663 g) compared to closer spacing M_1 (1.5 m x 0.25 m). This may be the direct consequence of improved growth characters, nutrient uptake and yield attributes. This is in conformity with the findings of Singh (2000) in French bean and Mini (1997) in vegetable cowpea. Productivity was maximum (6.73 t ha^{-1})

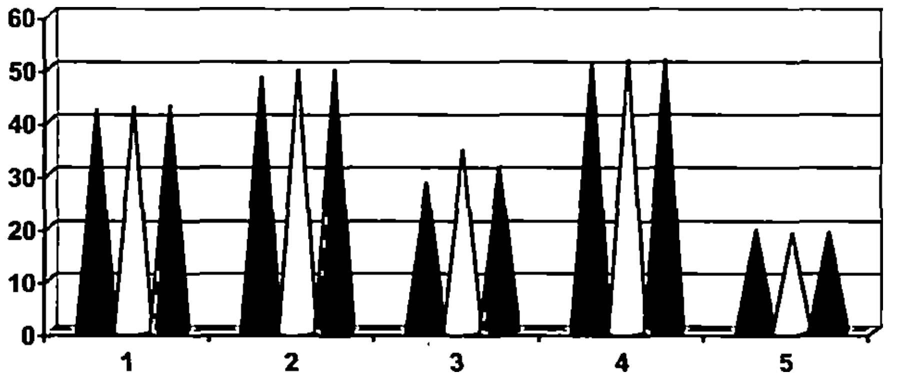

Figure 5.3. Yield attributes of yard long bean as influenced by spacing

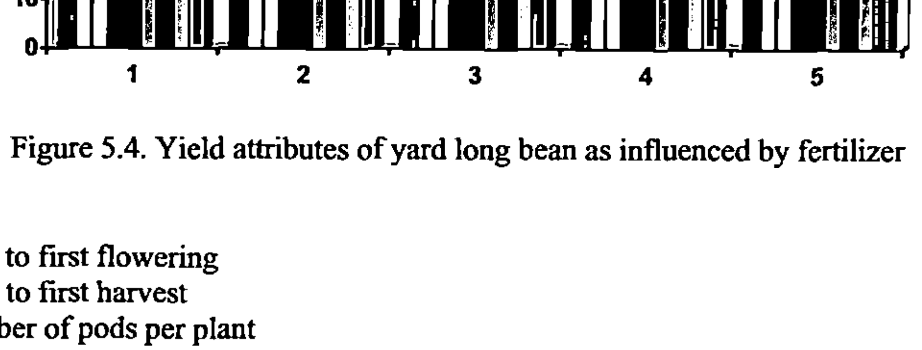

Figure 5.4. Yield attributes of yard long bean as influenced by fertilizer

1 : Days to first flowering
2 : Days to first harvest
3 : Number of pods per plant
4 : Pod length (cm)
5: Pod weight (g)

in lower spacing treatment M_1 (1.5 m x 0.25 m). This was due to higher plant population in closer spacing (26666.67) compared to wider spacing (8888.89) that contributed to increased pod yield per hectare. The decrease in per plant yield in closer spacing was only 42% whereas, the increase in per hectare yield due to increased plant population was three fold. The increased yield per plant in wider spacing could not surpass the yield increase in plant population in closer spacing. Singh (2000) also reported similar results in French bean.

Application of increased doses of fertilizers influenced the yield per plant and consequently yield per hectare of yard long bean. Even though, package of practices recommendation for cowpea is 20: 30: 10 kg NPK ha^{-1} (KAU, 1996), in the present study, maximum response (385.96 g and 5.66 t ha^{-1}) was obtained for 40: 60: 20 kg NPK ha^{-1} (T_3). The higher vegetable yield might be the direct effect of improved growth, nutrient uptake and yield attributes. Such a positive relationship between yield and yield components has been observed by Singh (1985) and Geetha (1999) in cowpea. Kumar *et al.* (1976) reported that pod yield in cowpea was ultimately associated with number of pods per plant, length of pods, number of seeds per pod and pod weight. In the present study also, the highest fertilizer dose T_3 recorded maximum values for pods per plant, length of pods and pod weight.

The treatment combination M_3T_3 (wider spacing with highest level of fertilizers in two splits) recorded the maximum yield per plant (480.27 g) and the combination M_1T_3 (closest spacing with highest level of fertilizers) produced maximum green pod yield per hectare (7.33 t ha^{-1}) but was on par with M_1T_2 (closest spacing with 50% increase in fertilizers) and M_1T_6 (closest spacing with highest level of fertilizers in five splits). Though application of fertilizers in five splits did not show any superior effect when fertilizers alone were considered, they had influence when interaction was considered. At closer spacings, application of fertilizers in more split doses may be advantageous

In plots that received organic manures alone, nutrient content of plants were found to be lower than chemical fertilizer treated plots. This may be the reason for reduced pod yield in organically treated plots. The nutrients may not be available to plants at the critical stage of crop growth Similar results were also obtained by Joseph (1985) in oriental pickling melon.

Correlation studies have shown that P and K content at flowering stage of the crop is positively correlated with pod yield in yard long bean. Phosphorus and potassium contents at flowering stage are low in FYM alone treated plots compared to chemical fertilizer treatments. Iron content at flowering and maturity stage of the crop had high negative correlation with yield. The organic treatments recorded high values for iron content. All these might have contributed to low yield in treatments receiving FYM alone (Mengel and Kirkby, 1987).

The pod yield per hectare recorded by treatments that received the maximum dose of fertilizers as per standard recommendation (two splits) was found to be significantly higher when compared to same dose of nutrients applied in five splits. In legumes like cowpea branching stage was more critical than pod formation stage. Here the demand for nitrogen in reproductive phase was low (Ghosal *et al.* (2000). Split application of nutrients was not found to be beneficial for improving the yield of yard long bean, though the nutrient content of plants was found to be better with split application. The split given may not be at the critical stage of plant growth. The finding was in agreement with that of Robertson *et al.* (1977).

