STUDIES ON FERTIGATION IN YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)

by

ELSA GILES

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"STUDIES ON FERTIGATION IN YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)"** is a bonafide record of research work done by me during the course of research and the 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 **"STUDIES ON FERTIGATION IN YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)"** is a record of research work done independently by Ms. Elsa Giles under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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LIST OF ABBREVAIATION

PE	Potential Evaporation
BCR	Benefit Cost Ratio
cm	Centimeter
cm^3	Cubic Centimeter
Cu	Consumptive use
et al.	co-worker, co-authors
Fig.	Figure
FYM	Farm Yard Manure
g	gram
ha	hectre
K	Potassium
KAU	Kerala Agricultural University
kg	kilogram
kg ha mm^{-1}	kilogram per hectre millimeter
L	litre
m	meter
MOP	Muriate of Potash
N	Nitrogen
NS	Non-significant
S	Significant
WUE	Water Use Efficiency
WP	Water Productivity
RDN	Recommended Dose of Nitrogen
RDF	Recommended Dose of Fertilisers
$Plant^{-1}$	per plant

Introduction

1. INTRODUCTION

Yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) occupies a pre eminent position among the vegetables raised in Kerala. It is a rich source of protein, minerals, vitamins and dietary fibre in the Kerala diet. Yard long bean is also referred as long podded cowpea, snake bean, pea bean or Chinese long bean. '*Kurutholapayar*', '*Pathinettumaniyan*', '*Achingapayar*' and '*Vallipayar*' are the traditional vernaculars used in Kerala. It is cultivated over in area of 7317 ha in Kerala (FIB, 2015). The crop is grown for its immature green pods as vegetable, mature seed as grain and foliage as fodder.

Yard long bean is an annual with trailing growth habit. It produces white, light green, dark green or brownish red long, slender and succulent pods (George, 2008). It is a warm season crop which can be planted in a wide range of climatic conditions. The plant tolerates hot weather and even drought to a certain extent. It is a true legume that fixes atmospheric N, improves soil fertility and suppresses weeds which inturn contribute to yield improvement of subsequent crops (Tarawali *et al.*, 2002).

Productivity and quality of yard long bean is low due to unscientific management practices. The growing demand of yard long bean has led to intensive cultivation of this crop which underscores the need for better farming practices. Among the crop husbandry practices for yard long bean, precision farming is one of the best option. This will go a long way in ensuring decrease in cost of input and increase in output.

Precision farming is a production technology wherein the variability among plots are managed and site specific input management is followed at the right time in the right way. The goal of such practice is to gather and analyse the variability and to maximize the efficiency of crop inputs within a small area of farm (Singh *et al.*, 2011). Improved management practices of precision farming include deep ploughing, preparation of raised beds, polythene mulching and drip fertigation.

Deep ploughing breaks the hard pan in soil, allowing better root growth and better penetration of water. It also helps in exposing soil borne insects or pests to harsh atmospheric conditions, which in turn reduces their population in field. Mulching is another practice followed for improve water use efficiency. Mulch is a material which protects the land from solar radiation, evaporation, wind velocity and weed. Surface mulches improved soil water retension and wind velocity at the surface (Kay, 1998). Use of reflecting type of mulching material also helps in regulating soil temperature.

Fertigation is an important component of precision farming that allows the application of precise amount of nutrient into root zone uniformly. It is a modern agro technique that provides anexcellent opportunity to maximize yield and minimize environmental pollution by increasing fertilizer use efficiency, minimizing fertilizer applicationand increasing return on the fertilizer invested. In fertigation, timing, amount and concentration of fertilizers applied could be easily controlled. Fertigation helps in saving of the valuable inputs *viz.,* fertilizers and water. In fertigation, as the nutrients are supplied in soluble form to root zone it enhances the uptake and improves the growth. This practice ensures high nutrient use efficiency and water use efficiency. Therefore, it is possible to dispense adequate nutrient quantity at an appropriate concentration to meet the crop demand during the entire growing season.

Yard long bean is a vegetable crop that responds well to fertilizers. Improvement in crop yield with increase in levels of nutrients mainly N and K has been reported by Puthupalli (2014). Though soil application of nutrients in several splits enhances the nutrient use efficiency and crop yield, it increases weed growth and is more labour intensive. Similarly, over irrigation also leads to leafiness in yard long bean. Hence, fertigation of water soluble fertilizers through drip system at shorter interval has the advantage of easy uptake of nutrient, improved crop yield and productivity.This reiterates the need for standardizing the fertigation *ie.,* levels of nutrients and interval of fertigation for improving the productivity of yard long bean, a preferred vegetable of Kerala.

In the light of the above, the present study entitled "Studies on fertigation in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)" was undertaken with the following objectives.

- To standardize the fertigation schedule in yard long bean under precision farming.
- To assess the impact of precision farming practices on growth and yield.
- To work out the economics.

Review of Literature

2. REVIEW OF LITERATURE

The experiment entitled "Studies on fertigation in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)" was conducted during summer season of 2015 to standardize the nutrient level and interval of fertigation for precision farming in yard long bean. Fertigation is an important component in precision farming which helps to maximize the yield and quality of produce and to reduce the cost of production, while maintaining the sustainability. Research work related to drip fertigation including the levels and intervals on crop performance are presented in this chapter. As research work on fertigation in yard long bean is meagre, related work on other vegetables are also reviewed.

2.1 DRIP FERTIGATION Vs CONVENTIONAL METHODS

Drip fertigation is the technique of supplying fertilizers through drip irrigation system to crops. Application of water soluble fertilizers in small quantities to the root zone of the crop, saves labour and reduces compaction in the field, thereby enhancing the productivity of crop. Fertigation with 50 per cent recommended dose (RD) of N recorded higher yield in tomato and brinjal compared to soil application of full dose of fertilizers (Papadopoulos and Ormorod, 1991). Results of which also revealed that application of any combination of fertilizers through drip was superior over soil application of the same.

An investigation carried out by Tu *et al.* (2000) in tomato revealed the superiority of drip fertigation over soil application of fertilizers. They found that the yield attributes and yield were higher when soil application was replaced with drip fertigation. Moreover, incidence of the blossom end rot of tomato was significantly reduced in treatments with drip fertigation. They also observed that drip fertigation had better effect when the rainfall was below normal during the period of flowering, fruit set and fruit growth.

Singh and Saxena (2001) reported that the yield obtained in chilli from soil application of fertilizers and check basin method of irrigation was equivalent to the yield obtained by the application of only 50 per cent of N through drip irrigation. They also reported that drip fertigation with 100 per cent RD of N produced 52 per cent higher yield than the conventional method.

Singh *et al.* (2002) reported that the better performance of crops under drip fertigation was attributed to the optimum soil moisture and application of fertilizers into the root zone which improved the uptake of nutrients by plant for its better growth and yield.

Singandhupe *et al.* (2002) reported fertigation as a practice that placed the required dose of nutrients directly into root zone which helped the plant to utilize the nutrients fully during critical periods of its growth. They also observed that application of N through drip at 8 days interval (10 splits) saved 20 to 40 per cent nitrogen in tomato as compared to conventional method of furrow irrigation and nitrogen application in two equal splits.

Tiwari *et al.* (2003) revealed that fertigation reduced the use of fertilizers and increased the yield in vegetables. Available soil P and K in root zone increased with drip fertigation (Hebbar *et al.*, 2004). Application of 40 per cent RD of nutrients through drip resulted in higher fertilizer use efficiency (81.58 per cent) and also resulted in saving of 87 per cent of fertilizers and 30 per cent of water over furrow irrigation method with soil application (Sawant *et al.*, 2004).

Compared to conventional method (40 to 60 per cent) higher nutrient use efficiency (90 per cent) was observed in fertigation. The amount of fertilizer lost through leaching was as low as 10 per cent in fertigation whereas, it was 50 per cent in the traditional system (Solaimalai *et al.*, 2005).

Hongal and Nooli (2007) opined that application of higher dose of fertilizers not only increased the cost of cultivation but also led to chemical changes in soil and reduced the yield. From their experiment, it was observed that fertilizer requirement could be reduced by 15 to 25 per cent with drip fertigation without affecting the yield over conventional method of fertilizer application.

Experiment conducted by Aujla *et al.* (2007) with various levels of irrigation and nitrogen in egg plant revealed that higher fruit yield was recorded when drip irrigation was given with 75 per cent water required for furrow irrigation and 120 kg N ha^{-1} with the saving of 25 per cent water. Singandhupe *et al.* (2007) and Bhogi *et al.* (2011) observed that as water was directly applied to the crop root zone in drip irrigation, it got stored there which helped in conserving water and minimized the loss due to deep percolation.

Rekha and Mahavishnan (2008) reported that water and fertilizer saving in vegetables through drip fertigation was around 40 to 70 per cent and 30 to 50 per cent respectively. Vijayakumar *et al.* (2010) reported that fertigation could decrease the bulk use of fertilizers and increased the yield of vegetable crops.

The studies on drip fertigation in various vegetable crops reported that drip fertigation as the most effective way of supplying water and nutrients to the crops which not only saved water and fertilizers but also increased yield of vegetable crops (Hatami *et al.*, 2012).

Pawer *et al.* (2013) noted that drip irrigation registered 14.6 per cent increase in yield with 58 per cent water saving in tomato as compared to furrow irrigation. Drip irrigation treatments saved almost 30 per cent of water compared to sprinkler irrigation. Therefore, drip irrigation with frequent fertigation reduced P load and increased efficient use of nitrogen, water and radiation than with sprinkler irrigation (Danso *et al.*, 2015)

2.2 DRIP FERTIGATION AND MULCHING

Mulching is the practice of covering soil surface around the plants to create favourable condition for the plant growth. Luckknov *et al.* (1988) reported that mulching could maintain soil moisture in the field during hot periods of a year. The detrimental aspects for plant growth like soil erosion, weed problem and nutrient loss could be reduced by mulching and also it had other benefits like temperature moderation, salinity reduction *etc.* (Clough *et al.*, 1990). Mulching is a general practice followed in precision farming of vegetables. Asiegbu (1991) reported that mulching could be done with organic and inorganic materials and black coloured polythene mulches are widely used in agriculture. He also reported that mulch materials were most effective in weed control in tomato and brinjal and resulted in more crop growth and higher fruit yield compared to organic mulches like cassava peel, giant star grass and guinea grass straw. The studies revealed that plastic mulches brought about 15 per cent conservation of moisture in brinjal (NCPAH, 1991).

Wien *et al.* (1993) found that polythene mulching in tomato resulted in better growth attributes like increased number of branches, root length and increased mineral nutrient uptake reflecting in higher yield than plants grown in plots which were not mulched. Gilshabai and Jobi (1998) noticed that soil water balance could be maintained during summer season by mulching.

Irrigation given through drip along with black plastic mulching met 100 per cent water requirement of bhindi and also produced higher yield (about 72 per cent increase) over the furrow irrigated bhindi without mulch (Tiwari *et al.*, 1998). Raina *et al.* (1998) reported that mulching had an advantage of earliness in flowering, yield improvement and quality of the crop.

Compared to surface irrigation, drip irrigation along with plastic mulching was effective in increasing the yield (Sunilkumar and Jaikumaran, 2002). Bharadwaj (2013) stated that white or aluminum reflective mulch also repelled aphids which spread some virus diseases in vine crops such as squash.

Mulching significantly influenced yield and yield attributes like number of pods per plant, pod length and pod weight in yard long bean than control treatment without mulch (Puthupalli, 2014).

2.3 DRIP FERTIGATION LEVELS AND GROWTH ATTRIBUTES

Narda and Lubana (1999) compared drip fertigation in tomato with three nitrogen levels 33.3, 50.0 and 100.0 kg N $ha^{-1}$and with furrow irrigation and band placement of 100 kg N ha^{-1} in two splits. The results revealed that the crops with drip fertigation performed better in terms of growth attributes *viz*., plant height, leaf area index, crop growth rate, relative growth rate, leaf area duration, biomass duration, net assimilation rate and dry matter production over furrow irrigated crop.

Drip fertigation of 125 per cent RD of solid soluble fertilizers recorded the highest plant height of 84.50 cm and plant spread of 52.08 cm as compared to check basin irrigation with normal fertilization in tomato (Shinde *et al*., 2002). Hebbar *et al.* (2004) reported that the total dry matter (TDM) production and leaf area index (LAI) of tomato crop were significantly higher in drip irrigation (165.80 g per plant and 3.12 respectively) over furrow irrigation (140.20 g per plant and 2.25 respectively). They also reported that fertigation with water soluble fertilizers enhanced TDM and LAI to 181.90 g per plant and 3.69 respectively due to the easy availability of nutrients to plant.

Fertigation with 100 per cent RD of fertilizers resulted in improved growth attributes like plant height, LAI and total dry weight of tomato over furrow and soil application of fertilizers (Shedeed *et al.,* 2009). Vijayakumar *et al.* (2010) reported that application of 75 per cent RD of N and K as drip fertigation registered a significant increase in shoot length and number of branches per plant in brinjal.

Application of 100 per cent water soluble fertilizers through drip at 80 per cent evaporation resulted in significantly higher growth attributes of tomato *viz.*, plant height (96.70 cm), number of branches (18.25), stem diameter (2.06 cm) and leaf area index (3.49) (Imamsaheb *et al.*, 2014).

An experiment on drip irrigation conducted by Patel and Patel (2011) revealed that growth parameters of bhindi *viz.*, plant height, LAI, dry matter accumulation per plant, crop growth rate (CGR) and total chlorophyll content at 90 days of crop and root length at harvest were higher under drip irrigation at 0.8 E_{pan} (pan evaporation) as compared to surface irrigation.

Puthupalli (2014) reported that the longest vine length was observed when the yard long bean was fertigated with 125 per cent RD than other lower levels of fertigation. Fertigation with 100 per cent RD of fertilizers showed an improvement in growth and growth attributes such as plant height, number of branches and number of leaves per plant of brinjal as reported by Ughade and Mahadkar (2014).

Application of 100 per cent RD of fertilizers through drip along with 25µ thickness black polythene mulch recorded an increase in plant height and number of branches in hybrid tomato over no mulch and soil application of 100 per cent RD of fertilizers (Basamma and Shanmughasundaram, 2016).

2.4 LEVELS OF FERTIGATION ON YIELD ATTRIBUTES AND YIELD

Based on a study in tomato, Locascio *et al.* (1997) reported 16 per cent increase in yield with drip irrigation over furrow method. They also stated that there was an increase in yield when 60 per cent of the N and K fertilizers were applied as drip fertigation than when all fertilizers were given as pre plant.

Prabhakar and Hebbar (1999) reported that tomato fruit yield of 45.70 t ha^{-1} was obtained with application of RD of fertilizers using polyfeed 19:19:19, mono ammonium phosphate (12:60:0) and urea through fertigation, which was 22 to 27 per cent higher compared to the crop which was provided with ordinary fertilizers through soil application.

Rajbir *et al.* (1999) observed that drip irrigation at 80 per cent pan evaporation gave significantly higher fruit yield in tomato (45.57 t ha^{-1}) compared to surface irrigation (29.43 t ha^{-1}). Sainju *et al.* (2001) reported a positive response of surface drip irrigation on tomato yield and quality to increasing N rates. They also noticed that marketable yield of tomato was maximum when N was applied @ 180 kg ha^{-1}.

From the experiment conducted in brinjal using different methods of irrigation and different levels of fertigation (50, 75, 100 and 125 per cent RD as solid soluble fertilizer), it was observed that micro irrigation with 100 per cent RD of solid soluble fertilizer recorded the highest number of fruits per plant (433.13), fruit weight (44.18 g) and fruit yield (41.51 t ha^{-1}) (Shinde *et al.*, 2002). According to Manjunatha (2004) fruits per plant and total yield were more under drip irrigation than under surface irrigation in brinjal with a fruit yield of 26.2 t ha^{-1}.

Banu (2005) conducted an experiment to investigate the effect of various levels of irrigation (0.5, 0.75 and 1.0 E_{pan}) and nitrogen levels (60, 90 and 120 kg ha^{-1}) on pod yield of bhindi. The results indicated that bhindi irrigated through drip at 1.0 E_{pan} and fertigated with 120 kg N ha^{-1} produced significantly higher yield as compared to other levels. From the field experiments conducted at Indian Institute of Vegetable Research, Varanasi, Bahadur *et al.* (2006) reported that drip irrigation at 100 per cent pan evaporation (Ep) resulted in maximum number of fruit, fruit weight and total yield of tomato compared to other levels of Ep and surface irrigation.

There was significant yield improvement in brinjal by drip fertigation over surface irrigation and soil application of fertilizers (Goswami *et al.*, 2006). Aujila *et al.* (2007) reported that there was 4 per cent increase in yield in brinjal when it was drip fertigated compared to furrow irrigation.

Number of fruits per plant, mean fruit weight, fruit yield per plant and total fruit yield of tomato were maximum for fertigation of 100 per cent RD of fertilizers over soil application of fertilizers (Shedeed *et al.*, 2009). They also reported that total fruit yield of tomato was significantly higher in 75 and 100 per cent NPK fertigation (54.16 and 58.76 t ha^{-1} respectively) than 50 per cent, which accounted to 12 and 22 per cent yield increase respectively. This yield increase resulted from higher number of fruits per plant and fruit yield per plant in drip irrigation over furrow irrigation. In bhindi, 54 to 57 per cent yield reduction was recorded for furrow irrigated crop than crop irrigated at 1.0 Epan and fertigated with 120 kg N ha^{-1} (Rekha *et al.*, 2009).

Brahma *et al.* (2010) revealed that drip irrigation at 100 per cent evaporation replenishment along with supplementation of 100 per cent RD of N and K through fertigation recorded 61.09 per cent increased yield over conventional fertilization in tomato. In brinjal, the highest yield of 42.33 t ha^{-1} was recorded in drip irrigation at 75 per cent of RD of N and K when compared to other levels of irrigation and fertigation (Vijayakumar *et al.*, 2010).

Imamsaheb *et al.* (2014) reported the highest yield of 63.78 t ha^{-1} when the tomato was drip fertigated with 100 per cent RD of NPK. Ravel *et al.* (2013) reported that drip fertigation at 100 per cent RD of nitrogen recorded the highest yield in bhindi but it was on par with 80 per cent RD of nitrogen.

Fertigation in yard long bean with 125 per cent recommended dose of fertilizers (RDF) resulted in significantly higher yield and yield attributes like number of pods per plant, number of seeds per pod, length and weight of pods compared to 75 and 100 per cent RDF (Puthupalli, 2014).

From field experiments conducted during two rabi seasons by Rajan *et al.* (2014) in tomato, it was observed that 75 and 100 per cent doses recorded same yield (52.1 t ha^{-1}) indicating that 75 per cent dose would be sufficient than trying fertigation at higher doses. Ughade and Mahadkar (2014) reported that yield and yield contributing characters like number of fruits per plant, average fruit length, average diameter of fruit, average weight of fruit and fruit yield per plant of brinjal were significantly higher in fertigation of 100 percent RDF.

Use of plastic mulch of 25 μ and 120 per cent RD of fertilizers as drip fertigation registered earliness in flowering and recorded the highest fruit yield in hybrid tomato (Basamma and Shanmughasundaram, 2016).

2.5 FERTIGATION INTERVAL ON GROWTH AND YIELD

Cook and Sanders (1991) found that marketable yield and fruit size of subsurface drip irrigated tomato were significantly higher in daily fertigation compared to biweekly or monthly fertigation on a loamy sand soil. The tomato yield was significantly increased when N was fertigated at 5 days interval compared to 9 days through surface drip system (Nwadukwe and Chude, 1994)

Application of nutrients in more number of splits enabled to put forth better growth, yield attributes and total yield in bhindi (Kadam *et al.*, 1995). Deek *et al.* (1997) reported that N supplied by drip fertigation in ten equal splits in equal intervals resulted in high tomato yield of 47.1 t ha^{-1} as compared to fertigation with three equal splits and equal time intervals (35.8 t ha^{-1}).

Drip fertigation of RD of N and K as urea and muriate of potash applied in 15 equal splits at eight days interval starting from 8 days after planting (DAP) to 120 DAP recorded higher tomato yield as compared to surface irrigation with conventional method of fertilizer application on sandy loam soil at Madurai in Tamil Nadu (Ajmalkhan, 2000).

Badr and El-Yazied (2007) observed that total tomato yield and yield components were responsive to N rate and to decreased fertigation frequency. The total fruit yield averaged 67.75, 65.13 and 63.29 t ha^{-1} under the frequencies of 1, 3 and 7 days respectively and were significantly higher than the frequency of 14 days (54.32 t ha^{-1}).

The continuous availability of nutrients in splits throughout the growth period of tomato *ie*., fourteen equal splits at 8 days interval resulted in superior yield and quality of tomato (Pandey *et al.,* 2013). Ravel *et al.* (2013) reported that drip fertigation of N at weekly interval recorded the highest fruit yield and fruit yield per plant over two and three weeks interval in bhindi. Danso *et al.* (2015) reported that in okra, when fertigation was done at weekly interval for eight weeks, the yield of drip fertigated okra was higher than fertigation at wider intervals.

2.6 DRIP FERTIGATION AND WATER USE

The different precision farming practices like drip irrigation alone, drip irrigation plus polythene mulch and surface irrigation, registered water use efficiencies (WUE) 0.34, 0.48 and 0.16 t ha cm^{-1} respectively indicating the favourable effect of drip irrigation and polythene mulch in enhancing WUE. Besides, drip irrigation saved 54 per cent irrigation water (Raina *et al.,* 1999). Singh *et al.* (2002) reported that drip irrigation at 50 per cent potential evaporation (PE) along with 100 per cent N and K through fertigation recorded the highest water use efficiency, water productivity and water saving in chilli over farmers' practice of surface irrigation (0.9 IW/CPE ratio) and entire NPK applied as soil application.

Singandhupe *et al.* (2002) reported that drip system in tomato resulted in 31 to 37 per cent saving of water compared to surface irrigation. Water use efficiency on an average was 68 per cent and 77 per cent higher in drip irrigation over surface irrigation in two consecutive year trials. In brinjal, drip irrigation recorded the highest water production efficiency of 69.3 kg ha mm^{-1} than surface irrigation (Manjunatha, 2004).

