Crop weather relationship of Yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Walp)

By

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(2012-11-154)

THESIS

Submitted in partial fulfillment of the requirement for the degree of

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COLLEGE OF HORTICULTURE
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DECLARATION

I hereby declare that this thesis entitled "Crop weather relationship of Yard long bean (*Vigna unguiculata* subsp. *Sesquipedalis* (L.) Walp)" is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Crop weather relationship of Yard long bean (*Vigna unguiculata* subsp. *Sesquipedalis* (L.) Walp)" is a record of research work done independently by **Aswini Haridasan** (2012-11-154) 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 her.

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Aswini

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INTRODUCTION

1. INTRODUCTION

Agriculture is an economic activity that is highly dependent upon weather and climate in order to produce the food and fibre necessary to sustain human life. Not surprisingly, agriculture is deemed to be an economic activity that is expected to be vulnerable to climate variability and change. Weather and climate are considered to be the most limiting factors in crop production. Weather plays a slightly different role in crop production. Despite technological improvements that increase crop yields, extreme weather events have caused significant yield reductions in some years. On year to-year basis, weather influences the number of growing degree days, length of the growing season, and timing and amount of precipitation and evapotranspiration from crops. These factors can combine in advantageous ways for optimal growing conditions; however, a late monsoon or lack of moisture during the growing season can severely limit yields and create a host of concerns for growers. Weather also determines the conditions under which pests appear in crops and how they might migrate.

Cowpea is a common vegetable grown throughout the country as a richest source of protein (8g/100g). It belongs to the family leguminosae. It is a typical warm season crop adapted to tropics. The crop is used in a variety of ways. Tender pods are used as vegetable and dry beans as pulse. Due to its nutritive value and soil improving properties, it is also used as a fodder, green manure and cover crop. Being a legume crop, cow pea fits well in inter-cropping system. Among legumes, the genus *Vigna* include more than 100 species distributed in tropical and sub tropical regions.

Yard long bean (also called as asparagus bean, string bean, sitao and snake bean) is one among the sub species cultivated throughout Kerala. Yard long bean variety Lola is a high yielding variety developed by the Kerala Agricultural University. The pods are lengthy with light green colour and purple tip. The seeds are brown coloured. Yard long beans are widely cultivated in India, Indonesia, Philippines, and Srilanka. The tender green pods are rich in crude protein (28%), iron (2.5 mg 100 g-1), calcium (80 mg 100 g-1), phosphorus (74 mg 100 g-1), vitamin A (941 IU 100 g-1), vitamin C (13 mg 100 g-1) and dietary fibre (2 g 100 g-1) (Singh *et al.,* 2001). In Kerala, cultivation of vegetable type cowpea cultivars is having more demand than pulse and dual purpose type. The landless agricultural workers and marginal farmers who depend on vegetable cultivation for their lively hood prefer yard long bean cultivars because of its protracted fruiting, more yield and steady demand in the market. It is a vigorous climbing annual which grows up to a height of three to four meters and produces very long, slender and succulent pods which may be white, light green or brownish red in color. Since it is climbing in habit, it has to be grown with proper staking on pandals or trellis.

Different characters and yield potential for a crop depend on environmental conditions prevailing during its growth. Therefore, a major problem towards productivity increase is the reaction of the crop to the varying agro climatic conditions. The yield response is very sensitive to the changing weather parameters that exist in different seasons peculiar to these agro climatic regions. The positive effect of environmental factors on growth and yield could be harnessed if the information on optimum time of sowing is made available. Defining the optimal sowing time plays a pivotal role in the potential yield and quality of any given crop. The relationship between the sowing date and crop development can interact with disease development and nutritional management. The effect of various environmental factors on the crop can be studied by varying the sowing dates so that an optimum date of sowing can be found out.

In this background, the present study is conducted to identify the optimum time of sowing with an objective to determine the crop weather relationship and to study the effect of date of sowing on the growth and yield of yard long bean

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Yard long bean or pole type vegetable [*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt] is an important vegetable of Kerala, next to bitter gourd in coverage and popular preference (KAU, 2004). It is an important legume vegetable grown for its tender long green pods and a highly relished vegetable which can be cultivated throughout the year. Climate change has been negatively affecting crop productivity in most parts of the world. This has affected the planting time of crops and resulted to reduced yield because of inappropriate planting dates. Available literatures on the influence of weather and growth of various crops are reviewed in this chapter.

2.1. EFFECT OF SOWING DATE ON GROWTH AND YIELD OF CROPS

Akinola and Whiteman (1975) reported that optimum sowing time for pigeon pea in Nigeria is from late November to mid-January for dry seed production in the late maturing accessions and not later than December for periodic green pod picking in the early maturing accessions.

According to a study conducted by Ezueh, M.I. (1982) in cowpea at Nigeria, it was found that the yield of dry seeds was highest in early season plantings, but the quality of the seed was better in late season plantings. The population of Maruca Testulalis was high during July to October, and the peak damage was caused to crops sown in August. Thrips were also found highest in August sown crop.

Fukugawa and Zheng (1999) reported that for seed production, the pigeon pea can be sown from the middle to the end of June in northern Kyushu; they also reported that in indeterminate type of chickpea, the variations of days from emergence to flowering and the vegetative growth among the sowing times were not different.