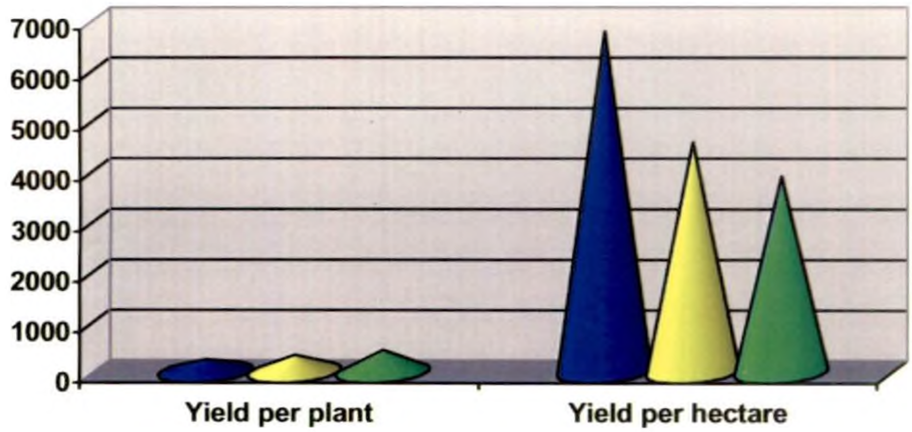

Figure 5.5. Yield of yard long bean as influenced by spacing

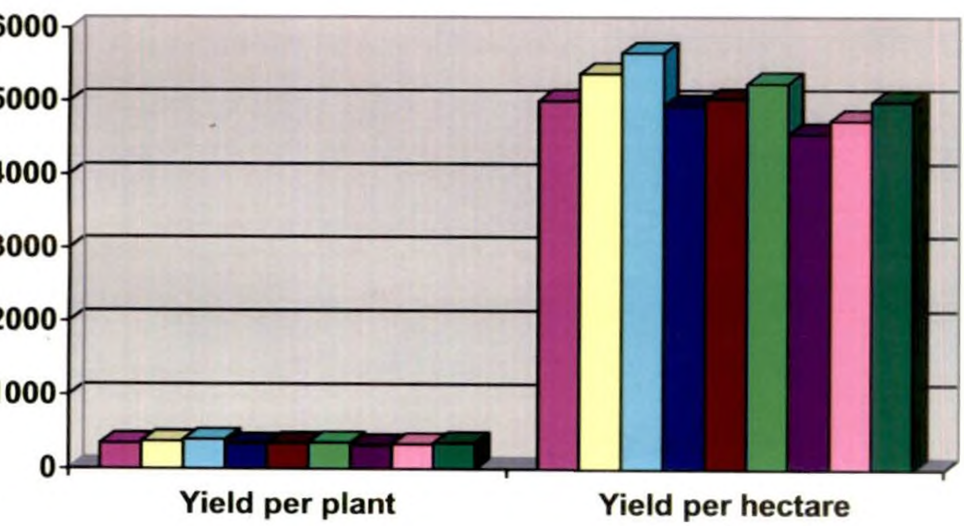

Figure 5.6. Yield of yard long bean as influenced by fertilizer

5.5. SOIL NUTRIENT STATUS AFTER THE EXPERIMENT

Soil physical parameters pH and chemical parameters organic carbon, available potassium, available magnesium and available iron status of the soil after the experiment did not differ significantly with varying levels of spacing (Tables 4.5.1 and 4..5.2). But there was significant difference in available phosphorus and calcium among the spacing treatments. Lime was applied uniformly to all the plots irrespective of treatments. Since plant population is more in closer spacing M_1, there could be more uptake of Ca from the soil. The calcium content of plants was also higher in closely spaced plants. All these have contributed to lower Ca content of the soil after the experiment.

There was significant influence for fertilizer on the soil nutrient status after the experiment. Since lime was applied uniformly to all the plots irrespective of treatments, those which received higher doses of fertilizers (T_3, T_6) registered lower increase in pH (5.280 and 5.330) compared to those, which received lower fertilizers (T_7, T_8). Application of higher levels of fertilizers in general improved the available nutrient status after the crop. This might be due to the reason that the crop had tapped more nutrients from the applied fertilizer with little depletion from soil pool. Similar results have also been reported by Gill *et al.* (1972), Faroda and Tomar (1975), and Geetha (1999) in cowpea.

In the case of application in five splits, there is increased uptake by the crop. That might be the reason for lower nutrient status of the soil.

In organically treated plots, in general, soil nutrient status after the experiment was high and plant uptake was less. The nutrients may not be available at the correct stage of crop growth in this case. But it might have become available towards the end of crop growth as is evident from the enriched nutrient status after the experiment, which is of no use for the crop.

5.6. PLANT NUTRIENT CONTENT

The content of N, Ca, Mg and Fe increased with age of the plant while that of P and K decreased with age (Figure 5.7). Mengel and Kirkby (1987) also reported similar results.

There was significant influence for spacing, fertilizers and their interactions on plant nutrient content at different stages of crop growth (Tables 4.6.1 – 4.6.12). Spacing exerted significant influence on P and K contents of plants at flowering stage and after harvest in yard long bean. At vegetative stage, the effect was not significant. Similarly, the effect of spacing was not significant on plant N content at all the three stages of crop growth. This could be attributted to the symbiotic N fixation in cowpea. At flowering stage, the P and K contents were maximum for the wider spacing M_3 (0.32 and 2.28%). This could be due to lesser competition among plants due to wider spacing. Mini (1997) also observed that plant nutrient uptake was less in high density planting. For minor nutrients Ca, Mg and Fe, the medium spacing M_2 was found to show better results. This might be due to competition between major and minor nutrients for uptake. This is further supported by the negative correlation between soil P content and Ca content of plants and soil K content and plant Mg. Similar results were also reported by Mengel and Kirkby (1987).

Application of NPK at higher levels resulted in higher content of above nutrients in the plant parts. T_3 recorded the maximum value for N content at all the three stages (2.61, 3.73 and 4.85%). For P and K, a definite pattern was not visible.

The treatments T_5, T_6 and T_2 recorded the maximum contents at vegetative, flowering and after harvest (0.39, 0.34 and 0.30%). The content was less in standard recommendation and organic treatments. For K, T_3 was superior to other treatments at vegetative stage (3.29%), T_6 at flowering stage (2.63%) and T_5 at after harvest stage (1.52%). Here also package of practices recommendation and organic treatments were inferior. The treatment T_5 (1.79, 2.66 and 2.78%) was superior for Ca content also. For Mg content T_2 was superior during vegetative and flowering stages (0.75 and 1.00%), while after harvest highest content was recorded for T_5 (2.95%). For iron, organic treatment T_7 (0.105, 0.165 and 0.205%) was found to be superior. But higher Fe content is detrimental to yield, which may be the reason for low yield in T_7.

Though split application of fertilizers resulted in a better plant nutrient content, they produced lower yields compared to standard application in two splits. This may be because, the split given may not be at the correct stages of crop growth, which had resulted in deficiency of those nutrients at the critical stages and ultimately reduced the crop yield. Nutrient content in pods is low in split application especially those of P and K. This shows lesser partitioning of nutrients to economic parts in split application due to deficiency at critical stages. This also supports the reduced yield obtained in split applications.