Drip fertigation in brinjal saved 37 to 49 per cent water when compared to surface irrigation (Goswami *et al.*, 2006). Aujla *et al.* (2007) stated that 50 per cent water saving could be achieved through drip irrigation in brinjal as compared to furrow irrigation. Rekha *et al.* (2009) observed that drip fertigated crop has extracted higher moisture (40 to 48 per cent) from top 0 to 15 cm soil depth than furrow irrigated crop (33 to 34 per cent).

Application of N and K at 75 per cent RD recorded the highest water use efficiency of 111.5 kg ha mm^{-1} in brinjal (Vijayakumar *et al.*, 2010). From three years of experiment in tomato, Tanaskovik *et al.* (2011) reported that treatments under drip fertigation showed almost 28 per cent more water use efficiency in comparison with soil application of fertilizers and furrow irrigation. Drip irrigation registered 87 per cent more WUE than furrow irrigation and conventional application of fertilizers.

2.7 DRIP FERTIGATION AND NUTRIENTS UPTAKE

Fertigation reduces the nutrient loss that would normally occur with conventional methods of fertilizer application and thus, permits better availability and uptake of nutrients by the crops, leading to higher yield with high fertilizer use efficiency. Stark *et al.* (1983) practiced continuous fertigation of surface drip irrigated tomato on sandy soils and they reported nitrogen use efficiency of 60 per cent even with 600 kg N ha^{-1} applied. Nitrogen use efficiency (NUE) in red chilli decreased with increasing N upto 240 kg ha^{-1} (Payero *et al.*, 1990). Application of nutrients in more number of splits in drip fertigation resulted in minimum or no wastage of nutrients either through deep percolation or evaporation, leading to higher uptake of nutrients in bhindi (Kadam *et al.*, 1995).

Fontes *et al.* (2000) opined that application of N and K fertilizers in combination with drip irrigation increased the potassium content and yield by the way of maximizing the mobility of the nutrients around the root zone. Unlike surface irrigation and conventional fertilizer application, fertigation makes uniform distribution of nutrient solution in the root zone and thereby increases the fertilizer use efficiency, since the uptake of nutrients by the plant roots depends on their availability to the root system Singh *et al.* (2002). Patel and Rajput (2003) observed that drip fertigation in bhindi has resulted in higher nitrogen use efficiency (70 kg bhindi kg^{-1} N) over broadcasting of nitrogen (48.7 kg bhindi kg^{-1} N).

Hebbar *et al.* (2004) reported that fertigation in hybrid tomato resulted in lesser leaching of nitrate and K to deeper layer of soil. Subsurface drip fertigation caused higher assimilable P in deeper layer. Root growth and NPK uptake were increased by fertigation with water soluble fertilizers compared to drip or furrow irrigated with soil application of fertilizers. They also observed that fertilizer use efficiency of 226.48 kg tomato kg^{-1} NPK was obtained with drip fertigation using water soluble fertilizers.

Badr and El-Yazied (2007) noticed that N rate and fertigation frequency resulted in significant differences in N uptake, N recovery and N use efficiency (NUE) in tomato. Total N uptake was appreciably higher with increasing N rate and with more frequent fertigation than with less frequent fertigation. The average N recovery was 60 and 54 per cent and NUE was 221 and 194 kg yield kg^{-1} N with 200 and 300 kg N ha^{-1} applied respectively. They also reported that the total N uptake by leaves was higher in the plants receiving the high N rate, but fertigation frequency did not significantly influence leaf N concentration.

Frequent supply of nutrients by fertigation significantly increased NPK uptake and recovery over drip irrigation. The applied NPK in soluble form in fertigation treatments might have been distributed better through root zone of tomato than soil applied treatments producing more available amount for plant uptake. Uptake of NPK and recovery were the highest under 100 per cent fertigation rate than in drip irrigation along with soil application in tomato (Shedeed *et al.*,2009).

Vijayakumar *et al.* (2010) reported that nitrogen and potassium use efficiencies of brinjal were higher in drip irrigation at 75 per cent pan evaporation and fertigation of 75 per cent N and K. Ravel *et al.* (2013) reported that in bhindi the maximum N content in plant and uptake of nitrogen were observed with 100 per cent RDN as fertigation. The magnitude of increase in N content in100 per cent RDN over 80 per cent RDN and control (farmer's practices) was 17 and 48 per cent respectively and for uptake it increased to 26 and 88 per cent respectively. They also reported that uptake by fruit was the highest in N fertigation at weekly interval than that at two and three weeks interval of N application through drip.

The fertilizer use efficiency of hybrid tomato was the maximum at 50 per cent RD of fertilizers than at other levels (Rajan *et al.*, 2014). Hence, application of 50 per cent RD proved to be sufficient for the optimum yield and it also saved 50 per cent of fertilizer through fertigation.

2.8 DRIP FERTIGATION AND SOIL NUTRIENT STATUS

The study conducted by Badr and El-Yazied (2007) revealed that residual soil nitrate N after harvest appeared to be higher at the higher N levels and was significantly affected by fertigation frequency. Residual soil nitrate N concentration with high N rate in lower soil profiles (50 to 70 cm soil depth) was marginally affected in daily, 3 days and weekly fertigation (15, 17 and 21 mg N kg^{-1}soil respectively). However, nitrate N concentration at the corresponding depth was more in biweekly fertigation frequency (80 mg N kg^{-1}soil).

Studies in tomato revealed that the magnitude of increase in available soil N after harvest of crop under 100 per cent RDN over 80 per cent and control (farmer's practice) were to the tune of 10 and 16 per cent, respectively. The magnitude of increase in available soil N after harvest of crop under weekly fertigation of N in comparison with fortnightly interval and control were to the tune of 8 and 15 per cent, respectively (Ravel *et al.*,2013).

Organic carbon content, available nitrogen, available phosphorus and available potassium on 45 DAS and at final harvest were the highest in treatments receiving 125 per cent RDF whereas, the highest pH and the lowest EC were recorded in 75 per cent RDF (Puthupalli, 2014).

2.9 DRIP FERTIGATION AND ECONOMICS

Muralikrishnasamy *et al.* (2006) observed an increase in benefit cost ratio (BCR) of 1.87 in chilli with drip irrigation at 75 per cent pan evaporation and 100 per cent N and K through fertigation over 1.77 with surface irrigation at 0.90 IW/CPE ratio and soil application of RD of N and K. Bhakare and Fatkal (2008) recorded a BCR of 3.30 under 100 per cent RDF applied as fertigation of water soluble fertilizers as against 2.78 in 100 per cent RDF with conventional fertilizer application and surface irrigation.

Study on fertigation efficiency and economics of cultivation revealed that fertigation with 100 per cent RD of N and K was the most efficient treatment with fertigation efficiency of 43.24 per cent and cost: benefit ratio of 1:2.28 (Brahma *et al.*, 2010). Imamsaheb *et al.* (2014) reported that fertigation level 100 per cent recommended NPK in tomato resulted in the highest net income, gross income and BCR of 3.22.

Puthupalli (2014) recorded the highest B:C ratio of 1.83 in yard long bean when irrigation was given at 60 or 80 per cent pan evaporation with mulching and fertigation of 125 per cent RDF.

Fertigation with conventional fertilizers recorded the highest B:C ratio of 1.96 which was 58 per cent higher than use of conventional fertilizers with liquid soluble fertilizers and 42 per cent higher than conventional fertilizers with solid soluble fertilizers in tomato (Rajan *et al.*,2014).

2.10 EFFECT OF FERTILISER APPLICATION, IRRIGATION AND MULCHING ON QUALITY

Amans *et al.* (2011) reported that increase in level of N fertilizers from 45 to 90 kg N ha^{-1} increased the crude fibre content in tomato. He also reported that irrigating at 10 days interval increased the crude fibre content than at 5 days interval. The fruit crude fibre content was significantly more in tomato with polythene mulch than unmulched one. This study revealed that mulching and N fertilizers increased the crude protein and carbohydrate content in tomato fruit. The irrigation from 5 to 10 days interval decreased crude protein and carbohydrate contents and further increase in interval to 15 days increased these parameters.

On perusal of research results on drip fertigation, nutrient levels, fertigation intervals and mulching it was evident that all these treatments in general improved crop growth and yield and increased nutrient uptake, reduced water requirement and enhanced water use efficiency of crops.

Materials and Methods

3. MATERIALS AND METHODS

The project entitled "Studies on fertigation in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)" was undertaken to standardize the fertigation schedule and its impact on growth, yield and profitability of yard long bean. The materials used and the methods adopted for the study are briefly described below.

3.1 EXPERIMENTAL SITE

The experiment was conducted in the farmer's field at Pirappancode, Thiruvananthapuram, Kerala located at 8.65°N latitude and 76.91°E longitude and at an altitude of 18 m above the mean sea level.

3.2 SOIL

The soil of the experimental field is sandy clay loam. The mechanical composition of the soil are summarized in Table 1.

3.3 CROPPING HISTORY OF THE FIELD

Upland rice was grown in the field prior to planting yard long bean.

3.4 SEASON

The experiment was conducted during the summer season 2015, crop period extended from 7th March 2015 to 21st June 2015.

3.5 WEATHER CONDITIONS

The weather data on rainfall, maximum temperature, minimum temperature, relative humidity and evaporation during the cropping period are shown in Fig. 1 and Appendix 1. The mean maximum temperature during the period was 32.9° C and

Table 1. Mechanical composition and chemical characteristics of soil of the experimental site

Particulars/ Parameters		Value		Method used
A. Mechanical composition (%)				
Sand		45.44		Bouyoucos hydrometer method (Bouyoucos, 1962)
Silt		26.66		
Clay		27.90		
B. Chemical characteristics of soil				
Particulars	Value	Rating	Method used	
Soil reaction (pH)	5.30	Strongly acidic	pH meter with glass electrode (Jackson, 1973)	
Electrical conductivity (dS m^{-1})	0.16	Normal	Digital conductivity meter (Jackson, 1973)	
Organic carbon (%)	1.70	High	Walkely and Black rapid titration method (Jackson, 1973)	
Available N (kg ha^{-1})	301.06	Medium	Alkaline Potassium Permanganate method (Subbiah and Asija, 1956)	
Available P (kg ha^{-1})	78.50	High	Brays colorimetric method (Jackson, 1973)	
Available K (kg ha^{-1})	104.12	Low	Ammonium acetate method (Jackson, 1973)	

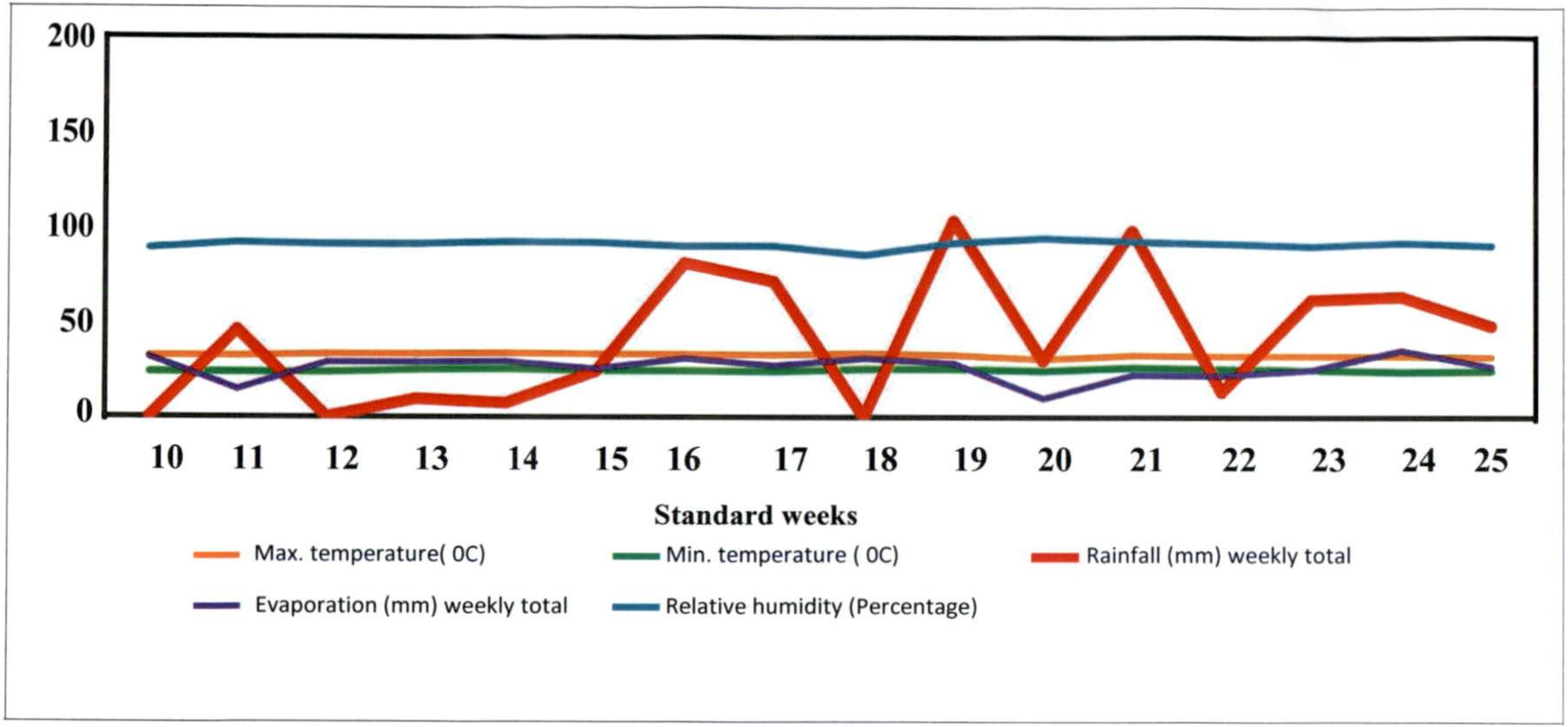

Fig 1. Weather data during cropping period (from 7th March 2016 – 21st June 2016)

minimum 23.3^0 C with a mean relative humidity of 90.5 per cent. The total rainfall received during the cropping period was 817.60 mm.

3.6 MATERIALS

3.6.1 Crop and Variety

Yard long bean variety *Githika,* released from the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani was selected for the study. The characters of the variety are given in Table 2.

3.6.2 Source of Seed Material

The seed for the experiment was obtained from the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani.

Table 2. Characters of yard long bean var. *Githika* (VS- 6)

Characters	Description
Parentage	Selection from Vellayani local
Growth habit	Indeterminate, climbing
Immature pod colour	Light green
Days to 50 per cent flowering	40- 43 days
Productivity	26 - 28 t ha^{-1}
Duration	105-110 days

3.6.3 Manures and Fertilizers

Farm yard manure analyzing 0.5% N, 0.4% P_2O and 0.4% K_2O was used as source of organic manure. Urea (46 per cent N), rajphos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as sources of nitrogen, phosphorus and potassium respectively. Water soluble fertilizers like 19:19:19, 13:0:45 and

12:61:0 were used for fertigation in control 1 (*ad hoc* recommendation of Kerala Agricultural University).

3.6.4 Mulching Material

Silver black polythene mulch of 30 gauge thickness was used for mulching the raised beds in all treatments except control 2.

3.6.5 Drip System with Fertilizer Injector

Inline drip system with a discharge rate of 4 L hr^{-1} was laid out in all the plots except control 2. A fertilizer injector connected to the sub main of the drip system was used for fertigation.

3.7 METHODS

3.7.1 Design and Layout

The field experiment was laid out in split plot design. The layout plan is given in Fig 2. The details of the experiment are given below.

Design - Split plot

Replication - Four

3.7.2 Treatment Details

Treatments included four levels of nutrients and two fertigation intervals along with two controls.

Main plot treatments: Levels of nutrients (L)

L_1 – 75 per cent recommended dose of N and K

L_2 – 100 per cent recommended dose of N and K

Plate 1. Field layout of drip system

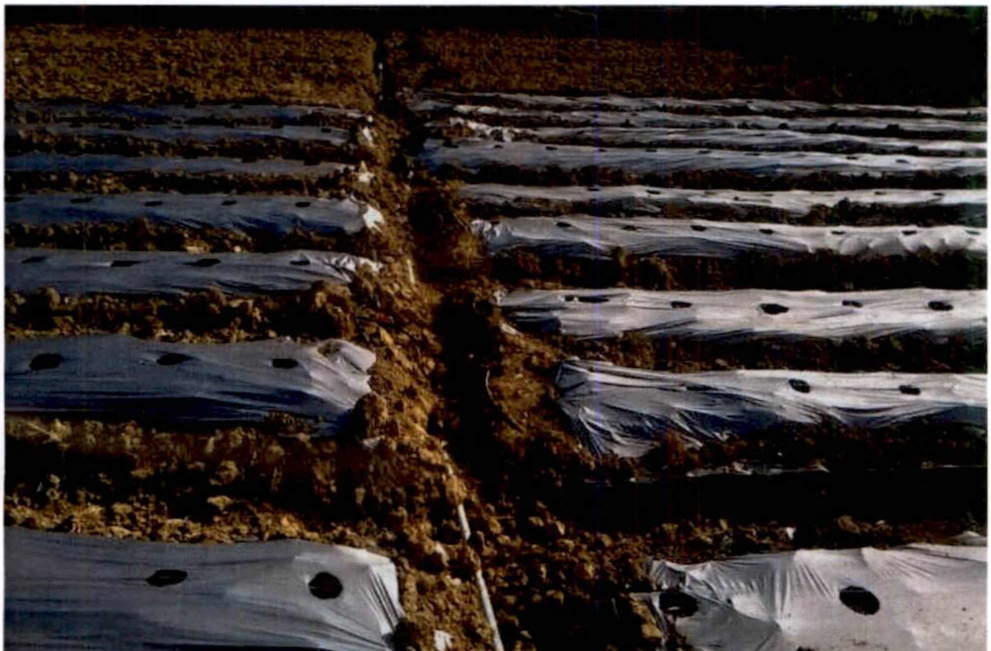

Plate 2. Raised beds with polythene mulch

L_3 – 125 per cent recommended dose of N and K

L_4 – 150 per cent recommended dose of N and K

Subplot treatments: Fertigation intervals (I)

I_1 – Fertigation once in 4 days

I_2 – Fertigation once in 8 days

Control 1- Kerala Agricultural University (KAU) *ad hoc* recommendation for precision farming (details given in Table 3) (KAU, 2013)

Control 2 –Kerala Agricultural University POP recommendation (Normal planting in shallow raised beds with basin irrigation and soil application of fertilizers without mulching) (KAU, 2011)

Treatment combination – 8+ 2 = 10

l_1i_1, l_1i_2, l_2i_1, l_2i_2, l_3i_1, l_3i_2, l_4i_1, l_4i_2, control 1, control 2

Deep ploughing, preparation of raised beds, polythene mulching and drip fertigation were followed uniformly for all treatments except control 2.

3.7.3 Plot Size

Sub plot size	Gross	– 3.0 m x 4.0 m
	Net	– 3.0 m x 2.5 m
Spacing		– 1.5 m x 0.5 m

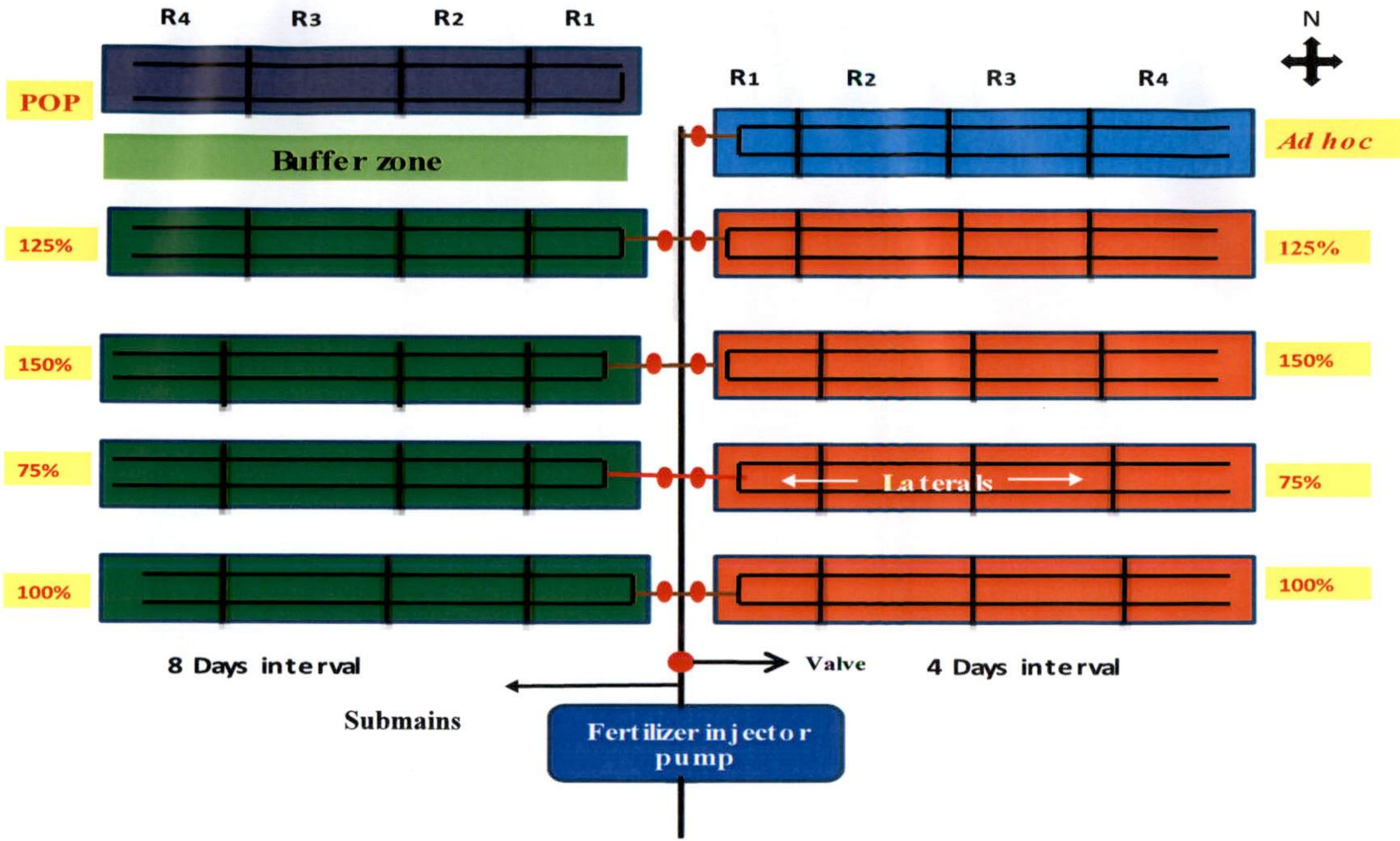

Fig 2. Layout plan of the experimental field

3.7.4 Crop Management

3.7.4.1 Land Preparation and Layout

For treatments except control 2, the experimental field was deep ploughed to a depth of 50 cm with cultivator and stubbles of previous crop were removed. The field was divided into main plots and sub plots. Raised beds of 3 m width were prepared at a height of 30 cm. A buffer strip of 75 cm width was provided around control 2 to account for the seepage loss of water. Within each sub plot, two furrows of 30 cm width were taken at 1.5 m spacing along the length of the plot. Silver black polythene mulch was laid along the plots except in control 2. Inline drip system with a discharge rate of 4 L hr^{-1} was installed in all the plots except in control 2. For control 2, the land was prepared by digging and weeds were removed and shallow raised beds of 3 m width were taken.