Peksen *et al.,* (1999) conducted an experiment in plastic green house at Turkey in cowpea with 4 dates of sowing viz, April 1, April 15, May 1 and May 15; which indicated the influence of sowing dates to green pod yield. The highest green pod yield pea plant was obtained from April and May 15.

According to an experiment conducted by Samanta *et al.,* (1999) at Bangladesh to evaluate the effect of sowing dates on grain yield of mungbean, with sowing dates at 15 day intervals from 15 December to 15 February, it was found that late-sown crops produced higher seed yield as compared to early sown crops.

Yadahalli *et al.,* (2001) conducted an experiment in black gram to evaluate the effect of three sowing dates viz. 16 June, 1 July and 16 July and it was found that all growth and yield components such as plant height, number of branches per plant, leaf area at 60 days after sowing, leaf area index at 60 days after sowing, total dry matter at harvest, days to 50% flowering, days to physiological maturity, number of pods per plant, seed weight per plant, 1000 seed weight and seed yield were higher when sowing was done early i.e. on 16th June.

According to a study on the effect of sowing date on green gram conducted by Ram and Dixit (2001) during the summer season of 1997 in Uttar Pradesh, with three sowing dates (20 and 30 March and 9 April) it was found that sowing on 30 March generated the tallest plants, highest number of branches, leaves and pods per plant, highest number of grains per pod, maximum dry matter accumulation 60 days after sowing and maximum grain yield.

Veni *et al.,* (2003) conducted a study in soybean in Southern Telengana region of Andhra Pradesh under different dates of sowing and reported 22.85 per cent loss in yield by sowing the crop on August 27 over the optimal time of sowing on June 28.

Singh *et al.,* (2004) conducted an experiment at Uttar Pradesh in chickpea during the rabi season to investigate the optimum sowing date of chickpea, with six sowing dates viz 15 and 30 October 15 and 30 November and 15 and 30 December and it was reported that the maximum grain yield, number of seeds per pod, grain size and seed yield were obtained in the 30 October sowing.

An experiment was conducted by Hussain *et al.,* (2004) in Pakistan to study the effect of sowing time on grain yield of mungbean, with 5 sowing dates viz, 15 April, 15 May, 15 June, 15 July and 15 August. It was found that sowing on April took more number of days to emergence but showed maximum plant height. Sowing on 15 August gave the highest number of days to 50% flowering and to Physiological maturity, while 15 April sown plant gave highest mean grain yield.

Kumar *et al.,* (2006) reported that in a field study with five sowing dates viz 20 October, 5 and 20 November, 5 and 20 December in chickpea at Haryana, it was found that dry matter accumulation in leaf, pods and stem decreased significantly on 5 December and 20 December compared to 5 November sowing, also chickpea planted on or before 5 November produced higher crop growth rate compare to delayed sowing.

Chaitanya *et al.,* (2006) conducted an experiment in Chittoor district of Andhra Pradesh on chickpea with four sowing dates i.e. 15 October, 1 November, 15 November and 1 December and it was found that among the four sowing dates, 1 November sown crop recorded the highest yield attributes like plant height, number of primary branches and secondary branches per plant at harvest, number of pods per plant, number of seeds per pod, 100 seed weight and seed and haulm yields.

According to an experiment conducted by Fraz *et al.,* (2006) in Pakistan to evaluate the effect of sowing dates viz. 3rd week of June, 1st week of July and 3rd week of July in mungbean, the results revealed that higher number of pods per plant, number of grains per pod, 1000 grain weight and harvest index were recorded in the crops sown during 3rd week of July. The maximum biological and grain yield was also recorded in the crops sown during 3rd week of July sowing.

According to a study conducted by Moniruzzaman *et al.,* (2007) in french bean at Agricultural Research Station, Raikhali, with six sowing dates at 10 days internal from November 1 to December 20, showed that higher pod yield per plant and pod yield per hectare was found with November 10 and November 20 sowing. The dry weight per plant and pod length was also higher for November 10 and November 20 sowing. Superior basic capital in terms of dry matter under November 10 and November 20 sowing dates due to favourable temperature might have contributed to higher yield. The reduction in yield under late sown condition may be attributed to poor development of yield attributes i.e. number of pods per plant, pod size (length x width) and pod weight due to low minimum temperature prevailed during reproductive phase of the crop. The reduced yield in early sowing of November 01 may be due to highest mean temperature experienced during the early stage of crop which resulted in poor growth of plants.

According to study conducted in black gram by Kandasamy and Kuppuswamy (2007) at Tamil Nadu, with four dates of sowing (12^{th}, 19^{th}, 26^{th} January and 2^{nd} February), it was observed that 19^{th} January sowing recorded the highest values of all growth and yield component i.e. highest leaf area index, number of pods per plant, number of seeds per pod, pod yield and seed yield. This might be due to optimum temperature, duefall, high relative humidity, low temperature and low wind velocity during the cropping period.

Singh and Sekhon (2007) conducted an experiment at Ludhiana during kharif season to study the effect of sowing date on growth and yield of mung bean during 2002 and 2003. It was found that during 2002, the crop sown on 8 July recorded the highest yield compared to 16 July, 24 July, and 1 August sowing and during 2003, 25^{th} July sowing produced the highest grain yield, 10 July being at par with it and both being significantly superior to 10 August sowing.