5.7. QUALITY OF PODS

Quality of pods was measured in terms of its moisture content, crude protein, carbohydrate, minerals (P, K, Ca and Fe) and crude fibre. In general, organically grown pods had higher values for the above quality attributes.

Spacing did not exert any significant influence on the quality parameters of pods except for crude fibre content. Closer spacing M_1 was better than wider

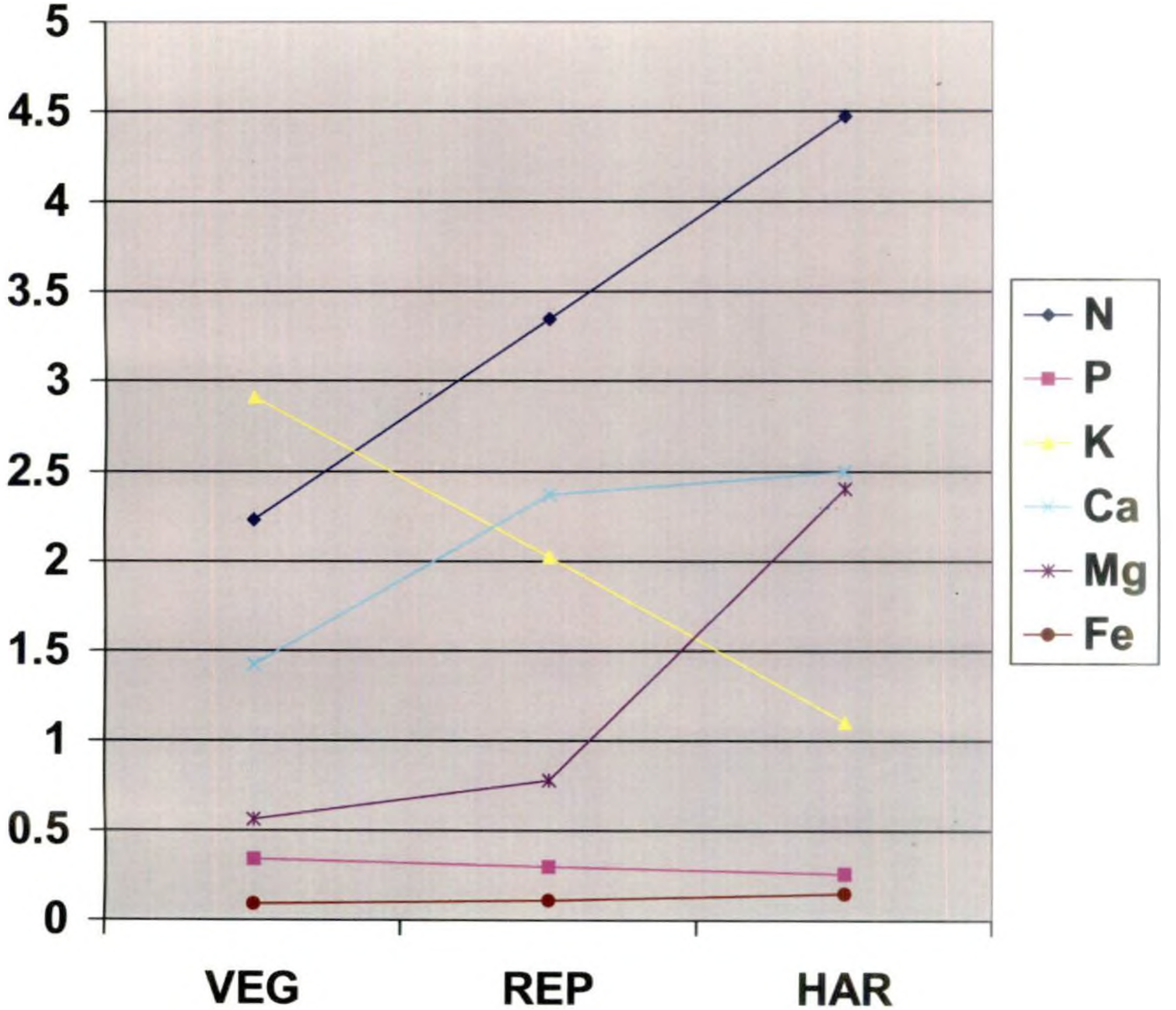

Figure 5.7. Plant nutrient content at the three stages of crop growth

spacing. Kumar *et al.* (1997) also reported that spacing will not affect crude protein content in cowpea.

Fertilizers significantly improved the quality parameters of cowpea pods. Higher moisture content was seen for organically produced pods (95.76, 95.52 and 95.55%). The results conformed to those obtained by Nandini (1998) in okra. Crude protein was not significantly altered by fertilizer treatments. Similar results were also recorded by Malik *et al.* (1972), Chandran (1987) and Jain *et al.* (1993) in cowpea. Maximum carbohydrate content was obtained with organic treatment T_9 (4.22%). Prasanna (1998) also obtained similar result in brinjal. Mineral content of yard long bean pods were significantly increased with increase in fertilizer application. Maximum P and K contents were noticed in T_3 (0.51 and 2.32%) due to better partitioning of nutrients. Organic treatments recorded the highest values for Ca and Fe. The results were in agreement with the results obtained by Luzzati *et al.* (1975) and Vityakom and Seripong (1988). Crude fibre content was low in organically treated plots and in those that received lower doses of fertilizers. This was in conformity with those of Singh and Rajput (1985) and Geetha (1999) in cowpea.

5.8. STORAGE STUDY

There was a steady decline in the moisture content of pods during storage irrespective of the treatments (Joseph, 1985). Influence of fertilizers on moisture loss was only in the first two days of storage. At this stage, organic treatments were found to have reduced moisture loss than inorganic treatments. Superiority of organic manures over inorganic fertilizers in reducing moisture loss in storage was also reported by Joseph (1985) in oriental pickling melon, Prasanna (1998) in brinjal and Narayanankutty et al. (2002) in ashgourd and oriental pickling melon.

The moisture loss was less in zero energy cool chamber than under ambient conditions. This may be due to reduced temperature and higher relative humidity in zero energy cool chamber (village model) than in ordinary conditions. Veenakumari (1992) also obtained comparable results in bittergourd.

The percentage of unmarketable fruits increased with the period of storage. Significantly lesser percentage of damage was observed for organic treatments. Increased doses of nitrogen improve the efficiency of metabolism. The increased metabolic efficiency due to nitrogen application might have resulted in a faster senescence process resulting in an early spoilage as observed by Veenakumari (1992) in bittergourd and Prasanna (1998) in brinjal.

The storage life was only 3 days in zero energy cool chamber compared to 5 days under open condition. The pods were found to be completely rotten by fungal attack in village model cool chamber after 3 days. This may be due to high protein content of pods, which made the pods vulnerable to fungal growth under high humidity conditions (Jenkins, 1954 and Dasgupta and Mandal, 1989). High protein foods are preferred by microbes due to their narrow C:N ratio.