3.7.4.2 Sowing

Two seeds were dibbled at 50 cm spacing in the furrows taken at 1.5 m apart.

3.7.4.3 Application of Manures and Fertilisers.

As the soil was strongly acidic, lime requirement was worked out based on initial pH and lime @ 350 kg ha^{-1} was applied to all plots along with ploughing. Farm yard manure @ 20 t ha^{-1} was applied uniformly to all plots and thoroughly incorporated before sowing. The initial soil status showed medium N, high P and low K. Hence, the present recommendation of yard long bean (30:30:20 kg N: P_2O_5: K_2O ha^{-1}) was modified as 30:25:25 kg N: P_2O_5: K_2O ha^{-1} for all treatments except control 1. The KAU *ad hoc* recommendation for precision farming using polyfeed water soluble fertilizers was followed for control 1 (details given in Table 3). Soil application of phosphorus @ 25 kg ha^{-1} was followed in all treatments except *ad hoc* treatment where 50 per cent of P_2O_5 (52.5 kg P_2O_5 ha^{-1}) was supplied as basal. Fertigation started 7 DAS and N and K were supplied as urea and MOP for

Plate 3. Fertilizer injector used for fertigation

Plate 4. An overview of experimental field

treatments except control 1 and control 2. For control 2, 30 kg N and 25 kg K were given in five split at fortnightly interval. Fertigation schedule for treatments and control 2 are provided in Table 4.

Table 3. KAU *ad hoc* recommendation for precision farming (g/treatment)

Control 1 (*ad hoc*)	$1-6^{th}$ application (3-18 DAP)	$7-18^{th}$ application (21-54 DAP)	$19-36^{th}$ application (57-110 DAP)
19:19:19	25.20	1.80	1.80
13:0:45	28.80	57.60	57.60
Urea	23.40	5.40	27.00
12:61:0	-	3.60	3.60

Table 4. Quantity of fertilizers required for each fertigation in different treatments.

Mainplot \ Subplot	Urea(g/treatment)		MOP (g/treatment)		Application
	I_1(4 days interval)	I_2 (8 days interval)	I_1 (4 days interval)	I_2 (8 days interval)	
L_1 (75% RD of N & K)	6.28	15.30	4.00	9.80	Fertigation was done from 7^{th} DAS to 103^{th} DAS
L_2 (100% RD of N & K)	8.38	20.49	5.30	13.00	
L_3 (125% RD of N & K)	10.48	25.61	6.69	16.36	
L_4 (150% RD of N & K)	12.50	30.73	8.00	19.60	

Control 2 (KAU POP) 30 N : 25 K kg ha^{-1}.	290 g urea /treatment	185 g MOP/treatment	Urea and MOP was applied in equal quantity at fortnightly intervals for five times

3.7.4.4 Aftercultivation

Germination was uniform and gap filling was done in few plots at five days after sowing (DAS). The crop was thinned ten days after sowing and a single plant was maintained at a spacing of 50 cm spacing in each row. Trellises were erected using casuarina poles and crop was trailed on plastic net by three week after emergence. Two weedings and intercultivations were given at 20 and 40 DAS in control 2. Weeding was not required in other treatments due to mulching.

3.7.4.5 Irrigation

In all plots except control 2 irrigation was given @ 1 L $plant^{-1}$ during initial stages upto 15 DAS and later it was increased to 1.5 L $plant^{-1}$. In control 2, measured quantity of water was given. Irrigation was given on all days except rainy days.

3.7.4.6 Plant Protection

Application of Quinalphos (Ekalux 25 EC) @ 0.05 per cent was done against leaf eating caterpillars and bugs at 15 and 45 DAS. Soil drenching with Copper oxychloride @ 0.3 per cent was done three times in localised spots as *Fusarium* wilt was observed in patches.

3.7.4.7 Harvesting

Picking of pods commenced from 47 DAS. Subsequent harvests of green pods were done on alternate days from all treatments and fresh weight was recorded separately.

3.8 OBSERVATIONS

The observations were recorded from the five observational plants selected from the net plot area of each subplot and the mean values were worked out.

3.8.1 Biometric Observations

3.8.1.1 Primary Branches per Plant

Counted the number of branches arising from main stem at an interval of 30, 60, 90 DAS and the mean was worked out.

3.8.1.2 Length of Vine at Harvest

Length of vine at harvest was measured from ground level to the top most leaf bud and expressed in cm.

3.8.1.3 Number of Productive Branches per Plant

Total number of branches bearing inflorescence was noted as productive branches.

3.8.1.4 Leaf Area Index at Flowering

The leaf area was measured from the observational plants of each treatment at flowering stage. Representative leaves were taken from the lower, middle and upper part of the plant and the leaf area of these leaves were measured using graph paper. The total leaf area was worked out using the leaf area of selected leaves and number of leaves coming under each group. Leaf area index (LAI) was determined using the following formula.

$$LAI = \frac{\text{Total leaf area of the plant } (cm^2)}{\text{Land area occupied by the plant } (cm^2)}$$

3.8.1.5 Dry Matter Production at Harvest

Plants were uprooted at last harvest without damaging the root and separated into stem, root and leaves. These were shade dried and oven dried at $70^{0} \pm 5^{0}C$ till constant weight was reached. The weight of different plant parts including the total pod weight were added to get dry matter production and expressed as t ha^{-1}.

3.8.1.6 Crop Duration

Period from sowing upto the last harvest was noted and expressed in days.

3.8.2 Yield and Yield Attributes

3.8.2.1 Days to 50 per cent Flowering

Days taken for flowering of 50 per cent of the net population from each treatment was recorded and expressed as number of days.

3.8.2.2 Setting Percentage

It was calculated by dividing the total number of pods set from tagged inflorescence with total number of flowers in a same inflorescence and expressed as percentage.

3.8.2.3 Number of Flowers per Inflorescence

Total number of opened flowers from three inflorescence of observational plants were counted and mean worked out.

3.8.2.4 Pods per Plant at each Harvest

Number of pods collected from each observational plant at each harvest were recorded. The total number of pod per plant was obtained by adding the number of pods of all harvests.

3.8.2.5 Pod Length at each Harvest

Pod length expressed in cm was the distance measured from the pedicel attachment to the apex of pod using twine and scale. Observation on pod length at each harvest was taken and the mean length calculated and expressed in cm.

3.8.2.6 Pod Girth at each Harvest

The diameter of the broadest part of the pod was measured at each harvest and the mean expressed in cm.

3.8.2.7 Weight of Pod at each Harvest

Weight of a five pod at each harvest from each treatment was recorded separately and average was found out and expressed in g.

3.8.2.8 Pod Yield per Plant at each Harvest

Weight of pods collected from each observational plant at each harvest was recorded and expressed in g.

3.8.2.9 Pod Yield per Plot at each Harvest

Total pod yield at each harvest from all treatments were recorded seperately and expressed in t ha^{1}.

3.8.2.10 Total Pod Yield

For each treatment, total yield obtained from all harvests was noted and expressed in t ha^{-1}.

3.8.2.11 Number of Pickings

Total number of harvests obtained was noted.

3.8.2.12 Harvest Index

Harvest index was calculated by using the formula

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}} \qquad \text{(Donald, 1962)}$$

Economic yield = Dry weight of economic part (pod)

Biological yield = Total dry weight (pod yield + bhusa yield)

3.8.3 Root Studies at Final Harvest

3.8.3.1 Root Length

Plants were uprooted after the final harvest and length of root from base of stem to tip of root was taken and expressed in cm.

3.8.3.2 Root Volume

After the final harvest plants were uprooted carefully and roots were immersed in water taken in a graduated cylinder and the root volume determined by water displacement method and expressed in cm^3.

3.8.3.3 Root Weight

Recorded the fresh weight of roots after final harvest and expressed in g.

3.8.4 Moisture Studies

3.8.4.1 Water Use Efficiency

Water use efficiency was calculated by dividing the economic crop yield by the total water requirement and expressed in kg ha mm^{-1}.Water requirement is calculated by adding the irrigation requirement of the crop and effective rainfall.

[Effective rainfall= 70 percent of total seasonal rainfall (Dastane,1974)]

$$WUE = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Total water requirement (mm)}}$$

3.8.4.2 Water Productivity

Water productivity was estimated by using the formula suggested by Kijne *et al.*, 2003 and expressed in kg ha mm^{-1}.

$$\text{Water productivity (WP)} = \frac{\text{Total biomass (kg ha}^{-1}\text{)}}{\text{Total water required (mm)}}$$

3.8.5 Pest and Disease Incidence

Observation on the incidence of major pests and diseases was made.

3.8.6 Chemical Analysis

3.8.6.1 N, P, K Uptake by Crop at Harvest

Observational plants were uprooted after final harvest, dried under shade, oven dried to constant weight at 70 ± 5^{o}C and N, P and K contents of root, stem, leaves and pods were analysed. The nitrogen content was estimated by micro kjeldhal method (Jackson, 1973), phosphorus content by vanadomolybdo phosphoric yellow colour method (Jackson, 1973) and potassium content was determined by flame photometry method (Jackson, 1973). The nutrient uptake was calculated as the product of the respective nutrient content in percentage and total dry weight and expressed in kg ha^{-1}.

3.8.6.2 Soil Nutrient Analysis Before and After the Experiment

A composite sample was collected before the experiment for nutrient analysis. After the experiment, soil samples collected from individual plots were dried, powdered and sieved through 2 mm sieve. Available N was estimated by alkaline permanganate method (Subbiah and Asija, 1956), available P_2O_5 by Brays colorimetric method (Jackson, 1973) and available K_2O by neutral normal ammonium acetate method (Jackson, 1973) and expressed in kg ha^{-1}.

3.8.6.3 Organic Carbon

The estimation was done using Walkley and Black rapid titration method (Jackson, 1973) and expressed as percentage.

3.8.6.4 Soil pH

Soil reaction (pH of soil) from each treatment after the crop was estimated using pH meter with glass electrode (Jackson, 1973)

3.8.7 Chlorophyll Content and Quality Attributes

3.8.7.1 Chlorophyll Content of Leaf at Flowering

The chlorophyll content of fresh green leaves was estimated using Dimethyl sulphoxide (DMSO) method (Yoshida *et al.,* 1976) and reading was taken using spectrophotometer and expressed in mg g^{-1} fresh weight.

3.8.7.2 Crude Protein

Crude protein of the pod was calculated by multiplying the nitrogen content with Simpson factor 6.25 (Simpson *et al.*, 1965) and expressed in per cent.

3.8.7.3 Crude Fibre

Crude fibre content of pod was determined by A.O.A.C method (A.O.A.C, 1975) and expressed in per cent.

3.8.8 Economic Analysis

Economic analysis was done in terms of gross income, net income and benefit cost ratio (B:C ratio) considering the cost of cultivation and prevailing market price of produce.

3.8.8.1 Net Income

Cost of inputs including mulching material, drip installation cost and labour cost prevailed during the period of experiment was considered to work out the cost of cultivation in ₹ ha^{-1}. Net income was calculated by deducting the cost of cultivation from the gross income and it is expressed in ₹ ha^{-1}.

3.8.8.2 B:C Ratio

B:C ratio was calculated as the ratio of the gross income to the cost of cultivation

$$\text{B:C ratio} = \frac{\text{Gross income}}{\text{Total cost of cultivation}}$$

3.8.9 Statistical Analysis

The data were analysed statistically by applying the technique of Analysis of Variance technique (ANOVA) for split plot design (Panse and Sukhatme, 1985). Significance was tested using F test (Snedecor and Cochran, 1967). Wherever the effect was found to be significant, critical difference (CD) values were calculated by using standard technique. Comparison was made between treatment mean and controls using t value (Rangaswamy, 2010).

Results

4. RESULTS

An experiment was conducted during summer season 2015 to standardize the fertigation schedule for yard long bean and to assess its impact on growth, yield and economics of yard long bean. The experiment data were statistically analysed and the results are furnished below.

4.1 GROWTH ATTRIBUTES

4.1.1 Primary Branches per Plant

Result on number of primary branches at 30, 60 and 90 DAS is given in Table 5.

The different levels of nutrients and fertigation intervals and their interaction had no effect on number of primary branches per plant at 30 and 60 DAS.

The number of primary branches per plant was influenced significantly by levels of nutrients at 90 DAS. Application of 150 per cent RD of N and K (L_4) registered the highest number of branches (15.50) which was on par with 125 and 100 per cent RD of N and K.

Fertigation intervals and interaction did not influence number of primary branches at 90 DAS.

Comparing control with treatments it was observed that *ad hoc* recommendation for fertigation (control 1) was significantly superior to treatments in number of primary branches at 30 and 90 DAS.

4.1.2 Length of Vine at Harvest

The result on length of vine at harvest as influenced by treatments is presented in Table 6.

The levels of nutrients influenced the length of vine. Application of N and K at 150 per cent RD (L_4) recorded the highest vine length of 5.03 m and the

Table 5. Influence of levels of nutrients and fertigation intervals on number of primary branches plant^{-1}

Treatments	Number of primary branches plant^{-1}		
	30 DAS	60 DAS	90 DAS
Levels of nutrients			
L_1 (75% RD N & K)	4.50	10.75	12.88
L_2 (100% RD N & K)	4.50	11.75	14.75
L_3 (125% RD N & K)	4.88	10.63	14.00
L_4 (150% RD N & K)	5.00	11.63	15.50
SEm (±)	0.29	0.52	0.51
CD (0.05)	NS	NS	1.638
Fertigation intervals			
I_1 (4 days interval)	4.75	10.69	13.94
I_2 (8 days interval)	4.69	11.69	14.63
SEm (±)	0.142	0.374	0.327
CD (0.05)	NS	NS	NS
Interaction			
l_1i_1	4.50	11.25	13.00
l_1i_2	4.50	10.25	12.75
l_2i_1	4.75	11.25	14.50
l_2i_2	4.25	12.25	15.00
l_3i_1	4.75	9.50	14.00
l_3i_2	5.00	11.75	14.00
l_4i_1	5.00	10.75	14.25
l_4i_2	5.00	12.50	16.75
SEm (±)	0.28	0.75	0.65
CD (0.05)	NS	NS	NS
Treatment mean	4.72	11.19	14.28
Control 1 (KAU *ad hoc* recommendation)	5.50	11.75	17.25
Control 2 (KAU POP)	5.25	12.75	15.75
Control 1 Vs Control 2	NS	NS	NS
Control 1 Vs Treatment	S	NS	S

lowest length of 4.17 m was recorded for 75 per cent RD of N and K (L_1). Comparing the fertigation intervals, 8 days interval (I_2) was found significantly superior (4.92 m) to 4 days interval (I_1).

Among the combinations, 150 per cent of RD at 8 days interval (l_4i_2) registered the highest vine length (5.11 m) and was on par with fertigation of 100 per cent of RD at 8 days interval (l_2i_2). The lowest vine length (3.69 m) was shown by 75 per cent of RD at 4 days interval (l_1i_1).

Ad hoc recommendation for fertigation (control 1) was significantly superior (5.26 m) to treatments and POP recommendation (control 2). The treatment mean registered a higher vine length (4.71 m) compared to control 2 (4.38 m).

4.1.3 Number of Productive Branches per Plant

Result on number of productive branches are presented in the Table 6.

Results revealed that different levels of nutrients influenced the number of productive branches while fertigation intervals and their interactions had no significant effect.

Among the fertigation levels, 150 per cent RD of N and K (L_4) registered the highest number of productive branches (15.50) which was on par with 125 per cent (L_3) and 100 per cent RD of N and K (L_2).

Ad hoc schedule (control 1) was observed superior to treatments and control 2 in its effect on number of productive branches at 30 and 90 DAS. KAU POP (control 2) was found superior to treatment mean.

4.1.4 Leaf Area Index at Flowering

Observation on the leaf area index at flowering is presented in Table 6.

Table 6. Influence of levels of nutrients and fertigation intervals on length of vine at harvest, number of productive branches plant^{-1} and leaf area index at flowering

Treatments	Length of vine at harvest (m)	Number of productive branches plant^{-1}	Leaf area index at flowering
Levels of nutrients			
L_1 (75% RD N & K)	4.17	12.88	1.72
L_2 (100% RD N & K)	4.87	14.75	1.80
L_3 (125% RD N & K)	4.77	14.00	1.81
L_4 (150% RD N & K)	5.03	15.5	1.83
SEm (±)	2.79	0.51	0.02
CD (0.05)	0.080	1.638	0.067
Fertigation intervals			
I_1 (4 days interval)	4.50	13.94	1.80
I_2 (8 days interval)	4.92	14.63	1.78
SEm (±)	2.19	0.33	0.02
CD (0.05)	0.064	NS	NS
Interaction			
l_1i_1	3.69	13.00	1.73
l_1i_2	4.66	12.75	1.72
l_2i_1	4.77	14.50	1.81
l_2i_2	4.98	15.00	1.80
l_3i_1	4.58	14.00	1.82
l_3i_2	4.95	14.00	1.81
l_4i_1	4.96	14.25	1.86
l_4i_2	5.11	16.75	1.81
SEm (±)	4.38	0.65	0.03
CD (0.05)	0.139	NS	NS
Treatment mean	4.71	14.28	1.79
Control 1 (KAU *ad hoc* recommendation)	5.26	17.25	1.87
Control 2 (KAU POP)	4.38	15.75	1.53
Control 1 Vs Control 2	S	S	S
Control 1 Vs Treatment	S	S	S
Control 2 Vs Treatment	S	NS	S

The different levels of nutrients imparted a significant influence on leaf area index. Among different nutrient levels, 150 per cent RD of N and K (L_4) recorded the highest LAI (1.83) which was on par with 125 per cent (L_3) and 100 per cent RD of N and K (L_2).

The LAI at flowering was not influenced by fertigation intervals and combination of fertigation levels and intervals.

Compared to control 2 (POP recommendation) the different treatments significantly improved the LAI and the *ad hoc* fertigation schedule (control 1) registered the highest LAI of 1.87 which was significantly superior to treatments.

4.1.5 Dry Matter Production at Harvest

Dry matter production by different plant parts and total dry matter production are depicted in Table 7.

Fertigation levels significantly influenced the leaf, stem, pod and total dry matter production. In case of leaf dry matter production 150 per cent RD of N and K (L_4) recorded the highest value of 1.47 t ha^{-1} which was on par with 125 per cent RD of N and K (L_3). Fertigation with 125 per cent RD of N and K (L_3) recorded the highest dry matter of stem (2.33 t ha^{-1}). Maximum dry matter of pod (2.73 t ha^{-1}) and total dry matter production (6.62 t ha^{-1}) were registered by 150 per cent RD of N and K (L_4). Root dry matter production was not influenced by levels of nutrients.

Among the intervals, fertigation interval of 8 days (I_2) showed the highest dry matter production of leaf (1.37 t ha^{-1}), stem (2.34 t ha^{-1}) and total dry matter (6.11 t ha^{-1}). However, total pod dry matter production (2.43 t ha^{-1}) was found significantly higher in fertigation at 4 days intervals (I_1).

The interaction effect was found significant in leaf and root dry matter production. The highest leaf dry matter production of 1.53 t ha^{-1} was registered by l_3i_2 and it was on par with l_4i_2. Fertigation of 150 per cent RD of N

Table 7. Influence of levels of nutrients and fertigation intervals on dry matter production at harvest, t ha^{-1}

Treatments	Dry matter production at harvest				
	Leaf	Stem	Root	Pod	Total
Levels of nutrients					
L_1 (75% RD N & K)	1.13	2.10	0.13	2.11	5.48
L_2 (100% RD N & K)	1.26	2.21	0.14	2.17	5.79
L_3 (125% RD N & K)	1.43	2.33	0.13	2.35	6.26
L_4 (150% RD N & K)	1.47	2.26	0.14	2.73	6.62
SEm (±)	0.14	0.19	0.01	0.41	0.51
CD (0.05)	0.446	0.605	NS	1.309	1.644
Fertigation intervals					
I_1 (4 days interval)	1.27	2.11	0.14	2.43	5.96
I_2 (8 days interval)	1.37	2.34	0.14	2.25	6.11
SEm (±)	0.07	0.14	0.01	0.31	0.32
CD (0.05)	0.201	0.425	NS	0.955	1.001
Interaction					
l_1i_1	1.09	1.97	0.14	2.25	5.46
l_1i_2	1.16	2.24	0.13	1.96	5.51
l_2i_1	1.24	2.11	0.14	2.16	5.66
l_2i_2	1.28	2.31	0.14	2.18	5.92
l_3i_1	1.33	2.22	0.14	2.49	6.19
l_3i_2	1.53	2.43	0.13	2.21	6.32
l_4i_1	1.42	2.14	0.13	2.82	6.52
l_4i_2	1.52	2.39	0.14	2.65	6.71
SEm (±)	0.13	0.28	0.01	0.62	0.65
CD (0.05)	0.412	NS	0.046	NS	NS
Treatment mean	1.32	2.23	0.14	2.34	6.04
Control 1 (KAU *ad hoc* recommendation)	2.10	2.75	0.15	3.32	8.33
Control 2 (KAU POP)	1.28	2.45	0.14	1.97	5.82
Control 1 Vs Control 2	S	S	NS	S	S
Control 1 Vs Treatment	S	S	S	S	S
Control 2 Vs Treatment	S	S	NS	S	S

and K at 8 days intervals (l_4i_2) was significantly superior (0.14 t ha^{-1}) for root dry matter and was observed to be on par with l_1i_1, l_2i_1 and l_2i_2.