Sharma *et al.,* (2008) conducted on experiment in french bean in greenhouse to study the effect of four sowing dates (15^{th} April, 15^{th} may, 15^{th} June and 15^{th} July) in french bean which revealed that higher pod yield was obtained with 15^{th} April sowing. The higher yield in April sowing was mainly due to favourable weather conditions which had positive effect on the vegetative and reproductive phases of crop development. Sowing on 15^{th} April also increased plant height, branches per plant and number of pods per plant.

Bruin and Pederson (2008) conducted an experiment in soybean in the Upper Midwest with four dates of sowing and it was found that late April and early May planting was superior to late May and early June planting.

In an experiment conducted in chickpea at Andhra Pradesh during 2004 and 2005, Manirathnam and Sangitha (2009) observed that there is no significant influence of dates of sowing with respect to seed yield, whereas different dates of sowing significantly influenced the test weight. Higher values for test weight were recorded with early sowings i.e. second fortnight of October but were comparable with 1st fortnight of November sowings and significantly superior over 2nd fortnight of November.

Rathore *et al.,* (2010) conducted an experiment during kharif 2006 at Rajasthan in urdbean with two sowing dates (7th July and 27th July) and it was found that urdbean cultivars sown at onset of monsoon recorded maximum seed yield compared to 27th July sown crop. There was considerable increase in the values of yield attributing characters such as number of pods per plant, number of seeds per pod and 100 seed weight in July 7th sown crop compared to 27th July sown crop.

Ram *et al.,* (2010) conducted an experiment in soybean at Punjab Agricultural University during *kharif* 2008 and 2009 with three sowing dates i.e. June 5, June 15 and June 25. The results revealed that highest grain yield was recorded in June 5 sown crop, which was statistically on par with June 15 sowing in 2008. In June 2009, June 15 sowing recorded highest grain yield which was statistically on par with June 5. This might be due to higher pods per plant and 100 grain weight. They also reported that in 2009, the overall grain yield was lower than in 2008, which might be due to lower minimum temperature during 40-45 standard weeks which caused early senescence.

Experiment conducted in chickpea by Singh *et al.,* (2010) with two dates of sowing viz. October 15 and November 15 during rabi season in 2007-2008 and 2008-

2009, it was observed that October 15 sowing gave highest grain yield during both the years

Mansur *et al.,* (2010) reported that when kabuli chickpea was grown at 4 different sowing dates viz 1st fortnight of October, 2nd fortnight of October, 1st fortnight of November and 2nd fortnight of November at Dharwad. Second fortnight of October recorded significantly more plant height, more number of branches per plant, pods per plant, test weight and seed yield as compared to other sowing dates.

Field experiment was conducted by Pal *et al.,* (2011) in IARI with three dates of sowing in chickpea viz 15 November, 30 November and 15 December, it was observed that 30 November was better date of sowing than 15 November and 15 December. This may be due to comparatively low temperature experienced by the crop in which growth of flowers, pod formation and seed development was better in performance. Seed yield per plant, number of seeds per pod and yield of the crop was higher when sown on 30 November.

According to a study conducted by Mustafa *et al.,* (2011) with three dates of sowing in 28th February, 15th March and 30th March revealed that the plant height, number of leaves per plant, days taken to 50 % flowering, days taken to pod development for first picking, number of pods per plant, number of seeds per pod, length of pods, diameter of pods, fresh dry weight of pod and fresh pod yield were maximum at 15th March date of sowing in cowpea. This may be due to optimization of weather condition in respect to temperature and light intensity which resulted in better survival of crop plant.

Hari *et al.,* (2011) conducted an experiment in soybean with three sowing dates i.e. June 5, 15 and June 25 during *kharif* 2008 and 2009 to study the effect of time of sowing on the performance of soybean. It was reported that highest grain yield was recorded in June 5 sown crop which was statistically on par with June 15 sowing but significantly higher than June 25 sowing in 2008, and in 2009 June 15 sowing recorded highest grain yield which was statistically on par with June 5, but significantly higher than June 25 sowing.

According to a study conducted in French bean by Labuda and Brodaczewska (2011) at Lublin in the years 2003-2005, it was found that highest total and marketable pod yields were obtained from plants sown in the first ten days of June, and the lowest were obtained from plants sown in the middle of May.

Field experiment was conducted by Shaukat *et al.,* (2012) in pea under temperate conditions of Rawalakot Azad Jammu and Kashmir with four sowing date viz 20th April, 5th May, 20th May and 4th June and it was reported that sowing on 20th April and 5th May gave best results for plant height while sowing on 4th June recorded minimum plant height.

According to an experiment conducted by Prasad *et al.,* (2012) in chickpea at Haryana with three dates of planting (December 1, December 10, December 20), December 1 planting produced maximum number of pods per plant, highest seed yield and biomass yield. This could be attributed due to higher growth attribute, which may be responsible for better source sink relationship.