Split application was better compared to standard application of chemical fertilizers on the storage quality of the pods under both conditions of storage. This may be due to lesser nutrient content in split applications.

5.9. PALATABILITY STUDY

The effect of spacing, fertilizer and their interaction on organoleptic quality of yard long bean pods were significant. The spacing treatment M_1 recorded maximum value in palatability study. The superiority of closer spacing may be due to lesser crude fibre content in pods. Prasanna (1998) also reported that lowest dose of nitrogen recorded the highest score for flavour, texture and taste. The organic treatments recorded better organoleptic qualities compared to inorganic treatments owing to lesser crude fibre content. The superiority of organic treatments was also established by Nandini (1998) in bhendi and Prasanna (1998) in brinjal.

5.10. ECONOMIC ANALYSIS

Spacing, fertilizers and their combinations significantly affected the net returns and B: C ratio of yard long bean (Figure 5.8, 5.9, 5.10, 5.11, 5.12, and 5.13).

Highest net returns and B: C ratio was realized in closer spacing. This was due to increased plant population in closer spacing that contributed to higher total yield. The closer spacing resulted in a three fold increase in plant population. The corresponding reduction in per plant yield was only 42%. This has contributed to highest net returns since the increase in cost of seeds was only marginal when compared to the increase in the economic value realized from the harvested produce. Singh (2000) also reported similar result in French bean.

The fertilizer treatment T_3 with 100% increase in POP in two splits (16790 Rs ha^{-1} and 1.42) recorded maximum net returns and B:C ratio compared to all other treatments. This was due to significantly higher yield obtained in this treatment. Application of fertilizers in more than two splits was also not beneficial since it demands additional application charges with little or no increase in yield.

Organic treatments recorded lower net returns and B: C ratio due to lesser yield coupled with increased cost of farmyard manure compared to chemical fertilizers. This must be compensated by increased price offered for organically