Both the controls influenced dry matter production significantly. Control 1 recorded the highest dry matter production of leaves (2.10 t ha^{-1}), stem (2.75 t ha^{-1}), root (0.15 t ha^{-1}), pod (3.32 t ha^{-1}) and total dry matter (8.33 t ha^{-1}) and was significantly superior to treatments and control 2. Comparing treatments and control 2, the dry matter production of leaf, pod and total dry matter were the highest in treatments, whereas stem dry matter production was the highest in control 2 (POP recommendation). Root dry matter production did not vary between treatments and control 2.

4.1.6 Crop Duration

Different fertigation levels had significant influence on crop duration of yard long bean (Table 8). Among the levels, fertigation with 150 per cent RD of N and K (L_4) resulted in the longest crop duration (105.13 days) which was on par with 125 per cent RD of N and K (L_3). The crop duration was the shortest in 75 per cent RD of N and K (L_1), which was on par with 100 per cent RD of N and K (L_2).

The fertigation intervals and interaction effects were not found significant.

The duration of crop did not show any variation between treatments and controls.

4.2 YIELD AND YIELD ATTRIBUTES

4.2.1 Days for 50 per cent Flowering

The result furnished in Table 8 revealed that 100 per cent RD of N and K (L_2) recorded minimum days for 50 per cent flowering (41.63 days) which

Table 8. Influence of levels of nutrients and fertigation intervals on crop duration and days for 50 per cent flowering.

Treatments	Crop Duration (days)	Days for 50 per cent flowering
Levels of nutrients		
L_1 (75% RD N & K)	98.38	42.13
L_2 (100% RD N & K)	99.75	41.63
L_3 (125% RD N & K)	103.88	42.63
L_4 (150% RD N & K)	105.13	42.75
SEm (±)	1.26	0.20
CD (0.05)	4.044	0.653
Fertigation intervals		
I_1 (4 days interval)	101.88	43.50
I_2 (8 days interval)	101.69	41.06
SEm (±)	0.75	0.36
CD (0.05)	NS	1.105
Interaction		
l_1i_1	98.50	42.00
l_1i_2	98.25	42.25
l_2i_1	98.50	44.00
l_2i_2	101.00	39.25
l_3i_1	104.50	45.00
l_3i_2	103.25	40.25
l_4i_1	106.00	43.00
l_4i_2	104.25	42.50
SEm (±)	1.51	0.71
CD (0.05)	NS	2.201
Treatment mean	101.78	42.28
Control 1 (KAU *ad hoc* recommendation)	103.75	44.25
Control 2 (KAU POP)	99.50	39.75
Control 1 Vs Control 2	NS	S
Control 1 Vs Treatment	NS	S
Control 2 Vs Treatment	NS	S

was on par with 75 per cent RD of N and K (L_1). The fertigation interval of 8 days (I_2) recorded the lowest number of days for 50 per cent flowering (41.06 days) over fertigation at 4 days interval (I_1).

Among the combinations, l_2i_2 recorded minimum days for 50 per cent flowering (39.25 days) and it was on par with l_3i_2.

Comparing control with treatments, minimum days for 50 per cent flowering (39.75 days) was observed in control 2 (POP recommendation) and followed by treatment mean (42.28 days).

4.2.2 Setting Percentage and Number of Flowers per Inflorescence

The results of setting percentage and number of flowers per inflorescence in yard long bean are presented in Table 9.

The levels of nutrients and its interaction with interval of fertigation had no significant effect on setting percentage, while fertigation intervals significantly influenced this parameter. Fertigation at 8 days interval (I_2) was found significantly superior (73.00 per cent) to 4 days intervals (I_1).

The number of flowers per inflorescence was unaffected by different levels of nutrient, fertigation intervals and their interactions.

Control and treatments did not influence the setting percentage. Compared to control 1 (*ad hoc* recommendation) the number of flowers per inflorescence was significantly higher in treatments (8.34).

4.2.3 Pods per Plant

The different treatments and their interactions had a significant influence on pod number per plant (Table 10). Among the main plot treatments, fertigation with 150 per cent RD of N and K (L_4) recorded the highest pod number (66.38) and it was significantly superior to all other levels of nutrients and was followed by 125 per cent RD of N and K (L_3).

Table 9. Influence of levels of nutrients and fertigation intervals on setting percentage and number of flowers inflorescence $^{-1}$

Treatments	Setting percentage	Number of flowers inflorescence $^{-1}$
Levels of nutrients		
L_1 (75% RD N & K)	69.10	8.50
L_2 (100% RD N & K)	70.70	8.25
L_3 (125% RD N & K)	65.47	8.50
L_4 (150% RD N & K)	71.03	8.13
SEm (±)	2.95	0.32
CD (0.05)	NS	NS
Fertigation intervals		
I_1 (4 days interval)	65.14	8.31
I_2 (8 days interval)	73.00	8.38
SEm (±)	2.13	0.20
CD (0.05)	6.557	NS
Interaction		
l_1i_1	67.71	8.50
l_1i_2	70.49	8.50
l_2i_1	69.52	8.50
l_2i_2	71.88	8.00
l_3i_1	60.12	8.50
l_3i_2	70.83	8.50
l_4i_1	63.24	7.75
l_4i_2	78.82	8.50
SEm (±)	4.25	0.40
CD (0.05)	NS	NS
Treatment mean	69.07	8.34
Control 1 (KAU *ad hoc* recommendation)	61.90	7.25
Control 2 (KAU POP)	62.50	8.00
Control 1 Vs Control 2	NS	NS
Control 1 Vs Treatment	NS	S
Control 2 Vs Treatment	NS	NS

Fertigation at 4 days interval (I_1) recorded the highest pod number (59.06)

Fertigation with 150 per cent RD of N and K at 4 days intervals (l_4i_1) was found significantly superior (67.75) and was followed by 150 per cent RD of N and K at 8 days intervals (l_4i_2) (65.00).

Comparing treatments with control, *ad hoc* fertigation schedule registered a higher pod number per plant (75.75) and was superior to treatments and POP recommendation. The treatment mean registered higher pod number per plant than KAU POP.

4.2.4 Pod Yield per Plant

The data presented in Table 10 revealed the influence of levels of nutrients, fertigation intervals and their interactions on the pod yield per plant.

Fertigation with 150 per cent RD of N and K (L_4) was significantly superior (1549 g per plant) to other levels of nutrients which was followed by 125 per cent RD of N and K (L_3). Fertigation with 75 per cent RD of N and K (L_1) recorded the lowest pod yield of 1167.38 g per plant.

Fertigation at 4 days interval (I_1) registered the highest pod yield (1326 g per plant) and was significantly superior to 8 days intervals (I_2).

Among the combinations, 150 per cent RD of N and K at 4 days intervals (l_4i_1) was found significantly superior (1565 g per plant) and was followed fertigation with 150 per cent RD of N and K at 8 days intervals (l_4i_2). The treatment combination of 75 per cent RD of N and K at 8 days interval recorded the lowest pod yield (1110 g per plant).

Comparing controls with treatments, it was observed that the KAU *ad hoc* fertigation schedule recorded the highest pod yield per plant (1825.75 g) and was

Table 10. Influence of levels of nutrients and fertigation intervals on number of pods plant $^{-1}$, pod yield plant^{-1} and total pod yield

Treatments	Number of pods plant $^{-1}$	Pod yield plant $^{-1}$ (g)	Total pod yield (t ha^{-1})
Levels of nutrients			
L_1 (75% RD N & K)	54.25	1167.38	15.24
L_2 (100% RD N & K)	53.13	1191.88	15.36
L_3 (125% RD N & K)	57.25	1284.63	16.60
L_4 (150% RD N & K)	66.38	1549.00	19.57
SEm (±)	0.21	1.41	0.77
CD (0.05)	0.659	4.516	2.454
Fertigation intervals			
I_1 (4 days interval)	59.06	1326.00	17.17
I_2 (8 days interval)	56.44	1270.44	16.22
SEm (±)	0.14	1.68	0.39
CD (0.05)	0.436	5.165	1.217
Interaction			
l_1i_1	57.50	1224.75	16.14
l_1i_2	51.00	1110.00	14.33
l_2i_1	52.50	1209.25	15.52
l_2i_2	53.75	1174.50	15.21
l_3i_1	58.50	1305.00	17.00
l_3i_2	56.00	1264.25	16.19
l_4i_1	67.75	1565.00	20.01
l_4i_2	65.00	1533.00	19.14
SEm (±)	0.28	3.35	0.79
CD (0.05)	0.863	10.331	2.435
Treatment mean	57.75	1298.22	16.69
Control 1 (KAU *ad hoc* recommendation)	75.75	1825.75	24.23
Control 2 (KAU POP)	53.00	1014.75	13.56
Control 1 Vs Control 2	S	S	S
Control 1 Vs Treatment	S	S	S
Control 2 Vs Treatment	S	S	S

found superior to treatments and control 2. The treatments were found superior to KAU POP (soil application).

4.2.5 Total Pod Yield

Total pod yield presented in Table 10 showed variation due to treatments.

Among the levels of nutrients, fertigation with 150 per cent RD of N and K (L_4) was found significantly superior (19.57 t ha^{-1}) and was followed by 125 per cent RD of N and K (L_3) (16.60 t ha^{-1}). Fertigation at 4 days interval (I_1) was significantly superior to 8 days interval.

The combined effect of levels of nutrients and fertigation intervals showed that 150 per cent RD of N and K at 4 days interval (l_4i_1) was significantly superior (20.01 t ha^{-1}) and was followed by 150 per cent RD of N and K at 8 days interval (l_4i_2) (19.14 t ha^{-1}). The treatment 75 per cent RD of N and K at 8 days interval recorded the lowest value (14.36 t ha^{-1}).

Ad hoc fertigation schedule of KAU (control 1) was found significantly superior (24.23 t ha^{-1}) to treatments and control 2 and the treatments out yielded KAU POP.

4.2.6 Pod Yield per Plant at each Harvest

Data on pod yield per plant at each harvest are depicted in Table 11.

The highest pod yield per plant at each harvest was recorded in KAU *ad hoc* recommendation for precision farming and was followed by 150 per cent RD of N and K.

4.2.7 Pod Yield per Plot at each Harvest

Data on pod yield per harvest are presented in Table 12. Pod yield in different treatments increased from third harvest onwards and it was sustained upto fourteenth harvest. The maximum pod yield per harvest was recorded in *ad hoc* treatment and was followed by 150 per cent RD of N and K. the pod yield per

Table 11. Influence of levels of nutrients and fertigation intervals on pod yield plant^{-1} at each harvest (g plant $^{-1}$)*

Treatment	Number of harvest										
	1	2	3	4	5	6	7	8	9	10	11
l_1i_1	24.29	26.79	87.86	102.14	177.14	111.43	73.57	95.00	87.86	78.57	73.57
l_1i_2	22.14	30.71	104.29	150.00	112.86	72.86	85.71	75.00	72.14	77.14	67.86
l_2i_1	28.57	40.00	60.71	174.29	94.29	103.57	91.43	87.14	75.71	85.71	78.57
l_2i_2	39.29	22.71	66.43	180.00	92.86	85.71	98.57	80.00	64.07	87.86	62.86
l_3i_1	37.50	111.43	150.00	119.29	119.29	110.00	75.71	78.57	76.43	77.14	62.86
l_3i_2	24.29	26.21	90.71	80.00	145.71	95.71	119.29	108.57	84.29	93.71	73.57
l_4i_1	22.93	160.71	87.86	190.71	83.57	89.29	111.43	93.57	95.86	103.57	80.93
l_4i_2	48.21	89.29	80.00	145.71	93.57	162.14	105.00	80.00	86.43	85.00	87.86
Control 1 (KAU *adhoc* recommendation)	53.57	125.00	92.86	266.43	250.34	111.43	118.57	107.14	93.57	95.71	87.86
Control 2 (KAU POP)	29.29	63.86	72.14	62.50	72.86	86.43	81.43	68.14	76.43	91.14	61.14

Continued ...

Treatments	12	13	14	15	16	17	18	19	20	21	Total pod yield plant^{-1}
l1i1	71.43	70.71	77.86	67.14	55.71	45.71	24.29	16.71	0.00	0.00	1224.75
l1i2	62.71	67.86	62.71	57.79	47.14	31.07	21.96	52.38	0.00	0.00	1110.00
l2i1	62.57	56.36	69.29	52.43	61.07	48.29	32.43	24.43	0.00	0.00	1209.25
l2i2	56.21	87.86	70.00	60.36	40.50	38.79	48.21	24.64	0.00	0.00	1174.50
l3i1	75.00	86.43	70.71	63.57	56.36	41.79	22.29	21.57	0.00	0.00	1305.00
l3i2	79.29	63.57	66.71	78.57	55.71	40.21	24.29	29.43	0.00	0.00	1264.25
l4i1	73.57	81.43	106.43	69.86	68.93	62.57	54.79	40.29	24.79	0.00	1565.00
l4i2	79.29	70.93	73.57	53.21	77.86	75.00	64.07	46.71	30.07	0.00	1533.00
Control 1 (KAU *adhoc* recommendation)	58.00	86.43	73.57	102.14	88.57	65.14	46.93	56.00	46.57	32.57	1825.75
Control 2 (KAU POP)	44.64	62.57	54.64	69.64	40.50	46.71	40.14	32.29	0.00	0.00	1014.75

* Data is not statistically analysed

Table 12. Influence of levels of nutrients and fertigation intervals on pod yield per plot at each harvest (kg net plot^{-1})*

Treatment	Number of harvests										
	1	2	3	4	5	6	7	8	9	10	11
l_1i_1	0.34	0.37	1.23	1.43	2.48	1.56	1.03	1.33	1.23	1.10	1.03
l_1i_2	0.31	0.43	1.46	2.10	1.58	1.02	1.20	1.05	1.01	1.08	0.95
l_2i_1	0.4	0.56	0.85	2.44	1.32	1.45	1.28	1.22	1.06	1.20	1.10
l_2i_2	0.55	0.31	0.93	2.52	1.30	1.20	1.38	1.12	0.89	1.23	0.88
l_3i_1	0.52	1.56	2.10	1.67	1.67	1.54	1.06	1.10	1.07	1.08	0.88
l_3i_2	0.34	0.36	1.27	1.12	2.04	1.34	1.67	1.52	1.18	1.31	1.03
l_4i_1	0.32	2.25	1.23	2.67	1.17	1.25	1.56	1.31	1.34	1.45	1.13
l_4i_2	0.67	1.25	1.12	2.04	1.31	2.27	1.47	1.12	1.21	1.19	1.23
Control 1 (KAU ad hoc recommendation)	0.75	1.75	1.30	3.73	3.75	1.56	1.66	1.50	1.31	1.34	1.23
Control 2 (KAU POP)	0.41	0.89	1.01	0.87	1.02	1.21	1.14	0.954	1.07	1.27	0.85

Continued .....

Treatments	12	13	14	15	16	17	18	19	20	21	Total pod yield net $plot^{-1}$
l_1i_1	1.00	0.99	1.09	0.94	0.78	0.64	0.34	0.23	0.00	0.00	19.15
l_1i_2	0.87	0.95	0.87	0.80	0.66	0.43	0.30	0.00	0.00	0.00	17.84
l_2i_1	0.87	0.78	0.97	0.73	0.85	0.67	0.45	0.34	0.00	0.00	18.58
l_2i_2	0.78	1.23	0.98	0.84	0.56	0.54	0.67	0.34	0.00	0.00	18.30
l_3i_1	1.05	1.21	0.99	0.89	0.78	0.58	0:31	0.30	0.00	0.00	20.38
l_3i_2	1.11	0.89	0.93	1.10	0.78	0.56	0.34	0.41	0.00	0.00	19.32
l_4i_1	1.03	1.14	1.49	0.97	0.96	0.87	0.76	0.56	0.34	0.00	23.84
l_4i_2	1.11	0.99	1.03	0.74	1.09	1.05	0.89	0.65	0.42	0.00	22.88
Control 1 (KAU ad hoc recommendation)	0.81	1.21	1.03	1.43	1.24	0.91	0.65	0.78	0.65	0.45	28.61
Control 2 (KAU POP)	0.62	0.87	0.76	0.97	0.56	0.65	0.562	0.45	0.00	0.00	16.19

* Data are not statistically analysed

harvest was lower in KAU POP and yield increase in this treatment was evident from third to tenth harvest.

4.2.8 Pod Characters

The average value of pod characters like pod girth, pod length and pod weight are depicted in the Table 13.

Pod length was influenced by the levels of nutrients and interaction between levels and intervals. Fertigation interval had no influence on pod length. Among the levels, 150 per cent RD of N and K (L_4) recorded the highest pod (48.43 cm) and it was significantly superior to all other levels.

Among the combinations, l_4i_1 recorded the highest pod length (48.73 cm) which was on par with l_2i_1, l_3i_1 and l_4i_2.

The average pod girth and average pod weight were not influenced by the levels of nutrients, fertigation intervals and their interactions.

Ad hoc fertigation schedule recorded maximum pod length (50.13 cm) and was superior to treatments. Control 2 (POP recommendation) also registered longer pod (49.60 cm) than treatments. The *ad hoc* recommendation registered higher average pod weight over soil application (control 2). However, the pod weight was minimum in control 2 which was on par with treatments.

4.2.9 Number of Pickings

Data on number of picking presented in Table 14 indicated that the fertigation levels, intervals and their interactions had no significant influence on the number of pickings. However, compared to treatment *ad hoc* fertigation schedule of KAU (control 1) registered the highest number of picking (21.00).

Table 13. Influence of levels of nutrients and fertigation intervals on average pod length, pod girth and pod weight

Treatments	Average pod length (cm)	Average pod girth (cm)	Average pod weight (g)
Levels of nutrients			
L_1 (75% RD N & K)	47.23	3.61	21.69
L_2 (100% RD N & K)	47.66	3.65	22.75
L_3 (125% RD N & K)	47.79	3.49	22.31
L_4 (150% RD N & K)	48.43	3.60	22.75
SEm (±)	0.18	0.06	0.29
CD (0.05)	0.566	NS	NS
Fertigation intervals			
I_1 (4 days interval)	47.88	3.60	22.53
I_2 (8 days interval)	47.68	3.58	22.22
SEm (±)	0.15	0.06	0.27
CD (0.05)	NS	NS	NS
Interaction			
l_1i_1	46.58	3.45	21.63
l_1i_2	47.88	3.78	21.75
l_2i_1	47.78	3.78	22.75
l_2i_2	47.55	3.53	22.75
l_3i_1	48.43	3.50	22.50
l_3i_2	47.15	3.48	22.13
l_4i_1	48.73	3.68	23.25
l_4i_2	48.13	3.53	22.25
SEm (±)	0.30	0.13	0.54
CD (0.05)	0.915	NS	NS
Treatment mean	47.78	3.59	22.38
Control 1 (KAU *ad hoc* recommendation)	50.13	3.38	23.25
Control 2 (KAU POP)	49.60	3.58	19.75
Control 1 Vs Control 2	NS	NS	S
Control 1 Vs Treatment	S	NS	NS
Control 2 Vs Treatment	S	NS	S

4.2.10 Harvest Index

Results presented in the Table 14 revealed that harvest index was the highest in 150 per cent RD of N and K (L_4) (0.42) which was significantly superior to all other levels. Similarly fertigation interval of 4 days (I_1) had significant superiority over 8 days interval with a harvest index of 0.41.

The interaction of 150 per cent RD of N and K at 4 days interval (l_4i_1) was found significantly superior (0.44) to other combinations. The combination of 75 and 125 per cent N and K at 8 days interval were on par and registered the lowest harvest index.

On comparison of treatments with control, it was observed that *ad hoc* recommendation of KAU and treatment mean was found superior to control 2 (POP recommendation). There was no significant difference between *ad hoc* and treatment mean.

4.3 ROOT STUDIES AT FINAL HARVEST

Data on root parameters *viz.* root length, root volume and root weight are presented in Table 15.

Root parameters like root length and root volume were influenced by fertigation levels, intervals and their interaction. The highest root length (51.50 cm) and root volume (62.25 cm^3) were recorded by fertigation at 150 per cent RD of N and K (L_4) and was followed by 100 per cent RD of N and K (L_2). The variation on root weight between 100 and 150 per cent RDs of N and K was not significant and these two treatments were superior to others.

Fertigation interval of 4 days (I_1) registered the highest root length (50.75 cm), and the maximum root volume (54.94 cm^3) was noticed at 8 days interval (I_2). Fertigation interval had no effect on root weight.