Ichi *et al.,* (2013) conducted an experiment on Cowpea in the Sudan Savanna ecological zone of Nigeria with three sowing dates (mid- February, late – February and early March) which showed that planting cowpea in mid- march significantly increased the number of days to 50% flowering, but sowing in mid- February resulted in significant increase in grain yield per hectare.

Guriqbal *et al.,* (2013) conducted an experiment in black gram during summer 2008, 2009 and 2010 at Ludhiana to study the performance of spring black gram genotypes on different dates of sowing i.e. 10 March, 15 March, 20 March and 25 March. It was found that grain yield recorded in 20 March sowing was significantly higher than the other sowing dates, nodule dry weight was significantly higher in 15, 20 and 25 March sowings than 10 March sowing. Early sown crop took more number of days to 50 % flowering and maturity than late sown crop.

An experiment conducted by Sharma *et al.,* (2013) at Palampur with four dates of sowing at weekly interval starting from first June, showed that early sowing of French bean on June 1 took more days to flowering and seed maturity compared to other dates of sowing. The increased plant height was seen during June 1 compared to June 15 and June 22 sowing. Early sowing on 18th June produced highest seed per pod and pods per plant resulting in highest seed and straw yield. Significantly higher yield and attributing characters of early sown crop were due to relatively more favourable climatic conditions during the initial crop growth stage and they also reported that increase in the intensity of monsoon rains from early to late sowings proportionally reduced the vegetative growth and also affected flowering and pod setting in late sown crop.

Filho *et al.,* (2013) conducted an experiment to simulate sowing dates for cowpea using 20 years of historic daily weather data set from the weather station at Embrapa CNPMF based on CROPGRO cowpea model and it was observed that the time between mid June and mid July are the best time for sowing cowpea due to lesser risk for yield loss.

According to a study conducted in chickpea by Maurya *et al.,* (2014) at Jaunpur, it was found that higher crop yield was obtained from 29th October sowing out of six sowing dates viz 1st October, 8th October, 15th October, 22nd October, 29th October and 5th November.

In an experiment conducted in the Southern United states, Berger-Doyle *et al.,* (2014) observed that out of the three plantings i.e. late-April, mid-May and early June, May planting recorded the greatest yield and height, whereas the April planted crops recorded the lowest yield and shortest height. Also June planting resulted in longer days to maturity.

Matikuti (2015) conducted an on-station and on-farm study in cowpea at Zimbabwe with 14 December and 16 January as on-station planting dates and 15 December and 17 January as on-farm planting dates, and it was observed that highest grain yield was obtained with late planting in January, while highest leaf yield was obtained with early planting in December. This suggests that the growth conditions were optimum for vegetative growth during early planting in December and conversely the low grain yield in this phase indicate that the conditions in the late as second planting dates could be sub- optimal.

2.2. EFFECT OF WEATHER PARAMETERS ON THE GROWTH AND YIELD OF CROPS

According to a field experiment conducted by Tewari (1965), in cowpea, it was observed that cowpea crops required a day length of more than 12 hours to initiate flower formation, and May planting gave the best results whereas August and September plantings failed to form flowers.

Enyi (1973) reported that in Tanzania, March planting of cowpea resulted in higher dry matter production and grain yield than January and May plantings and the grain yield was closely related to the total amount of rainfall received.

Kay (1979) reported that mean temperature requirement for optimum growth of French bean is 14-24°C.

According to Kamara and Godfrey-Sam-Aggrey (1979), early September planting of cowpea produced the tallest plants and higher grain yields than from other planting dates in Sierra Leone and also reported the positive effect of rainfall on grain yield based on the studies carried out in Nigeria.

Siddique and Goodwin (1980) found that high temperature (33°c) during seed growth reduced seed quality of bean at Sydney.

Duke (1981) reported that in pea temperatures above 27°C shorten the growing period and adversely affect pollination. Peas can be grown successfully during midsummer and early fall in those areas having relatively low temperatures and a good rainfall, or where irrigation is practiced.

Doto and Whittington (1981) conducted an experiment in cowpea by exposing it to different day and night temperatures and it was found that early vegetative development was enhanced by the higher day, higher night temperature and flowering occurred first in plants which received higher day and higher night temperatures.

According to study conducted by Warrag and Hall (1984), it was observed that floral development of cowpeas at 33/22°C day/night temperature appeared to be normal. However, at 33/30°C day/night temperature all flowers abscised within 48 h after anthesis due to male sterility resulting from abnormal pollen development and anther indehiscence. Ridge and Pye (1985) found that in pea, yields were reduced by 0.6 t/ha for each 1°C increase in mean temperature during flowering when the mean daily temperatures ranged from 13- 18°C.

Bond *et al.,* (1985) reported that even in areas where conditions are favorable for vegetative development of faba bean, high temperatures when pods are setting and filling may reduce reproductive growth.

According to an experiment conducted by Jadhav *et al.,* (1991) in cowpea at Dapoli between December 1986 and November 1987, it was found that time from sowing to flowering or maturity was longest after sowing in December 1986, January 1987 or February 1987 and shortest when sown in September and October 1987. The shorter period to flowering from September and October sowing was attributed to short photoperiods combined with warm nights.

Ellis and Fiho (1992) reported that temperature during and after the seed filling significantly influenced the development of seeds of bean whereas lower temperature extends higher potential longevity of bean seeds. Rashid (1999) reported that mean temperature requirement for optimum growth of French bean is 15-25^{o}c.