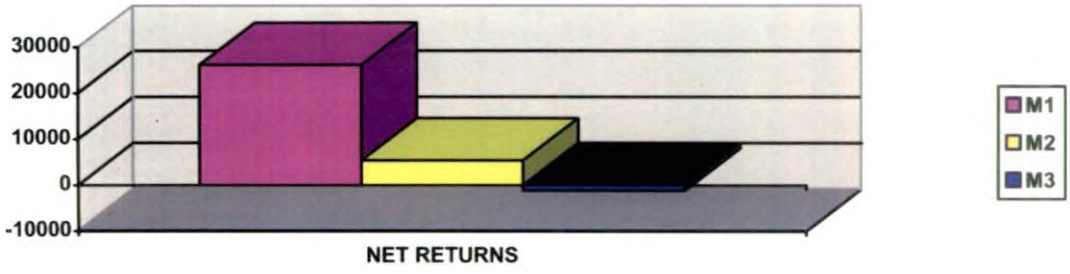

Figure 5. 8.Net returns as influenced by spacing

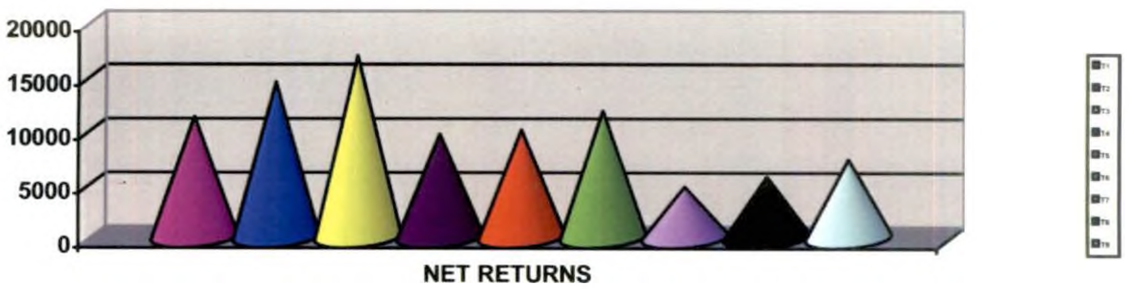

Figure 5. 9.Net returns as influenced by fertilizers

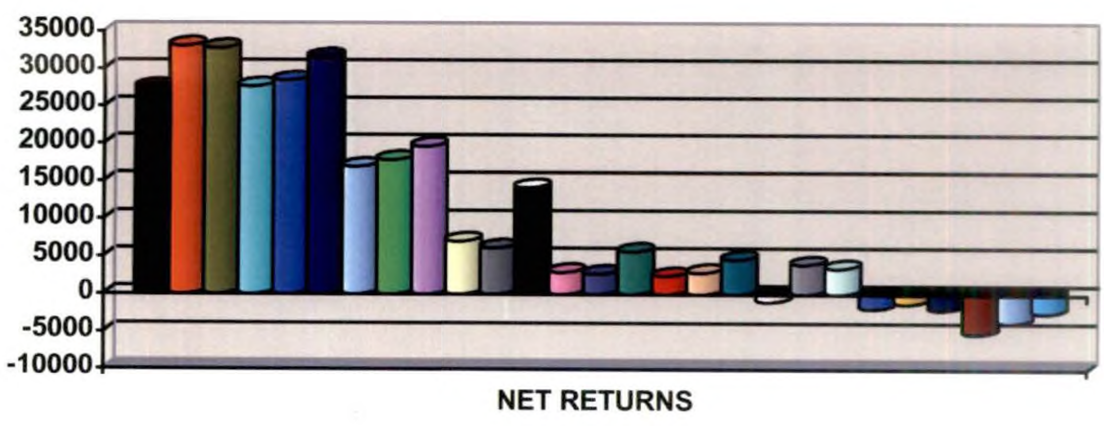

Figure 5. 10. Net returns as influenced by interaction effects

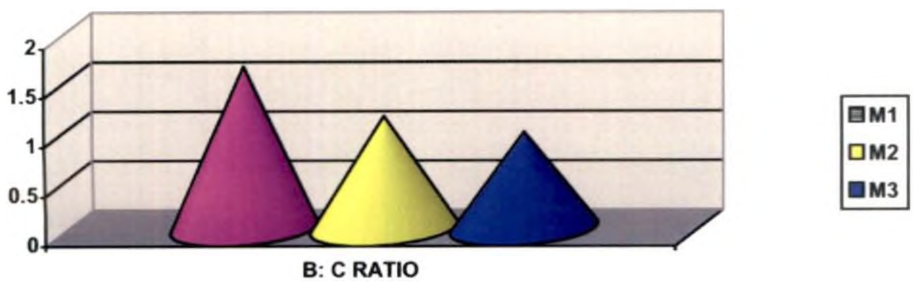

Figure 5.11 B:C ratio as influenced by spacing

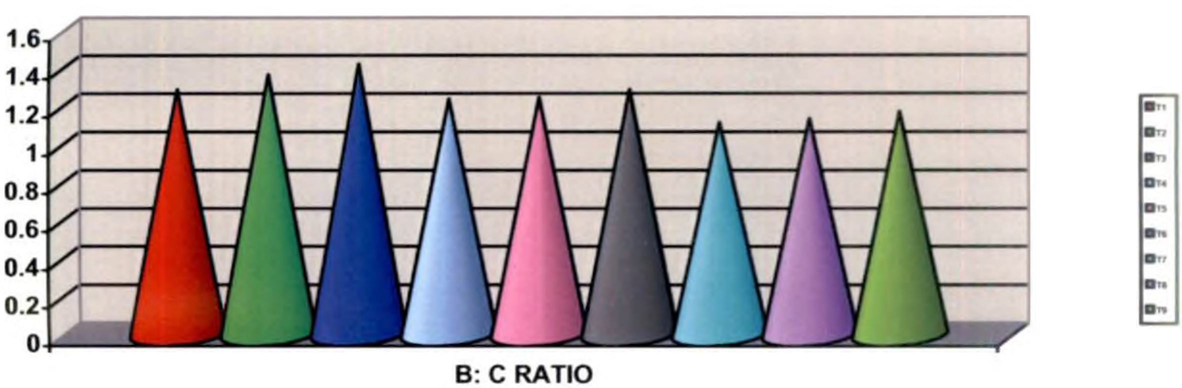

Figure 5.12. B:C ratio as influenced by fertilizers

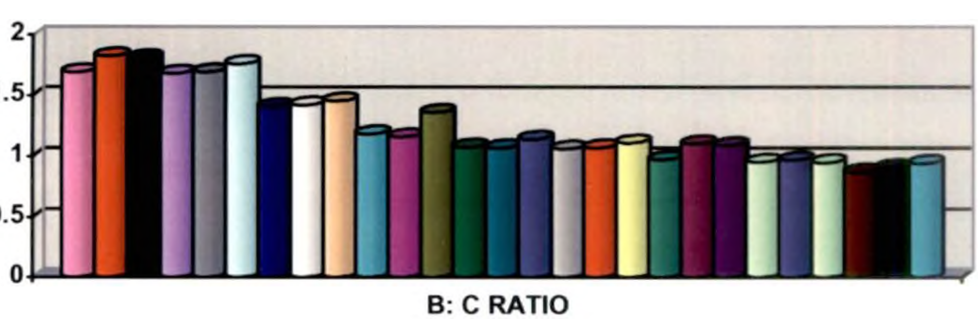

Figure 5. 13. B:C ratio as influenced by interaction effects

grown produce. In the present study B:C ratio was worked out fixing the same price (Rs 10 kg^{-1}) for the produce in all the treatments. This has resulted in reduced net returns and B:C ratio of the crop in organic treatments. The B:C ratio can be increased to 1.5 if premium price (Rs 15 kg^{-1}) is obtained for organic produce. Then it will be economically feasible and acceptable with additional advantages of superior storability and palatability.

The treatment combination M_1T_2 was the ideal combination from economic point of view (33030 Rs ha^{-1} and 1.82), though higher yields were obtained with the combination M_1T_3. The increase in yield with a 50% increase in dose of fertilizers was not significant when compared to the increase in cost of cultivation. So the combination of 1.5 m x 0.25 m spacing and 40: 60: 20 kg NPK ha^{-1} fertilizers applied in two splits – half N, full P and full K as basal and remaining half N 20 DAS was ideal from economic point of view.

FUTURE LINE OF WORK

In the present study, only an average yield (7 t ha-1) was obtained when compared to the production potential of the variety (10-12 t ha-1). Under intensive cultivation as practiced by farmers the crop will respond to application of increased doses of fertilizers in more split doses. So the effect of split application needs further research.

Summary

6. SUMMARY

The study entitled "Productivity management in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt) through crop geometry and nutrition" was undertaken at the Department of Olericulture, College of Horticulture, Vellanikkara during 2002-2004. The field expeiment was conducted during December to April of 2003-2004 in the rice fallows at Agricultural Research Station, Mannuthy. The soil of the experimental field was clayey in texture, acidic in reaction, medium in available nitrogen, phosphorus and potassium. The experiment was laid out in split plot design with spacing in mainplot and fertilizers in subplots. The treatments comprised of three spacing (M_1 - 1.5m x 0.25m, M_2 - 1.5m x 0.50m, M_3 - 1.5m x 0.75m) and 9 fertilizer treatments

T_1- POP recommendation (20: 30: 10 kg NPK ha^{-1} – half N, full P and full K as basal and half N 20 days after sowing (DAS))

T_2- 50% increase over POP (30: 45: 15 kg NPK ha^{-1} in 2 splits as in T1)

T_3- 100% increase over POP (40: 60: 20 kg NPK ha^{-1} in 2 splits as in T1)

T_4- 20: 30: 10 kg NPK ha^{-1} – N and K in 5 equal splits – basal, 20, 40, 60, and 80 DAS and full P as basal

T_5- 30: 45: 15 kg NPK ha^{-1} in 5 splits as in T4

T_6- 40: 60: 20 kg NPK ha^{-1} in 5 splits as in T4

T_7- 4 t ha^{-1} cow dung (equivalent to 20 kg N ha^{-1}) as slurry application in 4 equal splits- 20, 40, 60, and 80 DAS

T_8- 6 t ha^{-1} cow dung (equivalent to 30 kg N ha^{-1}) as slurry application in 4 equal splits- 20, 40, 60, and 80 DAS

T_9- 8 t ha^{-1} cow dung (equivalent to 40 kg N ha^{-1}) as slurry application in 4 equal splits- 20, 40, 60, and 80 DAS

Observations were made on the growth and yield attributing characters of the crop. Nutrient content of plant and pod were analysed. Storability and palatability of pods and

economics of various treatments were calculated. The data were statisitically analysed and the results of the study are summarized below.