Among the various interactions, the longest root (52.00 cm) was observed in fertigation at 100 and 150 per cent RD of N and K at 4 days interval which

Table 14. Influence of levels of nutrients and fertigation intervals on number of pickings and harvest index

Treatments	Number of pickings	Harvest index
Levels of nutrients		
L_1 (75% RD N & K)	18.75	0.39
L_2 (100% RD N & K)	18.63	0.38
L_3 (125% RD N & K)	19.00	0.38
L_4 (150% RD N & K)	20.00	0.42
SEm (±)	0.34	0.01
CD (0.05)	NS	0.016
Fertigation intervals		
I_1 (4 days interval)	19.31	0.41
I_2 (8 days interval)	18.88	0.37
SEm (±)	0.20	0.002
CD (0.05)	NS	0.007
Interaction		
l_1i_1	19.25	0.41
l_1i_2	18.25	0.36
l_2i_1	18.50	0.38
l_2i_2	18.75	0.37
l_3i_1	19.25	0.41
l_3i_2	18.75	0.35
l_4i_1	20.25	0.44
l_4i_2	19.75	0.40
SEm (±)	0.39	0.001
CD (0.05)	NS	0.015
Treatment mean	19.09	0.39
Control 1 (KAU *ad hoc* recommendation)	21.00	0.40
Control 2 (KAU POP)	19.00	0.33
Control 1 Vs Control 2	S	S
Control 1 Vs Treatment	S	NS
Control 2 Vs Treatment	NS	S

Table 15. Influence of levels of nutrients and fertigation intervals on root length, root volume and root weight

Treatments	Root length (cm)	Root volume (cm^3)	Root weight(g)
Levels of nutrients			
L_1 (75% RD N & K)	50.00	39.75	50.70
L_2 (100% RD N & K)	50.25	54.88	52.23
L_3 (125% RD N & K)	49.38	54.88	50.73
L_4 (150% RD N & K)	51.50	62.25	51.85
SEm (±)	0.22	0.44	0.14
CD (0.05)	0.689	1.395	0.442
Fertigation intervals			
I_1 (4 days interval)	50.75	50.94	51.36
I_2 (8 days interval)	49.81	54.94	51.39
SEm (±)	0.28	0.33	0.11
CD (0.05)	0.870	1.021	NS
Interaction			
l_1i_1	50.25	29.75	51.15
l_1i_2	49.75	49.75	50.25
l_2i_1	52.00	50.00	52.47
l_2i_2	48.50	59.75	52.00
l_3i_1	48.75	69.50	51.34
l_3i_2	50.00	40.25	50.13
l_4i_1	52.00	54.50	50.50
l_4i_2	51.00	70.00	53.20
SEm (±)	0.56	0.67	0.21
CD (0.05)	1.740	2.053	0.649
Treatment mean	50.28	52.94	51.38
Control 1 (KAU *ad hoc* recommendation)	53.00	80.00	55.13
Control 2 (KAU POP)	50.00	40.00	51.25
Control 1 Vs Control 2	S	S	S
Control 1 Vs Treatment	S	S	S
Control 2 Vs Treatment	NS	S	NS

were on par with 150 percent RD of N and K at 8 days interval. Root volume was maximum (70 cm^3) in l_4i_2 and was on par with 125 per cent RD of N and K at 4 days interval (l_3i_1). In case of root weight also 150 per cent RD of N and K at 8 days intervals (l_4i_2) recorded the highest (53.20 g).

Comparing treatments with control 1 and control 2, the *ad hoc* fertigation schedule (control 1) was found superior in terms of root length, root weight and root volume. Though treatments did not vary from POP on root length and root weight, treatments registered significant superiority on root volume over POP.

4.4 MOISTURE STUDIES

4.4.1 Water Requirement, Water Use Efficiency and Water Productivity

Results on total water requirement, water use efficiency and water productivity as influenced by treatments are given in Tables 16 and 17.

The water requirement of yard long bean ranged from 681 – 891 mm. Water requirement was the highest (891.16 mm) in KAU POP, where hose irrigation was practiced. Drip irrigation registered lower water requirements and the values ranged from 681.38 to 741.16 mm.

Fertigation at 150 per cent RD of N and K recorded the highest WUE (26.55 kg $ha.mm^{-1}$) and water productivity (8.98 kg $ha.mm^{-1}$) compared to all other fertigation levels.

Among the fertigation intervals, fertigation at 4 days interval recorded the highest WUE (23.90 kg ha mm^{-1}) and it was significantly superior to that at 8 days interval (22.79 kg ha mm^{-1}). Water productivity of 8.60 kg ha mm^{-1} was noticed in fertigation at 8 days interval and it was significantly higher than that at 4 days interval (8.30 kg ha mm^{-1}).

Interaction between fertigation levels and intervals significantly influenced WUE, while it was insignificant for water productivity. Fertigation at 150 per cent RD of N and K at 4 days intervals (l_4i_1) recorded the highest WUE

Table 16. Water requirement of yard long bean

Treatments	Water requirement (mm)
l_1i_1 (75 % RD of N & K at 4 days interval)	696.92
l_1i_2 (75 % RD of N & K at 8 days interval)	681.38
l_2i_1 (100 % RD of N & K at 4 days interval)	696.92
l_2i_2 (100 % RD of N & K at 8 days interval)	705.18
l_3i_1 (125 % RD of N & K at 4 days interval)	734.16
l_3i_2 (125 % RD of N & K at 8 days interval)	721.56
l_4i_1 (150 % RD of N & K at 4 days interval)	741.16
l_4i_2 (150 % RD of N & K at 8 days interval)	733.46
Control 1 (KAU *ad hoc* recommendation)	733.46
Control 2 (KAU POP)	891.16

Table 17. Influence of fertigation levels and intervals on water use efficiency and water productivity, kg ha mm^{-1}

Treatments	WUE	Water productivity
Levels of nutrients		
L_1 (75% RD N & K)	22.10	7.97
L_2 (100% RD N & K)	21.92	8.27
L_3 (125% RD N & K)	22.81	8.60
L_4 (150% RD N & K)	26.55	8.98
SEm (±)	0.11	0.07
CD (0.05)	0.341	0.228
Fertigation intervals		
I_1 (4 days interval)	23.90	8.30
I_2 (8 days interval)	22.79	8.60
SEm (±)	0.06	0.04
CD (0.05)	0.171	0.132
Interaction		
l_1i_1	23.17	7.85
l_1i_2	21.04	8.09
l_2i_1	22.27	8.13
l_2i_2	21.58	8.41
l_3i_1	23.17	8.44
l_3i_2	22.45	8.76
l_4i_1	27.00	8.81
l_4i_2	26.10	9.16
SEm (±)	0.09	0.09
CD (0.05)	0.342	NS
Treatment mean	23.34	8.45
Control 1 (KAU *ad hoc* recommendation)	33.05	11.36
Control 2 (KAU POP)	15.23	6.54
Control 1 Vs Control 2	S	S
Control 1 Vs Treatment	S	S
Control 2 Vs Treatment	S	S

and was followed by 150 per cent RD of N and K at 8 days interval. Comparing control with treatment, *ad hoc* fertigation schedule recorded the highest WUE and water productivity. The treatments were significantly superior to KAU POP recommendation with respect to WUE and water productivity.

4.5 CHEMICAL ANALYSIS

4.5.1 N Uptake by Crop

The N uptake by different plant parts and total uptake by the crop are presented in Table 18.

Among nutrient levels, 150 per cent RD of N and K (L_4) recorded the highest N uptake by leaf (56.96 kg ha $^{-1}$), pod (132.15 kg ha $^{-1}$), and total N uptake by plant (249.80 kg ha $^{-1}$). However, 100 per cent RD of N and K (L_2) registered The N uptake by the stem (69.38 kg ha $^{-1}$) was the highest in 100 per cent RD of N and K, which was on par with 125 per cent RD of N and K (L_3). Fertigation with 75 per cent RD of N and K (L_1) registered the highest N uptake by root (4.83 kg ha $^{-1}$).

The fertigation interval of 8 days (I_2) recorded maximum N uptake by leaves (50.24 kg ha $^{-1}$) and stem (63.18 kg ha^{-1}), however fertigation at 4 days interval recorded the highest N uptake by pod. The total N uptake was unaffected by fertigation interval.

N uptake by leaves and total N uptake were the highest in 150 per cent RD of N and K at 8 days interval (l_4i_2). Fertigation of 100 per cent RD of N and K at 4 days intervals (l_2i_1) recorded maximum N uptake by stem which was on par with 125 per cent RD at 8 days interval (l_3i_2). The combination of 75 per cent RD of N and K at 4 days interval (l_1i_1) recorded maximum N uptake by root. Regarding pod N uptake, l_4i_1 (150 per cent RD of N and K at 4 days interval) was superior to other treatments and was on par with l_4i_2.

KAU *ad hoc* recommendation for precision farming registered the highest N uptake by leaf, stem, pod and total uptake and was significantly superior to

Table 18. Influence of levels of nutrients and fertigation intervals on uptake of nitrogen, kg ha $^{-1}$

Treatments	Uptake of nitrogen				
	Leaf	Stem	Root	Pod	Total
Levels of nutrients					
L_1 (75% RD N & K)	43.63	53.64	4.83	80.65	182.75
L_2 (100% RD N & K)	48.56	69.38	3.94	87.47	209.35
L_3 (125% RD N & K)	44.78	65.28	2.92	109.71	222.70
L_4 (150% RD N & K)	56.96	57.23	3.45	132.15	249.80
SEm (±)	0.48	1.32	0.03	1.92	2.62
CD (0.05)	1.538	4.227	0.083	6.152	8.379
Fertigation intervals					
I_1 (4 days interval)	46.73	59.59	3.91	106.57	216.80
I_2 (8 days interval)	50.24	63.18	3.66	98.41	215.49
SEm (±)	0.23	0.95	0.02	1.44	1.68
CD (0.05)	0.718	2.928	0.062	4.436	NS
Interaction					
l_1i_1	38.42	42.05	4.91	86.93	172.30
l_1i_2	48.84	65.23	4.75	74.37	193.19
l_2i_1	52.10	73.94	3.93	87.78	217.75
l_2i_2	45.03	64.82	3.94	87.16	200.95
l_3i_1	46.57	62.37	2.94	117.15	229.04
l_3i_2	42.99	68.18	2.91	102.27	216.35
l_4i_1	49.83	59.99	3.86	134.44	248.12
l_4i_2	64.11	54.48	3.05	129.85	251.48
SEm (±)	0.47	1.90	0.04	2.88	3.37
CD (0.05)	1.436	5.847	0.135	8.875	10.37
Treatment mean	48.48	61.38	3.79	102.50	216.15
Control 1 (KAU *ad hoc* recommendation)	58.94	77.00	3.19	174.57	313.70
Control 2 (KAU POP)	35.84	50.93	2.95	72.02	161.73
Control 1 Vs Control 2	S	S	S	S	S
Control 1 Vs Treatment	S	S	S	S	S
Control 2 Vs Treatment	S	S	S	S	S

treatment and POP recommendation. The treatment mean was superior to POP on N uptake by various plant parts and total N uptake.

4.5.2 P Uptake by Crop

Uptake of P by different plant parts (Table 19) and total P uptake by the crop were influenced by the treatments. Among levels, fertigation at 150 per cent RD of N and K (L_4) recorded maximum P uptake by pod (7.89 kg ha $^{-1}$) and total P uptake by plant (17.61 kg ha $^{-1}$). P uptake by leaves and stem were the highest in 125 per cent RD of N and K (L_3) which was on par with 150 per cent RD of N and K (L_4). Fertigation at 75 per cent RD of N and K (L_1) recorded maximum P uptake by root.

The fertigation interval of 8 days (I_2) recorded maximum P uptake by leaves (3.92 kg ha $^{-1}$), stem (6.14 kg ha $^{-1}$) and total P uptake (16.53 kg ha $^{-1}$). P uptake by pod was the highest (6.65 kg ha $^{-1}$) at 4 days interval. P uptake by root was not influenced by fertigation intervals.

Among the interactions, l_4i_2 recorded maximum P uptake by leaf and stem. While in case of root uptake, 75 per cent RD of N and K at 4 days interval (l_1i_1) was found superior. P uptake by pod was superior for 150 per cent RD of N and K at 4 days intervals (l_4i_1). The treatment combination was insignificant for total P uptake.

Ad hoc recommendation for fertigation was found superior to POP recommendation and treatments in case of P uptake by leaf, stem, root, pod and total uptake. Comparing treatment mean and POP recommendation, POP was found superior for P uptake by leaf and stem, while treatment mean recorded the highest value for P uptake by pod and total uptake.

4.5.3 K Uptake by Crop

Result of K uptake by the different plant parts and total K uptake by the crop are presented in Table 20.

Table 19. Influence of levels of nutrients and fertigation intervals on uptake of phosphorus, kg ha $^{-1}$

Treatments	Uptake of phosphorus				
	Leaf	Stem	Root	Pod	Total
Levels of nutrients					
L_1 (75% RD N & K)	2.76	5.00	0.41	4.90	13.05
L_2 (100% RD N & K)	3.30	5.24	0.32	7.03	15.89
L_3 (125% RD N & K)	4.02	5.60	0.33	5.74	15.68
L_4 (150% RD N & K)	3.93	5.48	0.31	7.89	17.61
SEm (±)	0.03	0.05	0.004	0.04	0.21
CD (0.05)	0.107	0.153	0.014	0.114	0.672
Fertigation intervals					
I_1 (4 days interval)	3.08	4.51	0.34	6.65	14.58
I_2 (8 days interval)	3.92	6.14	0.34	6.13	16.53
SEm (±)	0.01	0.03	0.003	0.02	0.14
CD (0.05)	0.045	0.103	NS	0.076	0.418
Interaction					
l_1i_1	2.10	4.04	0.44	5.28	11.84
l_1i_2	3.42	5.96	0.38	4.52	14.27
l_2i_1	3.24	4.44	0.25	6.83	14.75
l_2i_2	3.36	6.04	0.40	7.24	17.03
l_3i_1	3.60	5.19	0.32	6.25	15.35
l_3i_2	4.44	6.01	0.34	5.23	16.01
l_4i_1	3.39	4.40	0.36	8.25	16.38
l_4i_2	4.48	6.57	0.27	7.53	18.84
SEm (±)	0.03	0.07	0.01	0.05	0.27
CD (0.05)	0.081	0.217	0.016	0.143	NS
Treatment mean	3.50	5.33	0.34	6.39	15.56
Control 1 (KAU *ad hoc* recommendation)	5.30	6.87	0.40	8.25	20.82
Control 2 (KAU POP)	3.64	6.06	0.31	3.43	13.44
Control 1 Vs Control 2	S	S	S	S	S
Control 1 Vs Treatment	S	S	S	S	S
Control 2 Vs Treatment	S	S	NS	S	S

Fertigation at 150 per cent RD of N and K (L_4) recorded maximum K uptake by leaf (51.72 kg ha $^{-1}$), stem (66.10 kg ha $^{-1}$), pod (47.60 kg ha $^{-1}$) and total K uptake by the crop (166.88 kg ha $^{-1}$). Maximum K uptake by root (3.27 kg ha $^{-1}$) was registered for 100 per cent RD of N and K (L_2).

The fertigation at 8 days interval (I_2) recorded maximum K uptake by leaves (45.53 kg ha $^{-1}$), stem (58.94 kg ha $^{-1}$), root (2.97 kg ha $^{-1}$) and total K uptake (149.24 kg ha $^{-1}$) by the plant. K uptake by pod was the highest (42.74 kg ha $^{-1}$) at 4 days interval.

Among the interactions,150 per cent RD of N and K at 8 days intervals (l_4i_2) was significantly superior in K uptake by leaves and total K uptake. In the case of K uptake by stem l_3i_2 registered the highest value while in case of root uptake, 100 per cent RD of N and K at 8 days interval (l_2i_2) was found superior. Pod K uptake was superior for 150 per cent RD of N and K at 4 days interval (l_4i_1) and it was on par with 150 per cent RD of N and K at 8 days interval (l_4i_2).

Comparing control with treatment mean, KAU *ad hoc* recommendation was found superior in K uptake by leaf, root, pod and total uptake. Treatment mean was significantly higher than control 2 in K uptake by stem, root, pod and total uptake. Soil application recorded the highest K uptake by leaf.

4.5.4 Available Soil N, P and K after the Experiment

Data presented in Table 21 revealed that different fertigation levels, intervals and their interaction had significant effect on soil N, P and K status of soil. The fertigation levels at 125 per cent RD of N and K (L_3) recorded maximum soil N (378.98 kg ha^{-1}), while 75 per cent RD of N and K (L_1) registered the highest value of soil P and K.

The fertigation at 4 days intervals was found significantly superior to fertigation at 8 days interval for soil N, P and K.

The combined effect of fertigation levels and intervals showed that 125 per cent RD of N and K at 4 days intervals (l_3i_1) was significantly superior

Table 20. Influence of levels of nutrients and fertigation intervals on uptake of potassium, kg ha $^{-1}$

Treatments	Uptake of potassium				
	Leaf	Stem	Root	Pod	Total
Levels of nutrients					
L_1 (75% RD N & K)	37.17	50.65	2.25	38.25	128.32
L_2 (100% RD N & K)	40.52	50.56	3.27	40.05	134.39
L_3 (125% RD N & K)	42.52	65.05	2.99	43.19	153.75
L_4 (150% RD N & K)	51.72	66.11	1.45	47.60	166.88
SEm (±)	0.47	0.49	0.03	0.02	0.24
CD (0.05)	1.512	1.569	0.09	0.069	0.77
Fertigation intervals					
I_1 (4 days interval)	40.43	57.24	2.01	42.74	142.43
I_2 (8 days interval)	45.53	58.94	2.97	41.81	149.24
SEm (±)	0.25	0.11	0.02	0.02	0.05
CD (0.05)	0.781	0.367	0.052	0.059	0.142
Interaction					
l_1i_1	33.30	52.67	1.38	38.35	125.70
l_1i_2	41.04	48.62	3.13	38.16	130.94
l_2i_1	41.27	49.67	2.43	38.90	132.26
l_2i_2	39.77	51.45	4.12	41.20	136.53
l_3i_1	40.91	59.87	3.01	46.06	149.84
l_3i_2	44.14	70.23	2.97	40.33	157.66
l_4i_1	46.26	66.76	1.24	47.66	161.91
l_4i_2	57.19	65.45	1.67	47.55	171.85
SEm (±)	0.51	0.24	0.04	0.04	0.095
CD (0.05)	1.563	0.725	0.114	0.119	0.295
Treatment mean	42.98	58.09	2.49	42.27	145.83
Control 1 (KAU *ad hoc* recommendation)	64.47	81.34	5.09	57.05	207.95
Control 2 (KAU POP)	46.33	47.81	2.16	32.95	129.25
Control 1 Vs Control 2	S	S	S	S	S
Control 1 Vs Treatment	S	NS	S	S	S
Control 2 Vs Treatment	S	S	S	S	S

Table 21. Influence of levels of nutrients and fertigation intervals on available soil nitrogen, phosphorus and potassium after the experiment, kg ha^{-1}

Treatments	Available soil nutrients after the experiment		
	N	P	K
Levels of nutrients			
L_1 (75% RD N & K)	363.08	69.11	127.61
L_2 (100% RD N & K)	368.63	67.19	126.78
L_3 (125% RD N & K)	378.98	67.32	119.55
L_4 (150% RD N & K)	356.71	67.25	120.01
SEm (±)	2.19	0.001	0.003
CD (0.05)	6.997	0.004	0.009
Fertigation intervals			
I_1 (4 days interval)	370.48	67.71	124.72
I_2 (8 days interval)	363.22	67.72	122.25
SEm (±)	2.24	0.005	0.002
CD (0.05)	6.909	0.017	0.007
Interaction			
l_1i_1	355.18	69.47	131.02
l_1i_2	370.99	68.74	122.54
l_2i_1	367.22	66.27	127.54
l_2i_2	370.05	68.12	127.67
l_3i_1	402.97	67.53	121.66
l_3i_2	354.99	67.11	117.44
l_4i_1	356.56	67.59	118.67
l_4i_2	356.87	66.91	121.34
SEm (±)	4.48	0.008	0.001
CD (0.05)	13.819	0.025	0.004
Treatment mean	366.85	67.72	123.48
Control 1 (KAU *ad hoc* recommendation)	367.23	68.91	132.21
Control 2 (KAU POP)	348.41	66.57	121.87
Control 1 Vs Control 2	S	S	S
Control 1 Vs Treatment	NS	S	S
Control 2 Vs Treatment	S	S	S

(402.97 kg ha^{-1}) for available soil N. The combination of 75 per cent RD of N and K at 4 days intervals (l_1i_1) recorded maximum soil P and K.

Comparing control and treatment, *ad hoc* fertigation schedule (control 1) recorded the highest soil N, P and K and was significantly superior.

4.5.5 Soil Organic Carbon and pH

The data on soil organic carbon and pH are presented in Table 22.

Soil pH was significantly influenced by fertigation levels, while organic carbon was not influenced by fertigation levels, intervals and their interaction.

Application of N and K at 75 per cent RD recorded the highest soil pH and was on par with 100 per cent RD of N and K.

Comparing the control and treatment, treatment mean was significantly superior to *ad hoc* recommendation of KAU (control 1). Soil application of fertilizers (control 2) recorded the highest soil pH over *ad hoc* and treatment mean and it was significantly superior. Soil organic carbon was not influenced by control and treatments.

4.6 CHLOROPHYLL CONTENT AND QUALITY ATTRIBUTES

4.6.1 Chlorophyll Content at Flowering

The results presented in Table 23 revealed that different treatments and their interaction had significant influence on the total chlorophyll content. Fertigation at 150 per cent RD of N and K (L_4) recorded the highest value (2.41 mg g^{-1}) and it was significantly superior to all other nutrient levels. Fertigation at 4 days interval (I_2) recorded maximum total chlorophyll (2.20 mg g^{-1}).

Among the various combinations of fertigation levels and intervals the treatment receiving 150 per cent RD of N and K at 4 days interval (l_4i_1) registered the highest total chlorophyll (2.42 mg g^{-1}) which was on par with l_3i_2 and l_4i_2.

Table 22. Influence of levels of nutrients and fertigation intervals on organic carbon and soil pH after the experiment

Treatments	Organic carbon (%)	Soil pH
Levels of nutrients		
L_1 (75% RD N & K)	1.66	5.24
L_2 (100% RD N & K)	1.67	5.22
L_3 (125% RD N & K)	1.67	5.16
L_4 (150% RD N & K)	1.68	5.15
SEm (±)	0.01	0.02
CD (0.05)	NS	0.065
Fertigation intervals		
I_1 (4 days interval)	2.09	5.19
I_2 (8 days interval)	1.67	5.20
SEm (±)	0.001	0.01
CD (0.05)	NS	NS
Interaction		
l_1i_1	1.67	5.24
l_1i_2	1.66	5.23
l_2i_1	1.67	5.21
l_2i_2	1.68	5.22
l_3i_1	1.68	5.15
l_3i_2	1.67	5.18
l_4i_1	1.68	5.14
l_4i_2	1.68	5.16
SEm (±)	0.01	0.02
CD (0.05)	NS	NS
Treatment mean	1.67	5.19
Control 1 (KAU *ad hoc* recommendation)	1.67	5.11
Control 2 (KAU POP)	1.68	5.26
Control 1 Vs Control 2	NS	S
Control 1 Vs Treatment	NS	S
Control 2 Vs Treatment	NS	S

The *ad hoc* recommendation for fertigation (control 1) was significantly superior to treatment and POP recommendation (control 2). Treatment mean registered higher chlorophyll content (2.18 mg g^{-1}) than POP recommendation.