Singh and Diwakar (1995) reported an optimal temperature of 28 to 33°C for the germination of chickpea seeds.

Gibson and Mullen (1996) at Manhattan in USA reported that environmental stress like high day and night temperature during reproductive growth of soybean reduced seed germination and seedling vigour. The largest yield reduction was 27% and occurred when 35^{o}C occurred for 10 hour per day from flowering to maturity.

Clarke *et al.* (2004) reported that low temperatures are a major constraint for improving the yield of chickpea in various regions of the world.

Sleimi *et al.,* (2013) reported that a strong variation of temperature had significant effects on seeds germination in chickpea.

Parwada *et al.,* (2016) conducted an experiment in cowpeas at Zimbabwe with planting at three different times and it was found that planting cowpeas in early December resulted in higher growth performance of the crop, i.e. tall plants, fewer days to 50% flowering and higher yields than in mid December and early January. The increase in yield with early planting may be attributed to the prolonged exposure to solar radiation.

2.3. EFEECT OF DATE OF SOWING ON THE INCIDENCE OF PESTS AND DISEASES

Ghosh (1970) reported maximum aphid population in french bean from March to April and November to early January in Bihar.

Akingbohungbe (1982) reported that at Nigeria in cowpea, flowering, podding and seed yield were found to decrease over the season from April to September (1996-1997), there seemed to be two peak periods of pest activity from April to July and from

October to December when severe damage to the crop occurred in unprotected plots also planting in June or July usually led to an escape from several major pests.

A field experiment was conducted during *kharif* 1989 with eight different dates at 10 days internal at Agricultural College, Dharwad by Kale and Anahosur (1993) to study the influence of sowing date on the development of cowpea rust. The observations revealed that percent disease index was significantly lover on crop sown on earlier date than on later; also the seed yield was generally higher with early sowing than later sowing.

Chhabra and Kaur reported (1994) that manipulation of date of sowing was effective in reducing the population of various aphid species.

Awurum (2000) reported that disease severity for leaf spot diseases in cowpea was significantly higher in the crops sown on 1 June, 21 June, and 12 July than those sown on 2 and 23 August. He also reported that the highest grain was obtained from cowpea sown in early August.

Planting of cowpea at the onset of monsoon reduced aphid, thrips and pod-sucking bug infestations, but increased Maruca infestation compared to delayed plantings and the grain yield was also higher in the early planting in Eastern Uganda (Karungi *et al.*, 2000).

According to Karungi *et al.*, (2000) planting at the on-set of rains in cowpea, with the 30×20 cm^2 or 60×20 cm^2 densities were the best cultural practices as far as pest management was concerned.

Prasad *et al.,* (2000, 2001a) reported that high soil temperature significantly decreased root to shoot ratio, root growth, nodule weight and nodule numbers in peanut. It was noticed that decrease in number of nodules and nodule dry weights were more sensitive to high soil temperature than high air temperature (Prasad et al., 2001b).

Asante *et al.,* (2001) reported that aphid infestation occurred only on cowpea planted between the first week of June and mid-July with the highest incidence recorded on crop planted in the last week of June also cowpea planted in June flowered and podded between early to mid-August when post-flowering pests densities were relatively low and produced significantly higher grain yields without insecticide protection compared to other planting dates.

Kumar and Kumar (2015) conducted an experiment in cowpea and reported that relative humidity positively influenced the populations of aphids and pod borer while those of jassid were affected by temperature and sunshine hours. A negative correlation was found between aphids and maximum temperature, sunshine hour and wind speed, jassid and thrips with relative humidity and pod borer with maximum temperature and wind speed.

2.4. CORRELATION STUDIES ON VARIOUS CHARACTERS OF YARD LONG BEAN

According to a study conducted in yard long bean by Lovely and Radhadevi (2006) at Vellayani, it was found that yield per plant showed strong positive genotypic correlation with pods per cluster, pods per plant, pod weight, pod length, pod breadth and seeds per pod. Also a negative correlation with yield was noted for days to 50 %flowering and days to first harvest.

Path coefficient analysis was conducted by Madhavi *et al.,* (2014) in vegetable cowpea and it was found that there was significant direct positive effect of plant height, dry matter, days of first flowering, days of first picking, pod length and mean pod weight exhibited considerable positive effects on pod yield per plant whereas negative effects on yield were observed with number of primary branches, number of leaves, days to 50% flowering, crop duration, pod girth, pods per plant, seeds per pod and test weight.

According to a study about correlation and path analysis for yard long bean conducted by Vavilapalli and Celine (2014) at Trivandrum, it was found that pod yield per plant was positively correlated with number of pods per plant and pod weight. They also found that the number of days to first harvest and 100 seed weight showed significant negative correlation with pod yield per plant and path analysis revealed that the number of pods per plant had greatest direct effect on yield followed by pod weight.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present experiment on "Crop weather relationship of Yard long bean (*Vigna unguiculata* subsp. *Sesquipedalis* (L.) Walp)" was carried out at the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara, Thrissur during 2013-2014.