1. Number of primary branches, internodal length and leaf area index of yard long bean increased progressively with age of the crop. Root:shoot ratio decreased as the age of the plant increased.
2. For growth characters like number of primary branches, internodal length, leaf length and leaf width the wider spacing of 1.5 m x 0.75 m was found to be better. The effect of fertilizers was insignificant on number of primary branches and internodal length at all the three stages of crop growth. For leaf length and leaf width, the treatments T_2, T_3, T_4, and T_5 were found to be superior.
3. Spacing, fertilizer and their interactions significantly affected leaf area index of yard long bean. The closer spacing 1.5 m x 0.25 m and the treatment with 100% increase over POP recorded the maximum value at all the three stages of crop growth. The combinations M_1T_2 and M_1T_3 were superior at all stages of crop growth.
4. The effect of split application of fertilizers on the growth characters of yard long bean was not significant. Vegetative growth was less in the organic treatments.
5. Earliness in flowering and harvesting was noticed at closer spacings, organic treatments and in lower doses of fertilizers and their combinations.
6. Pods per plant were maximum in medium spacing M_2 (1.5 m x 0.5 m), fertilizer treatment T_3 and its combination M_2T_3. Length of pods was significantly higher in M_3 and M_2 and fertilizer treatments T_6, T_5 and T_2. The interaction was also significant and the combinations M_3T_6, M_3T_5, M_2T_5, and M_2T_3 were the best. Maximum pod weight was recorded for M_1.
7. There was significant influence for spacing, fertilizers and their combinations on pod yield per plant and productivity of yard long bean. Wider spacing M_3 (1.5 m x 0.75 m) produced significantly more pod yield per plant (435.66 g) compared to closer spacing M_1. Application of increased doses of fertilizers positively influenced the yield per plant and consequently productivity of yard long bean. Even though, package of practices recommendation for cowpea is 20: 30: 10 kg

NPK ha^{-1} (KAU, 1996), in the present study, maximum response (385.96 g and 5.66 t ha^{-1}) was obtained for 40: 60: 20 kg NPK ha^{-1} (T_3). The treatment combination M_3T_3 (wider spacing with highest level of fertilizers) recorded the maximum yield per plant (480.27 g) and the combination M_1T_3 (closest spacing with highest level of fertilizers) produced maximum green pod yield per hectare (7.33 t ha^{-1}). Split application of fertilizers was not found to increase the yield of yard long bean. Organic treatments recorded the lowest yield. Split application of fertilizers was not found to increase the yield of yard long bean. Organic treatments recorded the lowest yield.

8. Spacing, fertilizers and their combinations significantly affected the net returns and B: C ratio of yard long bean. Highest net returns and B:C ratio was realized in closer spacing. The fertilizer treatment T_3 (100% increase over POP) recorded maximum net returns (16790 Rs ha^{-1}) and B:C ratio (1.42) compared to all other treatments. But the increase in net returns and B:C ratio over the treatment with 50% increase over POP (T_2) was only marginal. The treatment combination M_1T_2 was the ideal combination from economic point of view (33030 Rs ha^{-1} and 1.82).
9. Regarding quality of pods, organic treatments were found to be superior. Moisture content of pods was maximum for T_7, T_8 and T_9. Spacing had no significant influence on moisture content of pods. Crude protein content of pods was unaltered by various treatments. Carbohydrate content of pods was significantly increased by fertilizers. The treatments T_9 and T_6 were superior. Mineral content (P, K, Ca, Fe) of pods was significantly altered by various fertilizer combinations. Maximum P and K contents were noticed in T_3 while organic treatments recorded the highest values for Ca and Fe. Crude fibre was low in organic treatments.
10. Organic treatments recorded maximum values for available P, K, Ca, Mg and Fe contents in the soil after the experiment. The values were maximum for lower spacing M_1. In the case of split application in general, nutrient status of the soil after the experiment was lower.
11. The content of N, Ca, Mg and Fe increased with age of the plant while that of P and K decreased with age. Spacing exerted significant influence on P and K

contents of plants at flowering stage and after harvest in yard long bean. At vegetative stage, the effect was not significant. Similarly, the effect of spacing was not significant on plant N content at all the three stages of crop growth. For minor nutrients Ca, Mg and Fe, the medium spacing M_2 was found to show better results. Application of NPK at higher levels resulted in higher content of above nutrients in the plant parts. T_3 recorded the maximum value for N content at all the three stages. For P and K, a definite pattern was not visible. The treatments T_5, T_6 and T_2 recorded the maximum contents at vegetative, flowering and after harvest. The nutrient content was low in control plot and in organic treatments. For K, T_3 was superior to other treatments at vegetative stage, T_6 at flowering stage and T_5 at after harvest stage. The treatment T_5 was superior for Ca content also. For Mg content T_2 was superior during vegetative and flowering stages, while after harvest highest content was recorded for T_5. For iron, organic treatment T_7 was found to be superior.

12. Organic treatments were found to be superior regarding storage quality of pods. Moisture loss during storage and percentage of unmarketable pods were low in organic treatments. Zero energy cool chamber was not found suitable for cowpea storage as there was fungal attack to pods due to high humidity condition prevailing inside. Organoleptic quality of pods was also superior in organic treatments compared to inorganic treatments.

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* Originals not seen

Appendix

Appendix 1
Weekly averages of weather parameters during the cropping period
(December to April 2003-2004)

Parameters	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Mean relative humidity (%)	Evapo transpiration (mm)	Sunshine (hrs)	Wind (km hr^{-1})	Soil temperature (°C)
3.12.03-9.12.03	32.0	22.7	68	6.2	10.0	9.1	25.7
10.12.03-16.12.03	31.9	20.0	75	5.2	8.1	5.4	25.0
17.12.03-23.12.03	32.0	21.6	75	5.0	8.6	6.3	26.2
24.12.03-31.12.03	32.9	22.9	78	6.2	9.3	9.1	27.3
1.1.04-7.1.04	32.5	22.8	75	6.2	9.5	8.7	27.2
8.1.04-14.1.04	32.3	22.2	72	7.9	9.93	11.4	26.7
15.1.04-21.1.04	33.9	21.0	63	6.0	9.9	6.7	27.1
22.1.04-28.1.04	34.3	22.7	71	5.4	9.3	5.1	28.1
29.1.04-4.2.04	34.5	22.8	78	5.7	9.4	5.1	29.0
5.2.04-11.2.04	34.5	23.0	73	5.5	8.6	5.6	29.0
12.2.04-18.2.04	35.0	23.0	63	7.8	9.9	8.6	28.2
19.2.04-25.2.04	36.1	21.5	56	7.7	10.1	6.1	28.2
26.2.04-4.3.04	36.5	22.5	79	7.0	9.7	4.6	30.0
5.3.04-11.3.04	37.0	23.6	73	7.4	9.6	5.7	31.1
12.3.04-18.3.04	38.6	24.5	81	7.8	9.1	4.2	32.0
19.3.04-25.3.04	34.5	25.0	88	5.9	7.3	4.3	32.6
26.3.04-1.4.04	35.1	24.5	88	5.7	7.6	4.4	31.5
2.4.04-8.4.04	33.6	24.2	84	5.0	6.5	4.1	29.7
9.4.04-15.4.04	35.4	25.8	82	6.0	8.2	4.2	32.1
16.4.04-22.4.04	35.2	25.8	85	5.7	7.9	4.5	32.4