4.6.2 Crude Protein

Crude protein content of yard long bean pods as influenced by treatments is presented in Table 23.

The crude protein content was influenced by levels of nutrients, fertigation intervals and their interactions. Among the levels of nutrients, fertigation at150 per cent RD of N and K (L_4) recorded maximum crude protein (30.13 per cent), followed by 125 per cent RD of N and K (L_3).

The fertigation at 4 days interval registered the maximum crude protein content (27.08 per cent).

Among the various interactions, crude protein content was found superior (30.63 per cent) at 150 per cent RD of N and K at 4 days intervals (l_4i_1), and was followed by 150 per cent RD of N and K at 8 days interval.

Comparing control and treatment mean, KAU *ad hoc* recommendation (control 1) recorded the maximum crude protein (32.79 per cent) and it was significantly superior to KAU POP (control 2) and treatments.

4.6.3 Crude Fibre

The result presented in Table 23 showed that crude fibre was significantly influenced by fertigation intervals, while it was not affected by levels of nutrients and their interactions.

Crude fibre was the highest (16.58 per cent) in fertigation at 8 days interval.

KAU POP recommendation (control 1) registered the highest crude fibre and it was significantly superior to KAU *ad hoc* recommendation (control 2) and

Table 23. Influence of levels of nutrients and fertigation intervals on chlorophyll content at flowering, crude protein and crude fibre

Treatments	Chlorophyll content at flowering (mg g^{-1} fresh weight)	Crude protein (%)	Crude fibre (%)
Levels of nutrients			
L_1 (75% RD N & K)	1.92	23.83	16.33
L_2 (100% RD N & K)	2.10	25.01	16.38
L_3 (125% RD N & K)	2.28	29.01	16.48
L_4 (150% RD N & K)	2.41	30.13	16.56
SEm (±)	0.01	0.02	0.07
CD (0.05)	0.037	0.079	NS
Fertigation intervals			
I_1 (4 days interval)	2.20	27.08	16.30
I_2 (8 days interval)	2.15	26.90	16.58
SEm (±)	0.01	0.02	0.05
CD (0.05)	0.036	0.067	0.146
Interaction			
l_1i_1	1.92	24.06	16.02
l_1i_2	1.93	23.58	16.65
l_2i_1	2.07	25.34	16.26
l_2i_2	2.13	24.69	16.50
l_3i_1	2.20	29.30	16.44
l_3i_2	2.37	28.72	16.52
l_4i_1	2.42	30.63	16.47
l_4i_2	2.40	29.64	16.65
SEm (±)	0.02	0.04	0.10
CD (0.05)	0.072	0.135	NS
Treatment mean	2.18	27.00	16.44
Control 1 (KAU *ad hoc* recommendation)	2.67	32.79	16.53
Control 2 (KAU POP)	1.06	22.74	17.07
Control 1 Vs Control 2	S	S	S
Control 1 Vs Treatment	S	S	NS
Control 2 Vs Treatment	S	S	S

treatment mean. There was no significant difference between *ad hoc* recommendation for fertigation and treatment mean.

4.7 PEST AND DISEASE INCIDENCE

Pest incidence was comparatively less and minor attack by leaf eating caterpillar (*Spilosoma oblique*) and pod borer (*Maruca testulalis*) were observed. Treatment wise variation was not observed in pest incidence. Wilt caused by *Fusarium oxysporum* was observed in isolated patches and the incidence percentage varied from 1.59 to 2.30 as depicted in Table 24. Wilt incidence was not influenced by treatments. Incidence was noticed in plants near the water channel immediately after the heavy rain at 38 DAS.

4.8 ECONOMIC ANALYSIS

4.8.1 Net Income and B:C Ratio

The effect of treatments on net income and B:C ratio is presented in Table 25 and details on cost of cultivation is given in Appendix II.

Among the treatment combinations, KAU *ad hoc* recommendation for precision farming registered the highest net income (₹ 6.10 lakhs). Maximum B:C ratio (3.34) was obtained from the treatment combination of 150 per cent RD of N and K at 4 days interval. The B:C ratio of control 1 was 2.71 which is analogous to the conventional system of cultivation (control 2) (2.74).

Table 24. Influence of fertigation levels and intervals on pest and disease incidence*

Treatments	Incidence of wilt (%)
l_1i_1	2.30
l_1i_2	2.22
l_2i_1	2.13
l_2i_2	2.01
l_3i_1	2.11
l_3i_2	1.65
l_4i_1	2.10
l_4i_2	1.73
Control 1 (KAU ad hoc recommendation)	1.80
Control 2 (KAU POP)	1.59

Table 25. Influence of levels of nutrients and fertigation intervals on economics of yard long bean *

Treatments	Total cost of cultivation (₹ lakhs)	Gross Income (₹ lakhs)	Net Income (₹ lakhs)	B:C ratio
l_1i_1	2.391	6.457	4.065	2.70
l_1i_2	2.388	5.734	3.346	2.40
l_2i_1	2.394	6.209	3.814	2.59
l_2i_2	2.391	6.086	3.694	2.54
l_3i_1	2.396	6.803	4.406	2.84
l_3i_2	2.395	6.477	4.081	2.70
l_4i_1	2.399	8.004	5.604	3.34
l_4i_2	2.398	7.656	5.257	3.19
Control 1	3.577	9.695	6.118	2.71
Control 2	1.982	5.427	3.444	2.74

* Data is not statistically analysed

Discussion

5. DISCUSSION

The experiment entitled "Studies on fertigation in yard long bean *(Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)" was undertaken during summer 2015 to standardize the fertigation schedule for yard long bean in precision farming and to assess its impact on growth, yield and economics. This chapter encompasses the discussion of the results obtained.

5.1 INFLUENCE OF FERTIGATION LEVELS, INTERVALS AND THEIR INTERACTION ON GROWTH ATTRIBUTES.

Any management practice adopted for yield improvement of crops usually exerts a positive influence on the growth characters of the crop. In this experiment the treatments, *viz.,* levels of nutrients and interval of fertigation along with their interaction had significant influence on the different growth parameters recorded. In general, an enhancement in growth was observed by increasing the levels of N and K. The growth attributes like vine length at harvest, number of primary branches at 90 DAS, number of productive branches and LAI recorded at flowering were the highest when N and K were applied at the highest dose (150 per cent RD). This improvement in growth was mainly attributed to the availability of sufficient quantity of macronutrients through fertigation throughout the growth period of crop. In addition, the nutrient uptake by the crop was more at the highest nutrient level (Table 18,19 and 20) contributing to better growth. The role of N in cell division, growth and photosynthetic activities of plant was already pointed out by Brady and Weil (2008). Higher levels of N along with adequate quantity of K might have enhanced the photosynthetic rate resulting in better growth attributes.

Several workers have also reported improvement in growth attributes at higher nutrient levels. Puthupalli (2014) reported increase in vine length in yard long bean when it was fertigated with 125 per cent RD of N and K. Ughade and Mahadkar (2014) reported an increase in number of primary branches of brinjal by increasing N and K levels through fertigation. Kumawat (2012) attributed improvement in the LAI of yard long bean due to increased N levels through soil application. Growth improvement of crop by increasing nutrient levels through fertigation was also reported by Shinde *et al.* (2002) in brinjal.

The duration of yard long bean varied with varying levels of N and K through drip fertigation. Application of 150 per cent RD of N and K extended the crop duration by seven days. Yard long bean being an indeterminate plant might have continued its growth at higher nutrient levels resulting in extended duration. The continued availability of higher quantity of nutrients during the entire crop growth period might have prolonged the crop duration at higher nutrient levels.

Fertigation at 150 per cent RD registered the highest total dry matter production. The enhanced vegetative growth as evident from vine length and number of branches led to enhanced dry matter production. The same nutrient level registered the highest dry matter production of the economically important part, pod and also leaf. The improvement in vegetative growth at higher levels of N and K could be attributed to the increase nutrient uptake at this level and subsequent improvement in physiological activities of the plant as reported by Ramachandrappa *et al.* (2010) in chilli. Dry matter production by the stem was the highest at 125 per cent RD of N and K and the root dry matter was not at all influenced by the levels of N and K. Phosphorus, the nutrient involved in root development was applied uniformly to all treatments and this might have reflected in non significant variation on root dry matter production. To sum up, application of higher dose of water soluble fertilizers like urea and MOP through drip fertigation in the root zone improved the growth attributes and total vegetative growth of plant which in turn enhanced the dry matter production at higher nutrient levels. Udhade and Mahadkar (2014) reported similar improvement in total biomass production due to improvement in vegetative growth characters like plant height, number of branches and number of leaves in brinjal at higher levels of drip fertigation. Moreover, the total rainfall received during cropping period was also higher (817.6 mm) which enhanced the vegetative growth and dry matter production as a whole.

Considering the effect of fertigation intervals on growth attributes, no significant variation was noticed between 4 and 8 days interval on the number of productive branches, number of primary branches, LAI at flowering and crop duration. However, the total dry matter production varied with changes in fertigation interval. Fertigation at 8 days registered the highest total dry matter production over 4 days interval. Examining the dry matter partitioning towards the different plant parts it was noticed that dry matter accumulation in pod was the highest in 4 days interval while partitioning towards the uneconomic part like stem was the highest at 8 days interval. In leaf dry matter production also 8 days interval was observed superior to 4 days interval. Supply of water soluble nutrients at shorter interval of 4 days might have assured continuous availability of nutrients during the entire reproductive stage of the crop leading to better partitioning of assimilates towards the economic part, pod. Though the leaf dry matter was significant at 8 days interval, the LAI registered did not show any variation indicating that enhanced leaf dry matter production did not contribute to significant variation in LAI and photosynthetic efficiency of crop. Kadam *et al.* (1995) reported improvement in crop growth when nutrients were applied in more number of splits.

Among the interactions, significance was noticed for vine length at harvest and for leaf dry matter production. The combination of 150 per cent RD of N and K at 8 days interval recorded the highest vine length and leaf dry matter production. The individual effect of nutrient levels and fertigation interval along with good rainfall received during the crop period enhanced the vine length and leaf dry matter production.

The response of nutrient levels to root parameters was varying. Root length and root volume registered improvement at higher levels of N and K, while the root weight did not show any variation between 100 and 150 per cent. Under adequate nutrient supply, roots might have produced more root branches and better growth as evident from root length and root volume. Phosphorus, the major nutrient for root growth was sufficiently available and the entire dose of 25 kg ha^{-1} was applied to all plots as basal. Hence, variation was not observed among different levels of N and K on root weight. Fertigation at 8 days interval significantly enhanced the root volume but this did not influence root weight. Continuous availability of nutrients at shorter intervals of fertigation might have stimulated root length leading to higher root length at 4 days interval. The interaction effect showed that the highest levels of N and K at 8 days interval resulted in maximum root weight and root volume. However, the combinations of l_4i_1 registered maximum root length. Individual effect of each factor might have reflected in the interaction effect also.

5.2 INFLUENCE OF FERTIGATION LEVELS, INTERVALS AND THEIR INTERACTION ON YIELD ATTRIBUTES AND YIELD.

In any crop early flowering is the indication of early yield. In this experiment the different levels of N and K significantly influenced the days for 50 per cent flowering where the lower levels of N and K (75 and 100 per cent RD) registered minimum days for 50 per cent flowering. Enhanced nutrient availability at higher levels of nutrients, especially N might have prolonged vegetative growth resulting in a slight delay in 50 per cent flowering. Similar observation was also reported by Babu (2015) in yard long bean. However, the earliness in flowering at 75 and 100 per cent RD of N and K had not reflected in crop yield. This could be attributed to the reduced crop duration in these treatments resulting in lower number of picking (18.75) and crop yield.

Perusal of yield data revealed that the total pod yield showed a linear response to increasing levels of N and K. Number of pods per plant is an important yield determinant which was the highest at 150 per cent N and K. Significant increase in the number of productive branches observed at 150 per cent N and K led to more number of pods per plant leading to higher pod yield (Fig 3 and 4). The findings of the study is in agreement with the result of Shedeed *et al.* (2009) who also reported an increase in tomato yield at higher levels of NPK fertigation. They also attributed increased fruit number per plant as the main reason for enhanced crop yield. Moreover, the higher N and K levels enhanced crop duration by one week resulting in more number of pickings, though not significant. In addition, the length of individual pod was also the highest at higher level of N and K. Other yield parameters like setting percentage and average pod weight did not show any variation due to levels of fertilizers but the higher level recorded comparatively higher values. The cumulative effect of all these factors resulted in higher productivity at higher nutrient level.

Crop yield is decided mainly by the management practices and its interaction with microclimate. During the crop growth period 817.60 mm rainfall has been received. This conducive microclimate along with higher N and K nutrition (150 per cent RD) enhanced the LAI and chlorophyll content which might have enhanced photosynthetic rate resulting in higher assimilate synthesis and enhanced assimilate partitioning towards the sink (pod). It has been established that the chlorophyll content and LAI correlates positively with the crop yield (Taiz and Zeiger, 2006). Yield improvement at 150 per cent RD (Fig 5) could also be attributed to the increased availability of nutrients and enhanced uptake of nutrients as evident from Table 18,19 and 20. Puthupalli (2014) also reported increase in yield of yard long bean at 125 per cent of RD of N and K. Similar results were obtained by Kadam *et al.* (2007) and Ughade and Mahadkar (2015) in brinjal who reported higher yield at higher levels of N and K.

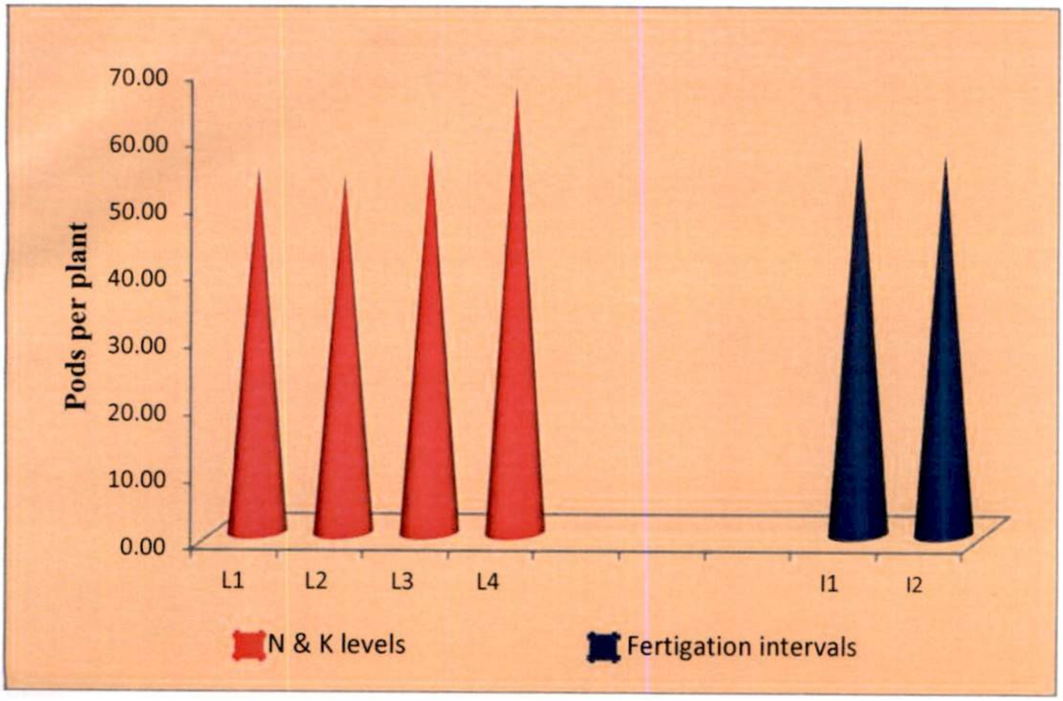

Fig 3. Effect of fertigation levels and intervals on number of pods $plant^{-1}$

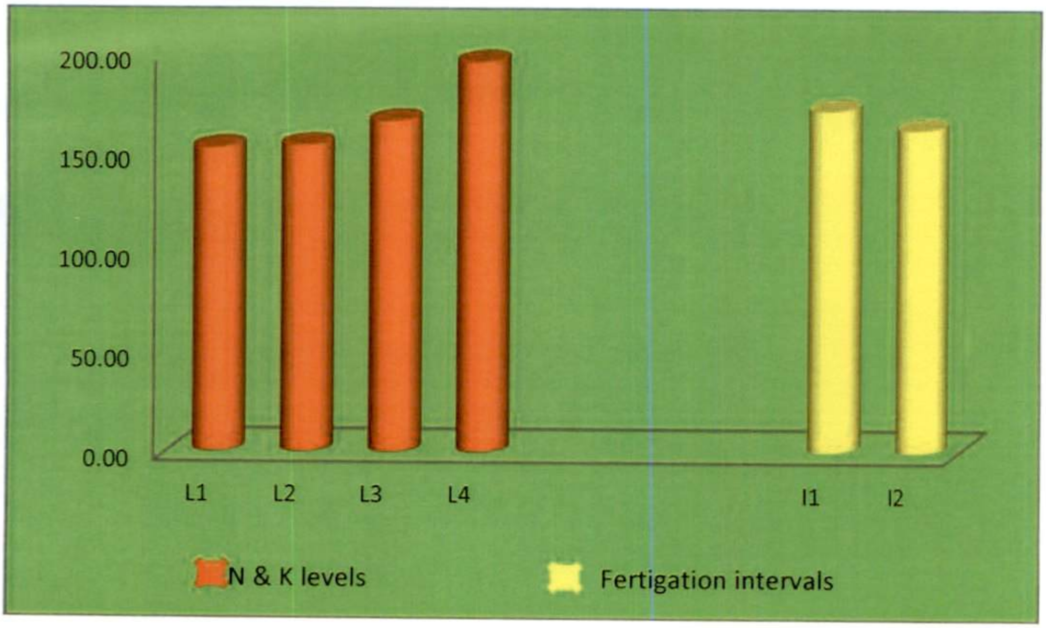

Fig 4. Effect of fertigation levels and intervals on total pod yield

In the present study, drip fertigation of 150 RD of N and K registered 27.37 per cent yield improvement over the recommended dose (Fig 4). The linear response of yield to N and K levels also indicated the possibility of enhancing the N and K for further improvement in productivity of yard long bean. This needs further investigation. The higher economic yield realized in 150 per cent N and K significantly enhanced the harvest index (0.42).

Comparing two fertigation intervals, it was observed that fertigation at 4 days interval registered the highest pod yield. Yield improvement was mainly attributed to the increased number of pods per plant registered at 4 days interval. Continued availability of nutrients at shorter intervals enhanced the crop growth as evident from LAI. The chlorophyll content, though not significant, is within optimum range for a healthy plant. These two parameters led to higher photosynthetic efficiency and crop yield. Though no significant variation was observed in yield attributes like pod length, pod girth and average pod weight, the values were slightly higher in fertigation at 4 days interval. In addition the partitioning of dry matter towards the pod was the highest in fertigation at 4 days interval. Several reports are available on the improvement of crop yield at shorter intervals of fertigation. Pandey *et al.* (2013) observed that fertigation at 8 days interval resulted in superior yield and quality of tomato over 10 and 14 days interval. Ravel *et al.* (2013) and Danso *et al.* (2015) reported that drip fertigation at weekly interval recorded the highest fruit yield plant^{-1} and total fruit yield in bhindi over fertigation intervals of three and two weeks. Better availability of nutrients continuously during the reproductive stage enhanced partitioning of photosynthates towards economic part which resulted in higher yield and harvest index at 4 days interval.