3.1. DETAILS OF FIELD EXPERIMENT

3.1.1. Location

The experiment was conducted at Instructional Farm, Vellanikkara, Thrissur during 2013-2014. The site is located at 10°31' N latitude and 76°13' E longitude with an altitude of 25 m above mean sea level.

3.1.2. Soil

The experimental location has a deep well drained sandy loam soil which is acidic in reaction.

3.1.3. Climate

The area experiences a typical warm humid tropical climate. The area is benefitted both by southwest and northeast monsoons. During the experimental period, the mean maximum temperature ranged between 27.8°C and 37.6°C and the mean minimum temperature varied from 21°C to 26.4°C. The average sunshine hour was 5.72 hrs day^{-1}.The mean forenoon relative humidity and afternoon relative humidity was 87.3% and 60.9% respectively. The average wind speed was 3.05 km hr^{-1}

The details of the weekly weather parameters experienced during the experiment are presented in table 3.1.

3.1.4. Season of Experiment

The experiment was conducted from September 2013 to August 2014.

Table.3.1. Weekly weather parameters during the crop growth period (2013-2014)

Week No.	Tmax (°C)	Tmin (°C)	RH1 (%)	RH2 (%)	VP1 (mm Hg)	VP2 (mm Hg)	RF (mm)	RD (nos)	Epan (mm)	WS (km hr^{-1})	BSS (hrs)
35	32.0	23.2	94	68	22.5	22.9	0.4	0.0	3.5	1.4	6.0
36	29.5	22.0	96	76	21.7	21.7	66.5	4.0	2.1	1.3	3.3
37	29.0	22.1	96	79	22.1	22.5	196.0	6.0	2.4	1.9	2.0
38	29.7	22.8	96	76	22.6	22.3	66.4	4.0	2.4	2.3	3.7
39	30.7	21.6	93	69	21.9	21.8	14.8	3.0	2.8	1.2	5.1
40	31.0	21.5	96	62	21.2	20.5	15.2	1.0	3.1	1.9	6.3
41	30.9	22.6	96	69	21.8	21.7	69.3	4.0	3.1	2.2	7.1
42	30.6	23.1	96	72	21.9	22.9	152.6	5.0	2.1	1.8	4.2
43	29.8	23.0	97	77	22.2	22.9	104.1	4.0	2.3	1.3	3.3
44	32.8	24.0	89	62	21.9	21.5	29.8	2.0	3.1	3.3	6.4
45	32.6	24.1	76	54	18.9	19.3	0.0	0.0	3.9	4.8	8.6
46	31.9	23.2	87	63	20.0	20.0	61.3	3.0	2.7	2.7	4.8
47	32.9	23.9	94	63	22.1	22.1	13.2	1.0	2.6	1.4	5.4
48	32.8	24.0	92	60	21.6	21.4	6.8	1.0	2.8	2.4	5.5
49	32.5	22.4	81	44	17.6	15.1	0.0	0.0	3.6	3.2	7.9
50	32.3	22.5	87	51	19.0	17.8	0.0	0.0	3.5	4.2	6.8
51	31.2	21.8	71	43	15.1	14.4	0.0	0.0	4.9	7.3	9.7
52	31.4	22.1	66	39	14.3	13.6	0.0	0.0	5.1	7.4	9.2
1	32.9	22.4	74	34	15.9	12.6	0.0	0.0	5.0	5.5	9.2
2	32.8	23.1	68	37	15.5	13.3	0.0	0.0	5.1	6.3	8.1
3	33.0	23.7	63	37	14.7	13.4	0.0	0.0	5.2	6.8	8.6
4	32.7	23.3	63	38	14.4	13.1	0.0	0.0	5.3	8.2	9.6

Week No.	Tmax (°C)	Tmin (°C)	RH1 (%)	RH2 (%)	VP1 (mm Hg)	VP2 (mm Hg)	RF (mm)	RD (nos)	Epan (mm)	WS (km hr^{-1})	BSS (hrs)
5	33.9	22.3	60	33	13.9	12.5	0.0	0.0	5.1	7.2	9.8
6	35.2	21.0	74	25	14.9	10.3	0.0	0.0	5.1	3.8	9.8
7	33.5	22.6	89	51	20.1	18.9	0.0	0.0	5.1	2.5	6.8
8	35.2	24.3	70	38	17.2	15.3	0.0	0.0	5.2	5.8	8.2
9	35.2	24.7	77	42	19.3	17.1	0.0	0.0	5.0	3.3	8.6
10	35.2	25.0	71	36	18.1	14.7	0.0	0.0	4.9	5.4	7.3
11	37.5	22.3	67	20	15.3	9.4	0.0	0.0	4.8	4.7	9.5
12	37.6	24.7	83	37	22.4	16.0	0.0	0.0	5.0	2.9	8.8
13	37.6	24.7	85	41	22.1	17.4	0.0	0.0	5.1	2.6	7.9
14	35.8	25.8	87	55	23.9	23.1	0.7	0.0	5.4	2.4	6.3
15	34.6	24.2	90	59	23.6	21.9	40.0	2.0	5.6	2.2	6.0
16	35.7	26.1	90	56	24.6	23.0	3.5	1.0	5.7	2.4	8.5
17	34.8	26.4	89	61	24.9	24.6	16.8	1.0	5.6	2.2	4.7
18	34.2	24.7	84	62	22.3	23.0	154.2	2.0	6.0	3.3	4.7
19	32.0	25.2	93	69	24.2	23.4	130.2	2.0	6.2	2.2	5.5
20	33.0	24.8	91	61	23.8	22.3	0.0	0.0	6.4	2.2	6.9
21	33.6	25.5	91	62	23.9	23.6	38.0	1.0	6.4	2.4	6.1
22	32.5	24.9	92	69	24.2	24.2	21.1	2.0	6.2	2.3	5.5
23	30.1	24.3	95	83	23.7	24.2	176.6	5.0	6.2	2.3	2.0
24	30.8	24.0	96	75	23.3	23.2	85.9	6.0	6.4	2.3	2.4
25	30.6	24.1	97	77	24.2	23.6	124.1	6.0	6.2	2.7	1.6
26	31.1	24.4	94	72	23.8	23.0	91.1	3.0	6.2	1.8	4.4