Appendix 2

Analysis of variance table for different observations

Mean square

Source	Degrees of freedom	Number of branches			Internodal length		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Replication	2	0.404	0.623	0.217	0.149	0.198	0.173
Factor A	2	1.495	0.172	0.638	0.156	0.776*	0.656*
Error	4	0.133	0.295	0.208	0.127	0.100	0.075
Factor B	8	0.393	0.184	0.112	0.126	0.113	0.144
AB	16	0.325	0.212	0.124	0.077	0.072	0.089
Error	48	0.309	0.196	0.116	0.075	0.087	0.102

Source	Degrees of freedom	Leaf length			Leaf width		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Replication	2	0.215	0.114	0.065	0.295	0.825	0.527
Factor A	2	0.010	0.777	1.398*	0.317	0.662	1.636*
Error	4	0.425	0.270	0.177	0.089	0.180	0.201
Factor B	8	0.369	0.473*	0.468**	0.348**	0.274*	0.310*
AB	16	0.256	0.281	0.265*	0.291**	0.282**	0.376**
Error	48	0.208	0.177	0.131	0.109	0.115	0.132

Source	Degrees of freedom	Leaf area index			Root:shoot ratio		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Replication	2	0.003	0.077	0.046	0.001	0.003	0.000
Factor A	2	1.653**	17.026**	35.619**	0.003	0.015*	0.001
Error	4	0.002	0.013	0.021	0.003	0.002	0.001
Factor B	8	0.229**	0.243**	0.310**	0.007	0.001	0.001
AB	16	0.056**	0.090**	0.234**	0.006	0.005**	0.001
Error	48	0.002	0.021	0.025	0.004	0.001	0.000

continued…

Source	Degrees of freedom	Days to 1st flowering	Days to 1st harvest	No: of pods per plant	Length of pods	Pod weight
Replication	2	0.077	0.161	2.826	0.081	0.113
Factor A	2	3.775**	5.018**	252.074**	2.195*	2.243*
Error	4	0.083	0.201	2.009	0.311	0.229
Factor B	8	77.867**	75.731**	34.668**	0.379*	0.621*
AB	16	1.042**	1.241**	6.409**	0.349*	0.441
Error	48	0.217	0.390	1.686	0.169	0.276

Source	Degrees of freedom	Yield per plant	Yield per hectare	Net returns	B:C ratio
Replication	2	272.754	71212.148	7121213.653	0.005
Factor A	2	226510.16**	60269674.213**	5468708823.812**	3.239**
Error	4	179.683	38507.057	3850705.890	0.002
Factor B	8	4283.761**	991325.078**	139566487.292**	0.093**
AB	16	776.556**	255897.848**	25589784.129 **	0.017**
Error	48	217.660	39885.813	3988582.495	0.003

Source	Degrees of freedom	Nitrogen			Phosphorus			Potassium		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Replication	2	0.108	0.108	0.108	0.001	0.000	0.000	0.850	0.019	0.008
Factor A	2	0.074	0.074	0.074	0.006	0.028**	0.034**	0.088	1.343**	0.172**
Error	4	0.039	0.039	0.039	0.002	0.000	0.000	0.306	0.021	0.022
Factor B	8	0.596**	0.596**	0.596**	0.005**	0.010**	0.005**	0.317*	1.418**	0.523**
AB	16	0.104	0.104	0.104	0.001	0.002**	0.005**	0.193	0.610**	0.103**
Error	48	0.097	0.097	0.097	0.001	0.000	0.000	0.145	0.021	0.012

continued….

Source	Degrees of freedom	Calcium			Magnesium			Iron		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Replication	2	0.005	0.043	0.038	0.000	0.001	0.012	0.000	0.001	0.001
Factor A	2	0.811**	0.088*	0.345**	0.064**	0.037**	0.178**	0.009**	0.010**	0.022**
Error	4	0.002	0.006	0.008	0.000	0.003	0.006	0.000	0.003	0.001
Factor B	8	0.287**	0.372**	0.546**	0.125**	0.143**	0.563**	0.001**	0.007**	0.011**
AB	16	0.492**	0.516**	0.344**	0.163**	0.191**	0.086**	0.002**	0.014**	0.008**
Error	48	0.005	0.009	0.020	0.000	0.004	0.017	0.000	0.002	0.001

Soil nutrient status after the experiment

Source	Degrees of freedom	pH	EC	Organic carbon	Available P	Available K	Available Ca	Available Mg	Available Fe
Replication	2	0.808	0.001	0.008	4476.755	1218.132	31566.370	499.152	90.840
Factor A	2	0.285	0.008**	0.031	4359.390 *	4734.321	112927.259**	19573.302	135.387
Error	4	0.135	0.000	0.006	120.865	1051.204	4778.963	14224.726	159.285
Factor B	8	0.204**	0.005**	0.031*	1997.866 **	1063.307**	111901.500**	57216.247**	3304.839**
AB	16	0.145**	0.005**	0.019	1422.558 **	209.423	43624.648*	45301.831**	3202.380**
Error	48	0.038	0.001	0.012	311.538	136.657	18476.210	11548.874	124.942

Quality of pods

Source	Degrees of freedom	Moisture	Crude protein	Carbohydrate	P	K	Ca	Fe	Crude fibre
Replication	2	0.195	9.225	0.052	0.001	0.023	0.036	0.087	0.041
Factor A	2	0.459	41.892	0.021	0.031	0.915*	0.000	0.269*	1.761**
Error	4	0.639	18.299	0.037	0.006	0.070	0.001	0.068	0.085
Factor B	8	11.114**	10.360	0.697**	0.026**	0.755**	0.028**	0.229**	5.971**
AB	16	0.474	10.416	0.042**	0.020**	0.738**	0.014*	0.379**	0.900**
Error	48	0.274	7.448	0.021	0.004	0.098	0.006	0.061	0.078

Organoleptic evaluation

Source	Degrees of freedom	Flavour	Taste	Texture	Appearance
Replication	2	0.006	0.019	0.031	0.030
Factor A	2	0.229*	0.219*	0.219*	0.184
Error	4	0.016	0.021	0.017	0.005
Factor B	8	3.641**	3.676**	3.663**	3.624**
AB	16	0.065	0.064	0.065*	0.066*
Error	48	0.034*	0.030*	0.032	0.033

continued…

Percentage of moisture loss under storage under ambient conditions

Source	Degrees of freedom	1st day	2nd day	3rd day	4th day	5th day
Replication	2	0.661	1.869	3.027	5.004	7.475
Factor A	2	0.177	0.655	1.062	1.755	2.621
Error	4	1.684	4.206	6.814	11.263	16.825
Factor B	8	9.680 **	1.994	3.231	5.341	7.978
AB	16	0.934	2.359	3.821	6.316	9.435
Error	48	0.684	1.721	2.787	4.607	6.882