Combination of 150 per cent RD N and K at 4 days interval was significantly superior to all other combinations in terms of yield. The increase was mainly attributed to the significant improvement in number of pods per plants. The improved pod yield had a positive reflection on harvest index of this combination. The

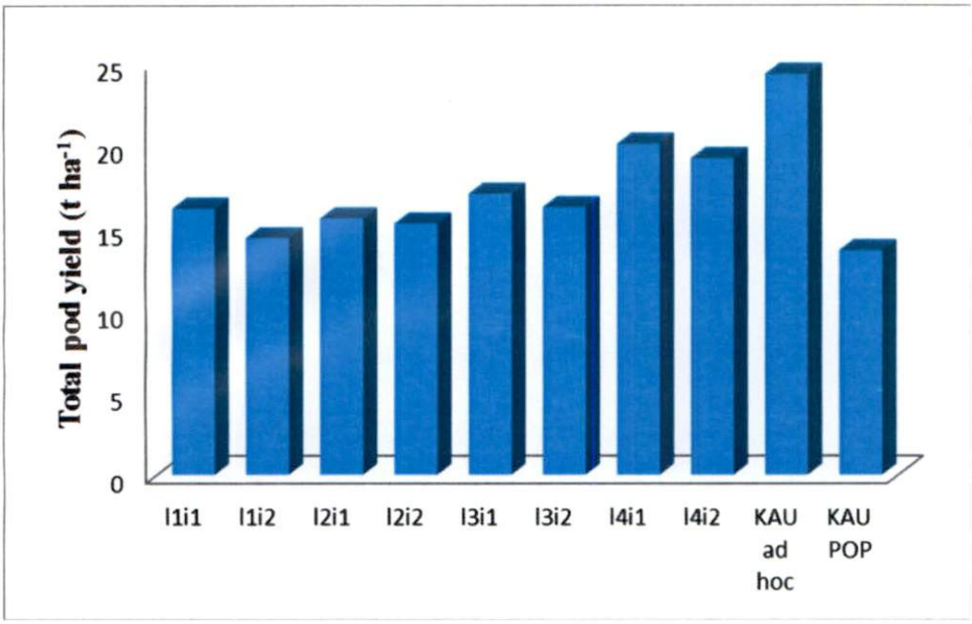

Fig 5. Interaction effect of fertigation levels and intervals on total pod yield

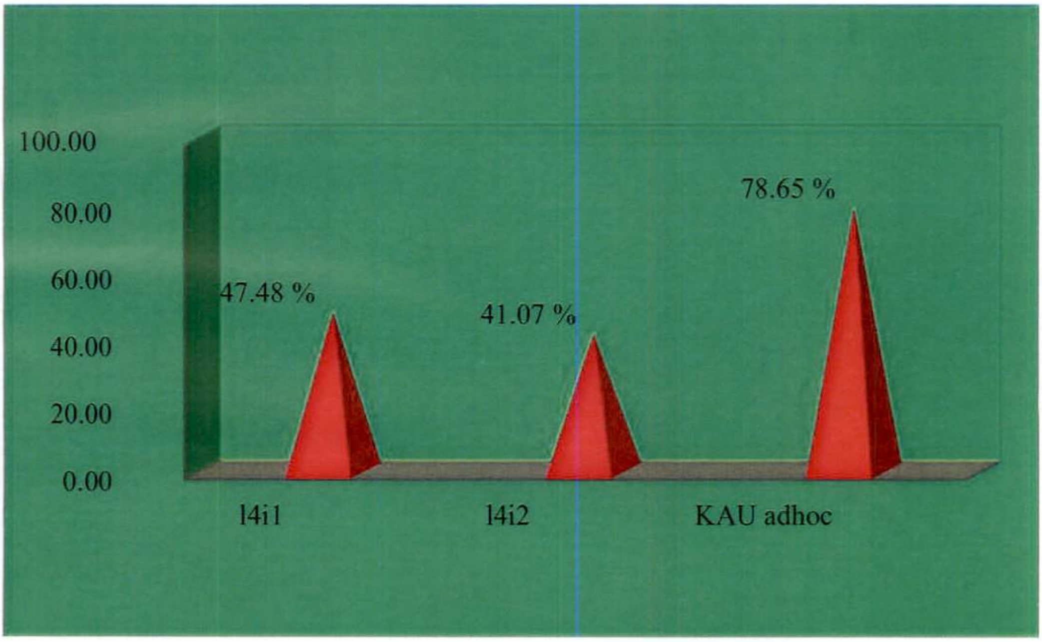

Fig 6. Percentage yield increase in best treatments compared to KAU POP

economic yield of any crop is the outcome of the agronomic manipulation and the environmental factors. The drip fertigation along with mulching modified the microclimate and helped the crop to exploit available resources more efficiently. Hence, the ideal combination of higher levels of nutrients supplied at shorter fertigation interval improved the nutrient uptake of crop and enabled it to use the resources of water and nutrients more effectively for enhancing the yield.

5.3 INFLUENCE OF FERTIGATION LEVELS, INTERVALS AND THEIR INTERACTION ON WUE AND WP.

From the present study it was observed that the water requirement of drip fertigated treatments ranged from 681 mm to 741 mm. WUE of a crop is an indication of the economic yield produced per unit quantity of water. The different levels of N and K tried showed significant variation on WUE. Drip fertigation at 150 per cent RD of N and K registered the highest WUE due to the highest economic yield realized at this level. Water productivity was also the highest at this level owing to the improvement in plant growth and high yield leading to higher total dry matter production. Enhancement in WUE and water productivity in tomato at higher fertigation level (120 per cent RD of N) was reported by Batchelor *et al.* (1996).

Fertigation at 4 days interval resulted in the highest WUE of 22.90 kg ha mm^{-1}. Continued availability of water and nutrients throughout the crop growth stage by way of drip fertigation at shorter intervals improved yield leading to higher WUE. Ravel *et al.* (2013) also observed high WUE in bhindi when fertigation was given at weekly interval than at two or three weeks interval. However, water productivity was the highest in fertigation interval of 8 days. This could be attributed to the enhanced dry matter production registered in this interval. WUE was significantly influenced by the combination of the highest nutrient levels at shorter interval of fertigation (150 per cent at 4 days interval). Higher pod yield obtained in this treatment combination resulted in the improvement of WUE. Water productivity was not influenced by the combinations.

5.4 INFLUENCE OF FERTIGATION LEVELS, INTERVALS AND THEIR INTERACTION ON QUALITY ATTRIBUTES.

The crude protein content of pod is mainly decided by the crop and is modified by its nutrition. The highest crude protein content of pod was registered at 150 per cent RD of N and K. The availability of adequate N at this level through fertigation and subsequent increase in N uptake by pod (Table 18) resulted in the highest crude protein content. Increase in crude protein content of yard long bean with increase in N supply was reported by Chandran (1987) and Babu (2015).

Fertigation at 4 days interval enhanced crude protein owing to the continuous availability of N and enhanced N uptake by the pod. The combination of 150 per cent RD of N and K at 4 days interval recorded maximum crude protein and this could also be attributed to the enhanced N uptake by the pod due to continuous N availability at fruiting stage of crop.

Crude fibre content in any vegetable plays an important role in human diet and yard long bean is considered as a vegetable rich in crude fibre. Fertigation levels and interaction between levels and interval of fertigation had no influence on crude fibre content indicating the feasibility of applying higher levels of N and K without affecting the fruit quality. However, the fibre content was the highest when fertigation was given at 8 days interval. The increase in fibre content at wider intervals of irrigation and soil application of fertilisers was reported earlier by Amans *et al.* (2011) in tomato.

5.5 INFLUENCE OF FERTIGATION LEVELS, INTERVALS AND THEIR INTERACTION ON PLANT NUTRIENT UPTAKE.

Fertigation levels and intervals significantly influenced the nutrient uptake by yard long bean. The highest N and K levels tried in this experiment (150 per cent RD) invariably registered the highest total N, P and K uptake by crop. Continued supply of higher levels of nutrients and water to crop root zone by drip fertigation enhanced the root length and root volume leading to better nutrient uptake, improved growth and total dry matter production at this level. Nutrient uptake being the product of dry matter production and nutrient content, the level of 150 per cent RD of N and K registered the highest total nutrient uptake due to high dry matter production. Fertigation reduced the nutrient loss from the crop root zone by way of leaching and this in turn enhanced the nutrient uptake by crop when higher levels were supplied (Shedeed *et al.*, 2009). Present result is in conformity with their findings. Higher levels of N had an indirect influence in enhancing the K uptake at higher K level (Havlin *et al.*, 2004). The result of the study is in agreement with this theory.

Between the intervals, though the N uptake was not influenced by fertigation interval, fertigation at 8 days interval significantly enhanced P and K uptake. This enhanced uptake could be attributed to the enhanced dry matter production in this treatment though it was not reflected in the yield. The variation in partitioning of dry matter to different plant parts might have resulted in changes in nutrient uptake by various plant parts. The interaction effect of fertigation at 150 per cent RD of N and K at 8 days interval recorded significantly higher N and K uptake compared to other levels. Here also enhanced dry matter production could be attributed as the reason for enhanced nutrient uptake.

5.6 INFLUENCE OF FERTIGATION LEVELS, INTERVALS, INTERACTION AND CONTROLS ON SOIL NUTRIENT STATUS.

Organic carbon content in soil after the experiment was not influenced by fertigation levels, intervals and their interaction. Compared to initial soil status, no considerable variation was observed in soil organic carbon after the experiment. However, the different levels of fertigation significantly influenced the soil pH. A slight reduction in pH was observed in all fertigated plots compared to initial soil status. Among the levels, the highest level of 150 per cent RD of N and K registered the lowest pH of 5.15 which was significantly different from other levels. It had already been reported that use of acid forming fertilizers and soluble salts have a direct impact in reducing the pH of soil (Havlin *et al*., 2004). Wein *et al.* (1993) also observed a decrease in soil pH with higher levels of N application. The results of this study were in confirmity with the findings of Puthupalli (2014) in yard long bean who observed that application of higher levels of N and K significantly decreased the soil pH.

The different nutrient levels also influenced the soil nutrient status after the experiment. Fertigation with 125 per cent RD of N and K registered the highest available N in soil, while 75 per cent RD of N and K registered high P and K content. Comparatively lower nutrient uptake by the crop at 75 and 125 per cent RD of N and K might have resulted in higher nutrient status at these levels. Compared to the initial nutrient status, an increase was observed in N and K status of soil after the experiment. This could be attributed to the reduced crop uptake towards later crop stages where a portion of N and K supplied through fertigation might be left unutilized in the soil leading to higher N and K after the experiment. Fertigation at 4 days interval registered the highest available N and K in soil and available P was higher at 8 days interval. Nutrient applied through fertigation at shorter intervals during later growth period might not be fully utilized by plant resulting in high N and K in soil after the crop. Considering treatment combinations, the reduced uptake of

Plate 5. Field view of l4i1 , KAU *ad hoc* and KAU POP at 85 DAS

nutrients resulted in higher content of N in l_3i_1 (125 per cent RD of N and K at 4 days interval) and P and K in l_1i_1 (75 per cent RD of N and K at 4 days interval).

Compared to soil application (control 2), the treatments and control 1 (*ad hoc* recommendation) registered significantly higher NPK content in soil. Application of fertilizer in small quantities in several split doses reduced the loss of nutrient resulting in higher soil NPK status compared to soil application. Moreover in fertigation treatments and control 1 mulching was provided. Both these practices helped to reduce the nutrient loss by way of leaching and deep percolation (Bhogi *et al.*, 2011). In control 2, though more quantity of fertilizers were applied to soil, the crop uptake was comparatively higher resulting in lower available nutrient status after the crop.

5.7 COMPARISON OF TREATMENTS WITH *AD HOC* RECOMMENDATION FOR PRECISION FARMING (CONTROL 1) AND SOIL APPLICATION (CONTROL 2) ON GROWTH, YIELD AND WATER USE.

Critical analysis of results revealed that the KAU *ad hoc* recommendation for fertigation (control 1) had an upper hand in all the growth attributes like number of productive branches, length of vine at harvest, LAI and total dry matter production over KAU POP (control 2). In *ad hoc* treatments the quantity of nutrients applied was much higher (208.72:104.80:292.80 kg N P_2O_5 K_2O ha^{-1}) and also fertigation was given at shorter interval of 3 days. This enhanced nutrient availability throughout the crop growth period along with good rainfall received during cropping period increased vegetative growth. The LAI and chlorophyll content were also the highest in *ad hoc* recommendation. These factors contributed to the enhanced photosynthetic efficiency of plant resulting in improvement in yield attributes like pod length, average pod weight and number of pods per plant leading to higher pod yield per plant and total pod yield. It was observed that *ad hoc* treatments registered 78 per cent yield increase over KAU POP where yard long bean was raised in the

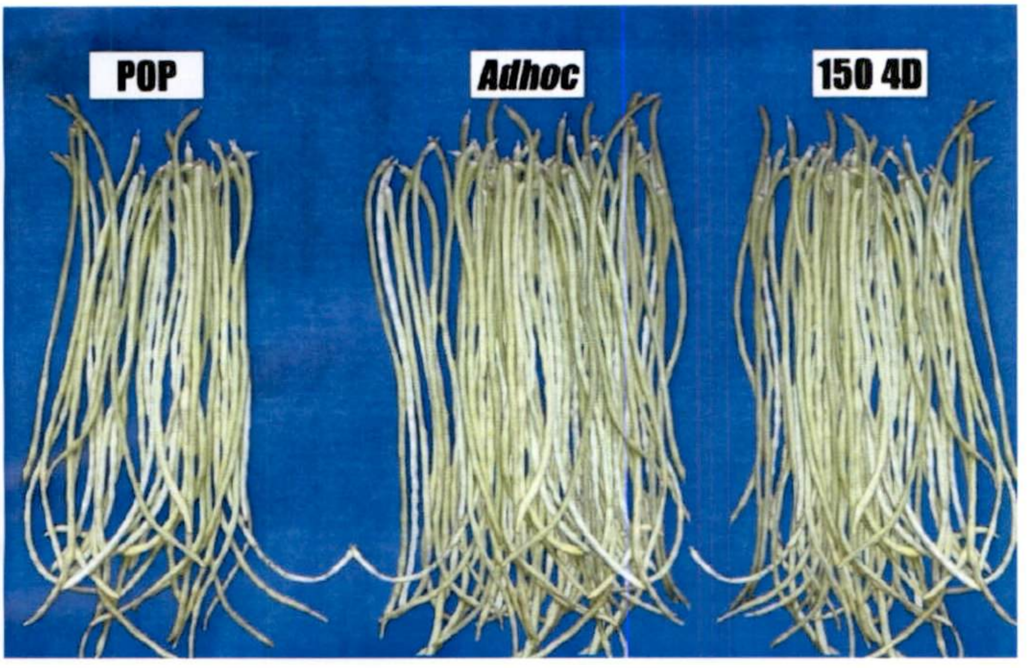

Plate 6 a. Comparison of pod yield of best treatments with POP at 2nd harvest

Plate 6 b. Comparison of pod yield of best treatments with POP at 6th harvest

Plate 6 c. Comparison of pod yield of best treatments with POP at 15th harvest

Plate 6 d. Comparison of pod yield of best treatments with POP at 19th harvest conventional method with soil application of fertilizers without mulching (Fig 6). Use of polyfeed fertilizers at shorter interval in *ad hoc* treatment ensured better nutrient availability throughout the growth period. This along with the favourable microclimate due to mulching resulted in yield improvement. It was also evident that though the pod yield in different treatments increased from third harvest and extended upto fourteenth harvest, the incremental increase was more in *ad hoc* which again contributed to higher yield. Studies in tomato also revealed that highest fruit yield was obtained when crop was fertigated with poly feed fertilizers than application of ordinary fertilizers through soil application (Prabhakar and Hebbar, 1996). In *ad hoc* recommendation as fertilizers were supplied mostly in the form of complex polyfeed fertilizers their solubility and subsequent availability was high leading to better root length, root volume, root weight and higher NPK uptake. Continued availability of P in water soluble form (19:19 :19 and 12: 61:0) along with N and K throughout the crop growth period also helped in better expression of yield attributes leading to higher yield. Sufficient quantity of P throughout the crop period in the readily available form has a favourable influence on flowering and yield of a crop (Havlin *et al.*, 2004).

In addition, the loss of nutrient by way of leaching was less by adopting fertigation and mulching and it helped to reduce other forms of losses which resulted in better utilization of applied nutrients (Shedeed *et al.*, 2009). The *ad hoc* treatment also recorded more number of pickings and higher yield per picking leading to high total yield and harvest index. The crude protein content increased in KAU *ad hoc* treatment owing to the high N uptake registered in this treatment. However, crude fibre content was reduced in this treatment. The high N uptake and increased succulence might have reduced the crude fibre content.

Comparing treatments with KAU POP (control 2), it was observed that plant height, LAI, number of branches and dry matter production were the highest in fertigation treatments over conventional method of irrigation and soil application of

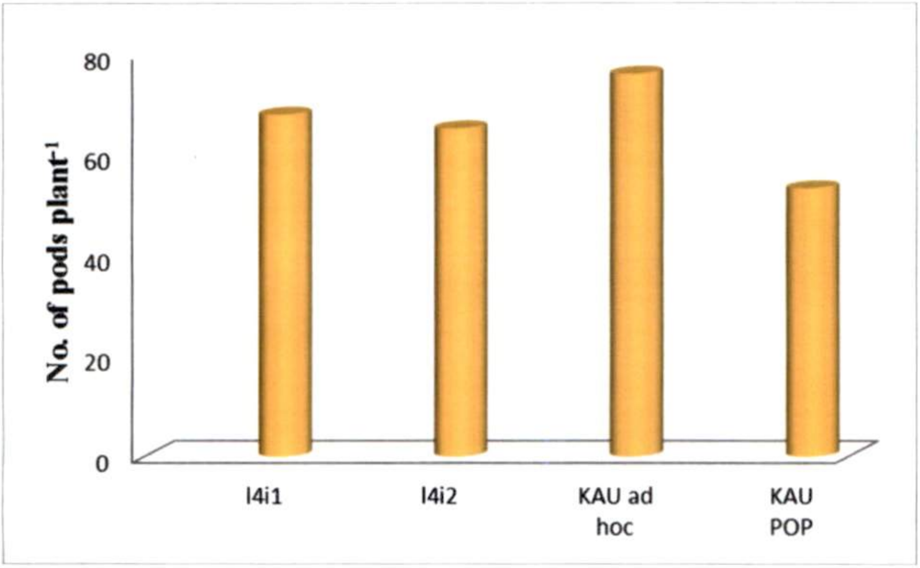

Fig 7. Comparison of best treatments with KAU POP on number of pods plant^{-1}

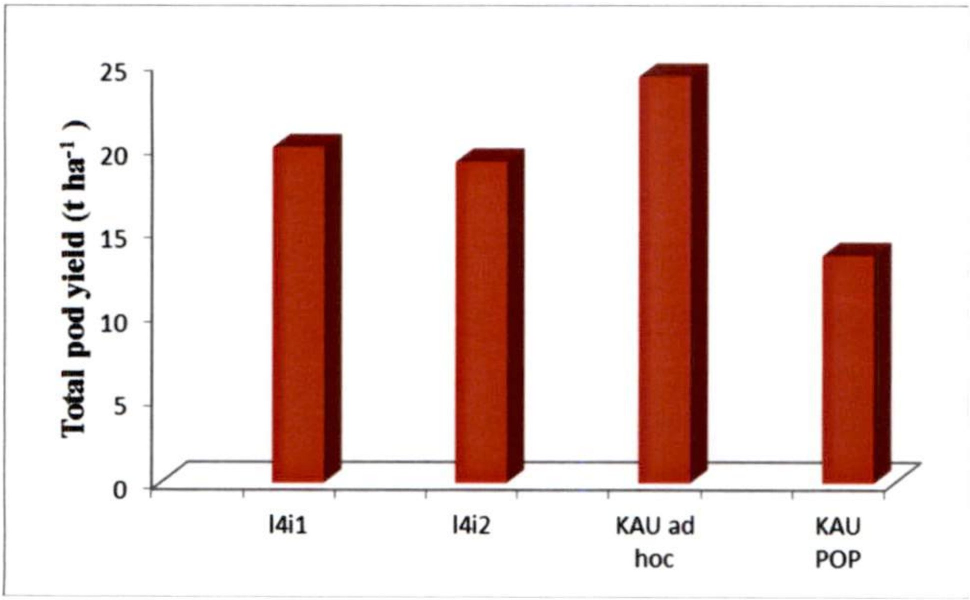

Fig 8. Comparison of best treatments with KAU POP on total pod yield

fertilizers. This improvement has also reflected in chlorophyll content and yield attributes like average pod weight and number of pods per plant, which in turn enhanced the pod yield per plant in fertigation treatments compared to control 2 (Fig 7 and 8). Solaimalai *et al.* (2005) observed that the amount of fertilizer lost through leaching could be as low as 10 per cent in fertigation, whereas it was 50 per cent in the traditional system. Moreover, in precision farming treatments, improved land management practices like deep ploughing, raised bed and polythene mulching were followed. These practices provided a well aerated root zone without any weed infestation and resulted in reduced nutrient loss which in turn improved the growth parameters and photosynthetic rate. Similar results on improvement in growth attributes of bhindi by drip fertigation was reported by Narda and Lubana (1999).

In general, fertigation treatments registered 23.1 per cent yield increase over KAU POP and also recorded high harvest index. In fertigation, small quantity of fertilizers were applied through irrigation water in root zone in several splits in contrast to larger quantity applied at wider interval in KAU POP. This reduced the nutrient loss and increased the nutrient uptake. Mulching in fertigation treatments provided a favourable soil microclimate and maintained better soil water relations and resulting in increased nutrient uptake. The enhanced nutrient uptake in fertigation treatments also contributed to higher yield attributes like pod length, average pod weight and number of pods per plant resulting in higher yield. Ughade and Mahadkar (2014) reported that fertigation provided uniform distribution of nutrient solution in the root zone and thereby increased the fertilizer use efficiency and nutrient uptake. Yield improvement in various vegetable crops by drip fertigation was reported by Hatami *et al.* (2012).

Quality attributes like crude protein showed improvement in treatments over control 2 (KAU POP) due to improved nutrient use efficiency especially that of N and this has resulted in reduced crude fibre content in fertigation treatments.