Week No.	Tmax (°C)	Tmin (°C)	RH1 (%)	RH2 (%)	VP1 (mm Hg)	VP2 (mm Hg)	RF (mm)	RD (nos)	Epan (mm)	WS (km hr^{-1})	BSS (hrs)
27	30.7	23.6	93	93	22.7	22.6	85.6	4.0	6.3	2.2	4.9
28	28.2	22.6	97	97	21.8	23.1	225.7	7.0	6.2	2.1	0.5
29	29.1	22.9	95	87	21.9	21.8	208.8	7.0	5.9	1.9	1.0
30	29.8	23.3	97	78	22.2	22.4	157.6	6.0	5.9	2.0	0.9
31	27.8	23.1	97	85	22.2	22.5	288.6	7.0	5.9	1.6	0.0
32	28.4	22.7	97	79	21.8	21.8	127.7	5.0	5.9	1.4	0.4
33	31.1	23.9	97	67	23.2	22.5	4.6	0.0	5.8	2.3	6.1
34	30.7	23.5	95	75	22.6	23.3	147.8	7.0	5.6	1.9	4.2
35	29.0	23.0	98	79	22.2	22.8	191.8	7.0	5.5	2.2	1.3
36	30.1	23.1	97	72	22.3	22.8	39.2	4.0	5.4	1.9	4.7
37	30.9	23.3	97	66	22.4	21.4	22	2.0	4.8	2.3	7.0
38	31.9	23.6	93	66	22.6	23.3	1.8	0.0	4.4	2.3	7.6
39	33.6	23.4	90	69	22.0	22.8	90.6	4.0	4.2	2.2	5.5