Percentage of moisture loss under storage in zero energy cool chamber

Source	Degrees of freedom	1st day	2nd day	3rd day	4th day	5th day
Replication	2	0.214	2.202	3.915	8.810	15.662
Factor A	2	0.001	0.400	0.711	1.599	2.843
Error	4	0.075	0.515	0.916	2.062	3.666
Factor B	8	17.148**	0.197	0.350	0.787	1.399
AB	16	0.316**	0.738**	1.311**	2.950**	5.245**
Error	48	0.033	0.205	0.364	0.820	1.457

Percentage of unmarketable fruits under both conditions of storage

Source	Degrees of freedom	% of unmarketable fruits on 3rd day in ambient conditions	% of unmarketable fruits on 5th day in ambient conditions	% of unmarketable fruits on 3rd day in zero energy cool chamber
Replication	2	4.938	53.086	3.704
Factor A	2	123.457	60.494	177.778
Error	4	29.012	29.012	31.481
Factor B	8	449.383**	373.457**	405.556**
AB	16	16.512	32.716	29.167
Error	48	27.932	28.704	29.167

Appendix 3

Organoleptic evaluation

No.	Character	Description	Score
1	Appearance	Excellent	5
2		Good	4
3		Fair	3
4		Poor	2
5		Very poor	1
1	Flavour	Excellent	5
2		Good	4
3		Fair	3
4		Poor	2
5		Very poor	1
1	Texture	Excellent	5
2		Good	4
3		Fair	3
4		Poor	2
5		Very poor	1
1	Taste	Excellent	5
2		Good	4
3		Fair	3
4		Poor	2
5		Very poor	1

Appendix 4

Cost of cultivation of yard long bean (Rs ha^{-1})

Cost of cultivation of yard long bean as per standard recommendation– Rs 38333 ha^{-1}

Additional costs incurred in various treatments

Spacing

Particulars	M_1	M_2	M_3
Seed rate (kg ha^{-1})	7	3.5	2.5
Cost per kilogram	300	300	300
Cost of seeds (Rs)	2100	1050	750

Fertilizers

Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T9
Urea (kg ha^{-1})	43.5	65.2	86.9	43.5	65.2	86.9	-	-	-
Cost (Rs)	217.4	326.1	434.8	217.4	326.1	434.8	-	-	-
Rajphos (kg ha^{-1})	166.7	250	333.3	166.7	250	333.3	-	-	-
Cost (Rs)	583.3	875	1166.7	583.3	875	1166.7	-	-	-
Potash (kg ha^{-1})	16.7	25	33.3	16.7	25	33.3	-	-	-
Cost (Rs)	83.3	125	166.7	83.3	125	166.7	-	-	-
Cowdung (t ha^{-1})	-	-	-	-	-	-	4	6	8
Cost (Rs)	-	-	-	-	-	-	1800	2700	3600
Additional application charges (Rs)	-	-	-	900	900	900	960	960	960

Total cost for the treatment combinations

Treatments	Cost (Rs ha^{-1})
M_1T_1	39683
M_1T_2	40126
M_1T_3	40569
M_1T_4	40583
M_1T_5	41026
M_1T_6	41469
M_1T_7	41560
M_1T_8	42460
M_1T_9	43360
M_2T_1	38633
M_2T_2	39076
M_2T_3	39519
M_2T_4	39533
M_2T_5	39976
M_2T_6	40419
M_2T_7	40510
M_2T_8	41410
M_2T_9	42310
M_3T_1	38333
M_3T_2	38776
M_3T_3	39219
M_3T_4	39233
M_3T_5	39676
M_3T_6	40119
M_3T_7	40210
M_3T_8	41110
M_3T_9	42010

PRODUCTIVITY MANAGEMENT IN YARD LONG BEAN
(*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)
THROUGH CROP GEOMETRY AND NUTRITION

By

PREETHA M. D.

ABSTRACT OF THE THESIS

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ABSTRACT

The present investigation entitled "Productivity management in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt) through crop geometry and nutrition" was carried out during 2002-2004 at Department of Olericulture, College of Horticulture, Vellanikkara. The field experiment was undertaken at Agricultural Research Station, Mannuthy. The experiment was aimed to standardize the optimum spacing and nutrient requirements of the crop.

Green pod yield per plant was maximum (435.66 g) with the wider spacing M_3 (1.5 m x 0.75m) compared to closer spacings. Application of increased doses of fertilizers significantly increased the yield of yard long bean. Eventhough the package of practices recommendation for vegetable cowpea is 20: 30: 10 kg NPK ha^{-1} (KAU, 1996), in the present study, maximum yield (385.96 g) was obtained when 40: 60: 20 kg NPK ha^{-1} (T_3) was applied. This was further supported by the superior vegetative growth characters and nutrient content of the plants. Though split application of fertilizers showed comparable nutrient contents in the plant parts this was not reflected in the yield of the crop. Organic treatments in general reduced the yield of yard long bean. The vegetative growth and nutrient contents of the plants were also low. The interaction effects were also significant for the pod yield and the treatment combination M_3T_3 recorded maximum green pod yield per plant (480.68 g).

Productivity of yard long bean was highest (6.73 t ha^{-1}) in closer spacing of 1.5 m x 0.25 m (M_1). With a three fold increase in plant population the yield per plant was reduced only by 42%. The combination M_1T_3 (closer spacing with 100% increase in fertilizers over standard recommendation applied in two splits) resulted in significantly higher productivity (7.33 t ha^{-1}).

However highest net returns (Rs 33030 ha^{-1}) and B:C ratio (1.82) were realized in the treatment combination M_1T_2 with closer spacing and 50% increase over POP

recommendation applied in two splits. Organic farming was not economically viable in yard long bean.

The quality of green pods was superior in organic treatments on account of significantly lesser crude fibre and higher moisture, carbohydrate and phosphorus contents. Organic treatments were also superior when storability and palatability of pods were considered. Zero energy cool chamber was not found suitable for cowpea storage as there was fungal attack to pods due to high humidity inside storage chamber.

Hence the recommendation of 20 t FYM ha^{-1} as basal and NPK 30: 45: 15 kg ha^{-1} applied in two splits – half N, full P and full K as basal and remaining half N 20 DAS and a spacing of 1.5 m x 0.25 m can be recommended for yard long bean to get economic returns.