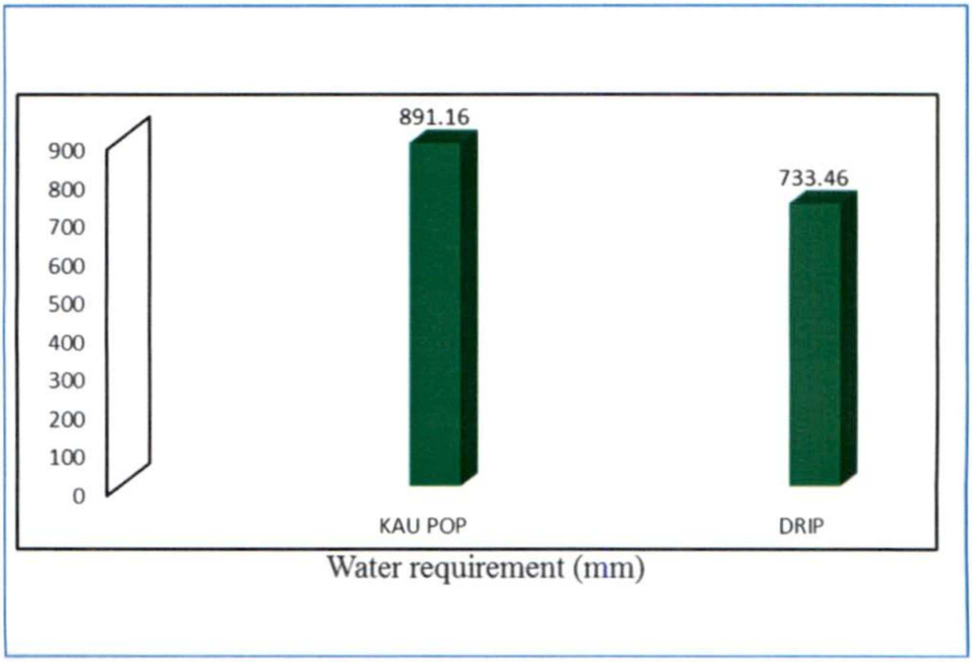

Fig 9. Comparison of water requirement of yard long bean in conventional *vs* drip irrigation

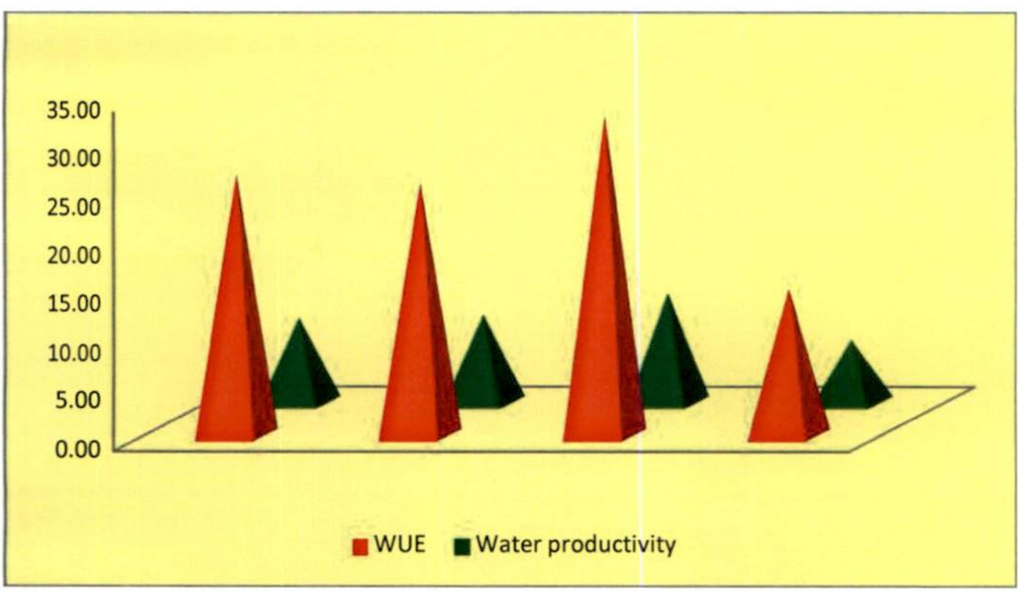

Fig 10. Comparison of best treatments with KAU POP on water use efficiency and water productivity

Assessing the variation between treatments and KAU *ad hoc* (control 1), it was evident that control 1 was found superior both in growth and yield attributes. KAU *ad hoc* recommendation registered 21.1 per cent yield increase over the best fertigation treatment (150 per cent RD of N and K at 4 days interval). In fertigation treatments P was applied as basal and N and K were supplied as urea and MOP, whereas in *ad hoc* higher amount of completely water soluble polyfeed fertilizers were used for fertigation which ensured better solubility and availability of nutrients resulting in higher nutrient uptake, growth and yield.

Application of irrigation water through drip system reduced the water requirement of yard long bean compared to the conventional method of basin irrigation. Water requirement in conventionally irrigated plot was 891 mm while in drip irrigation it ranged from 683 mm to 741 mm resulting in a saving of 19.6 per cent irrigation water (Fig 9). In drip irrigation as water was directly applied to the crop root zone, it gets stored there and helped in conserving water and minimizing the loss due to deep percolation (Bhogi *et al.*, 2011). Rekha and Mahavishnan (2008) also reported water saving of 40 to 70 per cent through drip fertigation in vegetables. Moreover, mulching was also provided to all the drip fertigation treatments, which helped to regulate the soil temperature and reduced evaporation loss from the surface. This could be attributed to the saving in water requirement.

The results also revealed that WUE and water productivity were significantly higher in KAU *ad hoc* (control 1) and drip fertigation treatments compared to control 2 (KAU POP) (Fig 10). The enhanced crop yield in drip fertigation due to easy availability and high efficiency of nutrients and lower water requirement in these treatments improved the WUE and water productivity over conventional method of cultivation. Singh *et al.* (2002) reported higher WUE and water productivity in chilli by drip fertigation compared to surface irrigation and soil application of fertilizers. Patel and Patel (2011) also reported water saving to the tune of 50 per cent by drip fertigation.

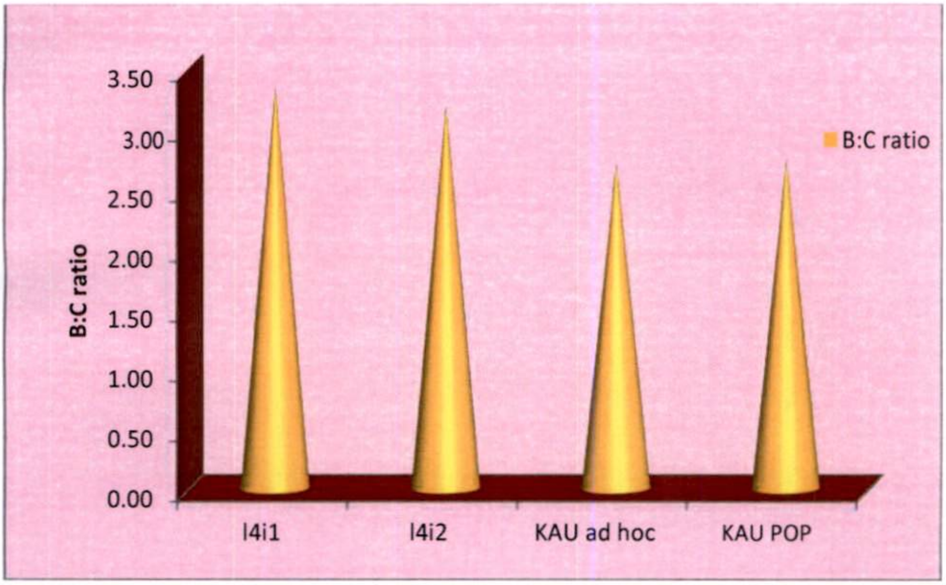

Fig 11. Comparison of best treatments with KAU POP fertigation on B:C ratio

5.7 ECONOMICS AS INFLUENCED BY TREATMENTS.

Economics is an important aspect determining the feasibility and acceptability of any technology. In this experiment also the different treatment combinations showed variation in net income and B:C ratio. Among the treatment combinations, fertigation of 150 per cent RD of N and K at 4 days interval recorded the highest B:C ratio (3.34), while net income was the highest in *ad hoc* recommendation of precision farming (₹ 6.10 lakhs). The higher pod yield obtained from KAU *ad hoc* recommendation resulted in the highest net return. However, this treatment recorded a B:C ratio of only 2.71 which is similar to the conventional system of cultivation (2.74) (Fig 11). This reduction in B:C ratio is mainly attributed to the high cost of cultivation in control 1. The high quantity of fertilizers required for this treatment along with the high cost of complex polyfeed fertilizers led to increased cost of cultivation and reduction in B:C ratio. Hence, based on the B:C ratio the N and K recommendation for higher yield and economic return from yard long bean could be identified as 150 per cent RD of N and K (45 kg N and 37.5 kg K ha^{-1}) applied as fertigation at 4 days interval using urea and MOP.

Summary

6. SUMMARY

An experiment on "Studies on fertigation in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)" was conducted at farmer's field at Pirappancode, Thiruvanathapuram, during the summer season of 2015 to standardize the fertigation schedule for yard long bean and to assess its impact on growth, yield and economics of yard long bean. The experiment was undertaken in split plot design with four main plot, two sub plot and two control and each were replicated four times. Different levels of fertigation, *viz*., 75 per cent RD of N and K (L_1), 100 per cent RD of N and K (L_2), 125 per cent RD of N and K (L_3), 150 per cent RD of N and K (L_4) constituted the main plot treatments. Fertigation at 4 days (I_1) and 8 days (I_2) interval were the sub plot treatments. The two control treatments were also included in the study, *viz*., Kerala Agricultural University *ad hoc* recommendation for precision farming (Control 1) and Kerala Agricultural University POP recommendation (modified as 30:25:25 kg N: P_2O_5: K_2O ha^{-1}) with normal planting in shallow raised beds, basin irrigation and soil application of fertilizers without mulching (Control 2). Deep ploughing, preparation of raised beds, polythene mulching and drip fertigation were followed uniformly for all treatments except for control 2. Farm yard manure @ 20 t ha^{-1} and lime @ 350 kg ha^{-1} were applied uniformly to all plots. Full dose of P were applied in all plots except in *ad hoc* treatment were half dose of P was applied as basal and the remaining half through fertigation. The nutrient status of soil was analysed for high organic carbon, phosphorous and potassium and medium nitrogen content.

The salient results of the study are summarized below.

The growth parameters showed a positive response to increased levels of fertigation. The application of 150 per cent RD of N and K registered maximum number of primary branches at 90 DAS, productive branches, higher vine length, root length, root volume, LAI and crop duration. Fertigation at 8 days interval recorded the highest vine length, root length and root volume. The dry matter of leaf, pod and total dry matter production were the highest for fertigation at 150 per cent RD of N and K. The highest leaf, stem and total dry matter production were observed at 8 days fertigation interval whereas, pod dry matter was the highest at 4 days interval.

Considering the interaction effect, 150 per cent RD of N and K at 8 days interval (l_4i_2) registered the highest vine length and root dry matter production. All other growth parameters were not influenced by the interaction between fertigation levels and intervals.

The yield attributes were positively influenced by fertigation treatments. The minimum days taken for 50 per cent flowering were recorded when fertigation was given with 100 per cent N and K at 4 days interval. The setting percentage was significantly higher at 8 days intervals.

Application of 150 per cent RD of N and K recorded the highest number of pods per plant (66.38), pod yield per plant, pod length, total pod yield (19.57 t ha $^{-1}$) and harvest index. The fertigation given at 4 days interval had benefit on yield, yield attributes and harvest index over 8 days interval. The pod characters like pod girth and average pod weight were not influenced by different levels of fertigation and intervals.

The effect of different levels of fertigation and intervals revealed that, fertigation with 150 per cent RD of N and K at 4 days intervals (l_4i_1) recorded maximum pods per plant, pod yield per plant, total yield and harvest index (0.44).

The total water requirement of yard long bean varied from 681 mm to 891 mm. Water productivity (8.98 kg ha mm^{-1}), WUE (26.55 kg ha mm^{-1}) and crude protein content (30.13 per cent) were the highest in fertigation at 150 per cent RD of N and K. Fertigation interval of 4 days recorded higher WUE and crude protein, while water productivity and crude fibre content were the highest at 8 days interval.

The application of 150 per cent RD of N and K at 4 days (l_4i_1) interval recorded the highest WUE and crude protein.

Regarding the soil nutrient status, pH was comparatively higher in the lowest fertigation level (75 per cent RD of N and K), whereas organic carbon was unaffected by the treatments. The available N content in soil was maximum at 125 per cent RD of N. Available soil P and K were the highest when fertigation was given at 75 per cent RD of N and K. The fertigation at 4 days interval positively influenced the N, P and K contents in soil. The interaction of 125 per cent N and K at 4 days interval recorded the highest N content, while 75 per cent N and K at 4 days interval recorded the highest P and K content in soil.

The uptake of nutrients was significantly influenced by fertigation levels, intervals and interaction of both. The total N, P, K uptake and total pod uptake were maximum at fertigation with 150 per cent RD of N and K, whereas 8 days interval recorded total N, P, K uptake. The combination of 150 per cent at 8 days interval recorded the maximum N, P and K uptake.

The chlorophyll content of leaves at flowering was more in treatment with 150 per cent RD of N and K and fertigation interval of 4 days. The interaction of 150 per cent of N and K at 4 days recorded maximum chlorophyll content in leaf.

Comparing controls and treatments, it was found that growth attributes like number of primary branches, productive branches, vine length, LAI, root length, root volume, root weight and total dry matter were observed the highest in *ad hoc* recommendation for fertigation, followed by treatment mean

Among the yield attributes, control 2 (POP recommendation) recorded minimum days for 50 per cent flowering (39.75 days) and this was followed by treatment mean (42.28 days). The number of flowers per inflorescence was significantly superior in treatments (8.34). *Ad hoc* fertigation schedule registered a higher pod number per plant, pod yield per plant, pod length, average pod weight, total yield (242.39 q ha^{-1}) and number of picking and it was superior to treatments and POP recommendation (control 2).

WUE (33.05 kg ha mm^{-1}) and water productivity (11.36 kg ha mm^{-1}), total chlorophyll content and crude protein also recorded maximum value in *ad hoc* fertigation schedule. KAU POP recommendation registered the highest crude fibre.

KAU *ad hoc* recommendation for fertigation registered the highest N, P and K uptake by leaf, stem, pod and total uptake and was significantly superior to treatment and POP recommendation (control 2).

Soil N and K status were the highest in *ad hoc* fertigation schedule. Soil P was maximum in treatment mean and was superior to control treatments. The soil application (control 2) recorded the highest soil pH over *ad hoc* and treatment. Soil organic carbon was not influenced by control and treatments.

The KAU *ad hoc* recommendation (control 1) recorded the highest gross income (₹ 9.06 lakhs) and net income (₹ 6.10 lakhs), whereas B:C ratio (3.34) was the highest for the treatment 150 per cent RD of N and K at 4 days interval.

From the results of the study it is inferred that a fertigation schedule of 98 kg urea ha^{-1} and 62.5 kg MOP ha^{-1} at 4 days interval (25 fertigations) along with a basal application of 125 kg rajphos (equivalent to 45:25:37.5 kg N P_2O_5 and K_2O ha^{-1}) could be recommended for the economic production of yard long bean in precision farming.

Future line of work.

- Evaluate the performance of yard long bean at higher nutrient levels.
- Standardize the spacing requirement for precision farming in yard long bean.

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STUDIES ON FERTIGATION IN YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)

by

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ABSTRACT

An experiment entitled "Studies on fertigation in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)" was taken up in farmer's field at Pirappancode, Thiruvananthapuram, Kerala during the summer season of 2015. The objective of the study was to standardize the fertigation schedule in yard long bean under precision farming, to assess the impact of precision farming practices on growth and yield and to work out the economics.

The experiment was laid out in split plot design with four levels of fertigation, *viz.,* 75 per cent recommended dose (RD) of N and K (L_1), 100 per cent RD of N and K (L_2), 125 per cent RD of N and K (L_3) and 150 per cent RD of N and K (L_4) as main plot treatments. Fertigation interval of 4 days (I_1) and 8 days (I_2) constituted the sub plot treatments. Two controls were also included in the study, *viz.*, Kerala Agricultural University *ad hoc* recommendation for precision farming (Control 1) and Kerala Agricultural University POP recommendation (Control 2). Farm yard manure @ 20 t ha^{-1} was applied uniformly to all plots. Based on the initial soil analysis, the nutrient recommendation for yard long bean was modified as 30:25:25 kg NPK ha^{-1} and lime @ 350 kg ha^{-1} was applied as basal. Full dose of P was applied as basal in all treatments except control 1 (half applied as basal and the remaining through fertigation).

The results of the study revealed that the growth parameters, *viz.*, number of primary branches at 90 days after sowing (DAS), productive branches, vine length, LAI and total dry matter production were the highest in 150 per cent RD of N and K. Root parameters (root length and volume) were also higher at this level.

The main yield attribute, the number of pods per plant was the highest in 150 per cent RD (L_4) resulting in maximum pod yield per plant (1549 g), total pod yield (19.57 t ha^{-1}) and harvest index (0.42). The same fertigation level also resulted in

longer pods and was on par with 125 per cent RD of N and K. Water use efficiency (WUE) and water productivity were the highest at 150 per cent RD of N and K. The crude protein content of pods (30.13 %), total NPK uptake by plant and leaf chlorophyll content were the highest in the highest level of nutrients (L_4).

Though fertigation at 8 days interval recorded higher values for growth attributes, the number of pods per plant, total pod yield and harvest index were higher at 4 days interval. Leaf chlorophyll content and WUE were also higher at 4 days interval, whereas fertigation at 8 days interval recorded higher water productivity.

Among the interactions, fertigation at 150 per cent RD of N and K at 4 days interval recorded maximum number of pods per plant, pod yield per plant, total pod yield, harvest index, chlorophyll and crude protein content. This combination also resulted in higher WUE, while the same level at 8 days interval recorded the highest water productivity and NPK uptake.

Comparison of treatment mean with the controls revealed that all growth characters, yield attributes, yield (24.23 t ha^{-1}), WUE (33.05 kg ha mm^{-1}), water productivity (11.36 kg ha mm^{-1}), NPK uptake by crop, leaf chlorophyll and crude protein content of pod were the highest in *ad hoc* recommendation (control 1). However economic analysis revealed the superiority of l_4i_1 (fertigation with 150 per cent RD at 4 days interval) over *ad hoc* recommendation registering a B:C ratio of 3.34.

The results of the study indicated that a fertigation schedule of 98 kg urea and 62.5 kg MOP ha^{-1} at 4 days interval (25 fertigations) along with a basal application of 125 kg rajphos (equivalent to 45:25:37.5 kg N, P_2O_5 and K_2O ha^{-1}) could be recommended for the economic production of yard long bean in precision farming.

സംഗ്രഹം

വള്ളിപയറിലെ കൃത്യതാകൃഷിയിൽ അനുവർത്തിക്കേണ്ട ഫെർട്ടിഗേഷന് ആവശ്യമായ വളത്തിന്റെ അളവും ഫെർട്ടിഗേഷൻ നൽകേണ്ട ഇടവേളകളും ചിട്ടപ്പെടുത്തുന്നതിനായി തിരുവനന്തപുരം ജില്ലയിലെ പിരപ്പൻകോടുള്ള കർഷകന്റെ കൃഷിയിടത്തിൽ 2015 മാർച്ച് മുതൽ ജൂൺ വരെ ഒരു പരീക്ഷണം നടത്തുകയുണ്ടായി. ഈ രീതി മൂലം വള്ളിപയറിന്റെ വളർച്ചയിലും വിളവിലുമുള്ള വ്യതിയാനം പഠന വിധേയമാക്കി.

നാലു അളവിലുള്ള മൂലകങ്ങളും (ശുപാർശയുടെ 75, 100, 125, 150% നൈട്രജനും പൊട്ടാസ്യവും) രണ്ടു ഫെർട്ടിഗേഷൻ ഇടവേളകളും (4, 8 ദിവസം) അതോടൊപ്പം രണ്ടു കൺട്രോളുകളെയും (കേരള കാർഷിക സർവ്വകലാശാലയുടെ വള്ളിപയറിന്റെ കൃത്യത കൃഷിക്കുള്ള ശുപാർശ, കേരള കാർഷിക സർവ്വകലാശാലയുടെ വള്ളിപയറിന്റെ സാധാരണ കൃഷിരീതിയ്ക്കുള്ള ശുപാർശ) പഠനവിധേയമാക്കി.

ഈ പഠനത്തിൽ നിന്നും ഒരു ഹെക്ടർ വള്ളിപയർ കൃഷിക്കുവേണ്ട മൂലകങ്ങളായ 45:25:37.5 കി.ഗ്രാം. നൈട്രജൻ, ഫോസ്ഫറസ്, പൊട്ടാസ്യം എന്നിവ ലഭിക്കുന്നതിനായി 125 കി.ഗ്രാം. രാജ്ഫോസ് അടിവളമായി നൽകുന്നതിന് പുറമേ 98 കി.ഗ്രാം. യൂറിയയും 65.5 കി.ഗ്രാം മ്യൂറിയേറ്റ്
ഷിൽ നൽകുന്നത്
ഓഫ് പൊട്ടാഷും 4 ദിവസത്തിലൊരിക്കൽ ഫെർട്ടിഗേഷൻ രീതി വള്ളിപ്പയറിന്റെ വളർച്ചയ്ക്കും ഉൽപാദന വർദ്ധനവിനും, ആദായം കൂട്ടുന്നതിനും സഹായകരമാണെന്ന് കണ്ടെത്തി.

Appendices

APPENDIX- I

Weather parameters during the crop period (March 2015 – June 2015)

Period	Standard week	Temperature (°C)		Rainfall (mm) weekly Total	Evaporation (mm) weekly total	Relative humidity (%)
		Max.	Min.			
2015	10	32.1	23.3	0.0	31.1	88.6
	11	32.1	23.6	45.7	14.7	91.4
	12	32.7	23.3	0.0	28.4	90.7
	13	33.0	24.7	9.4	28.3	90.7
	14	33.1	25.2	7.0	28.9	91.9
	15	32.6	24.3	23.8	25.3	91.4
	16	32.9	24.3	80.8	30.7	89.7
	17	32.5	23.8	71.0	26.9	89.6
	18	33.2	25.2	0.0	30.8	85.1
	19	32.5	25.2	103.1	28.1	91.4
	20	30.4	24.3	29.3	9.8	94.0
	21	32.3	26.1	97.7	22.2	92.1
	22	31.9	25.2	13.0	21.9	90.8
	23	31.9	24.7	61.5	24.5	89.7
	24	31.9	24.0	63.0	35.1	91.7
	25	31.6	24.4	47.8	26.3	90.3

APPENDIX – II

Economics of cultivation of yard long bean (₹ ha^{-1})

Treatments	Total cost excluding treatment cost	Treatment cost	Total cost of cultivation	Gross Income	Net Income
l_1i_1	157208	81942	239150	645720	406569
l_1i_2	157208	81599	238807	573460	334652
l_2i_1	157208	82206	239414	620900	381485
l_2i_2	157208	81952	239160	608620	369459
l_3i_1	157208	82471	239679	680340	440660
l_3i_2	157208	82293	239501	647700	408198
l_4i_1	157258	82686	239944	800420	560475
l_4i_2	157208	82648	239856	765640	525783
Control 1	157208	20053	357741	969550	611808
Control 2	176204	32051	198256	542720	344464

Unit cost of inputs used

Items	Price (₹ kg^{-1})
Urea	8
MOP	17
Raj phos	7
13:0:45	200
12:61:0	140
19:19:19	140
Cow dung	1

Sale price of yard long bean – ₹ 40 kg^{-1}