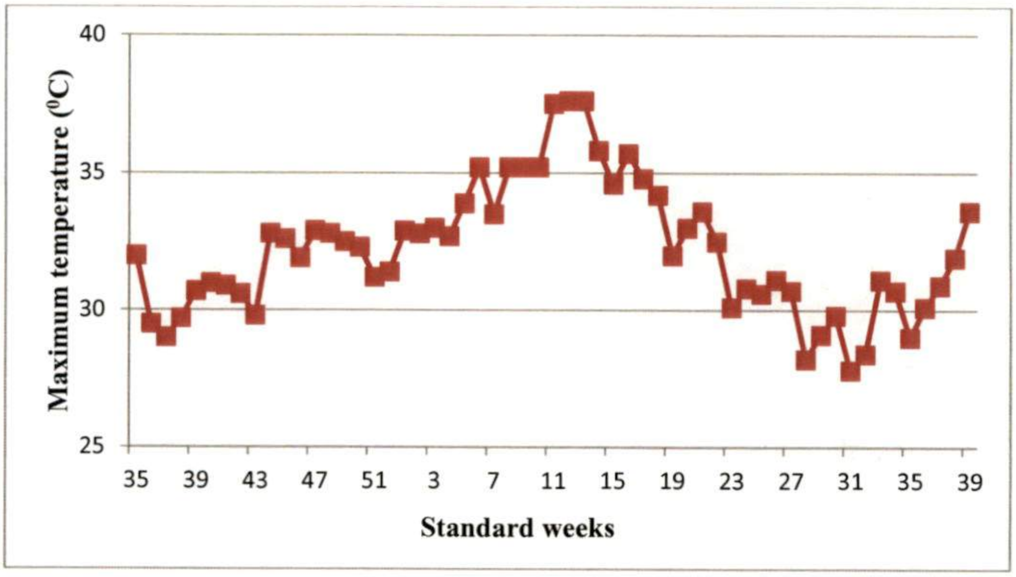

Fig. (a)Maximum temperature

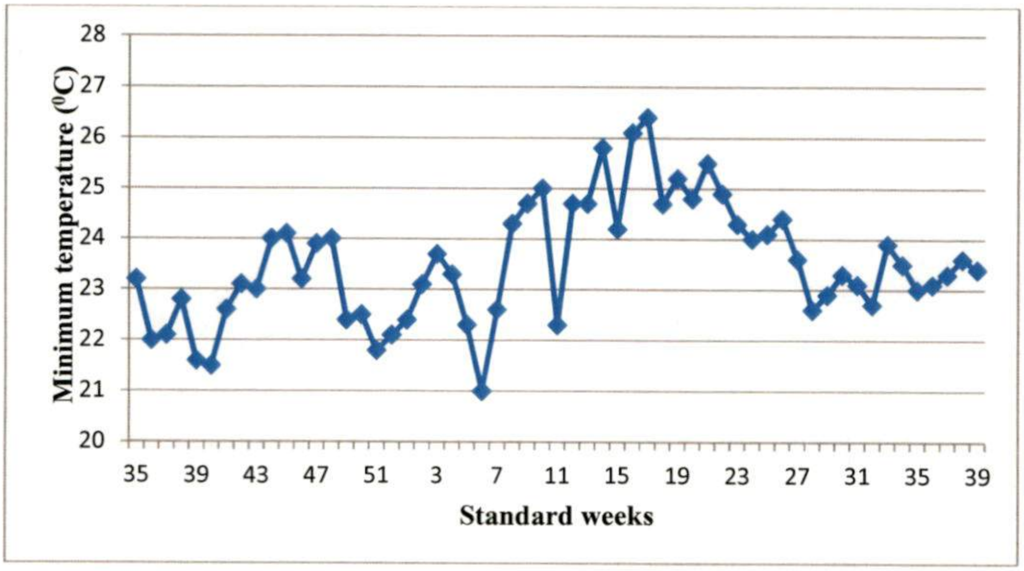

Fig. (b) Minimum temperature

Fig. 3.1. Weekly weather parameters during the experiment

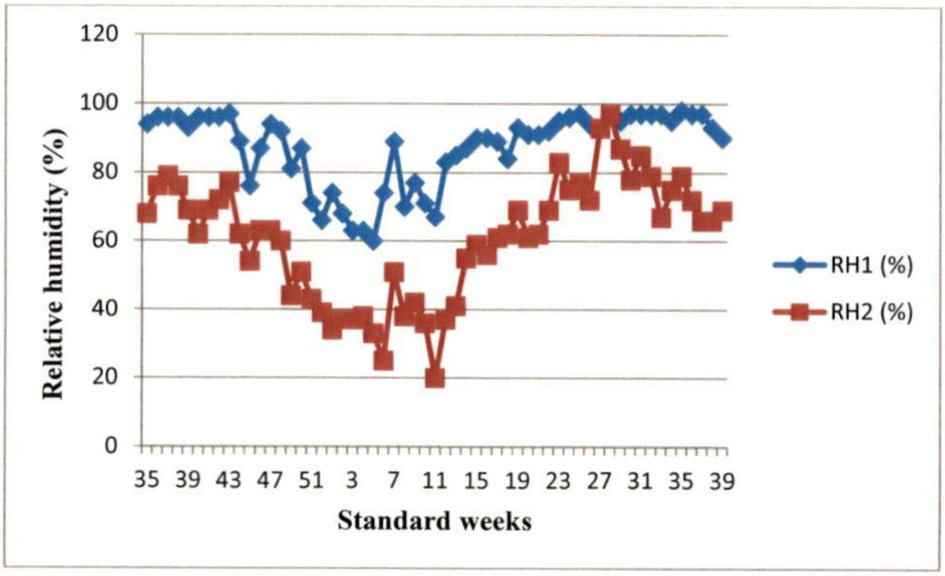

Fig. (c) Relative Humidity

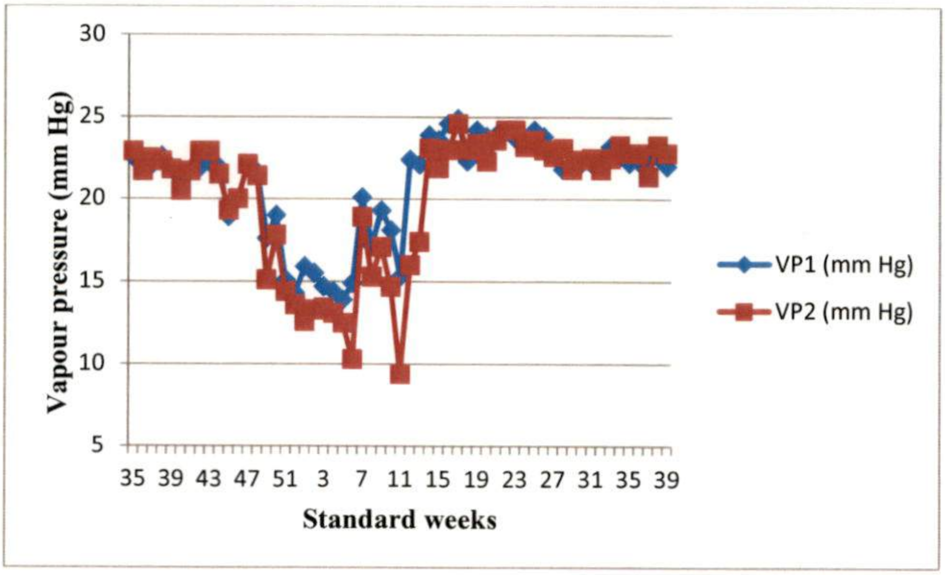

Fig. (d) Vapour Pressure

Fig. 3.1. Weekly weather parameters during the experiment (contd.)

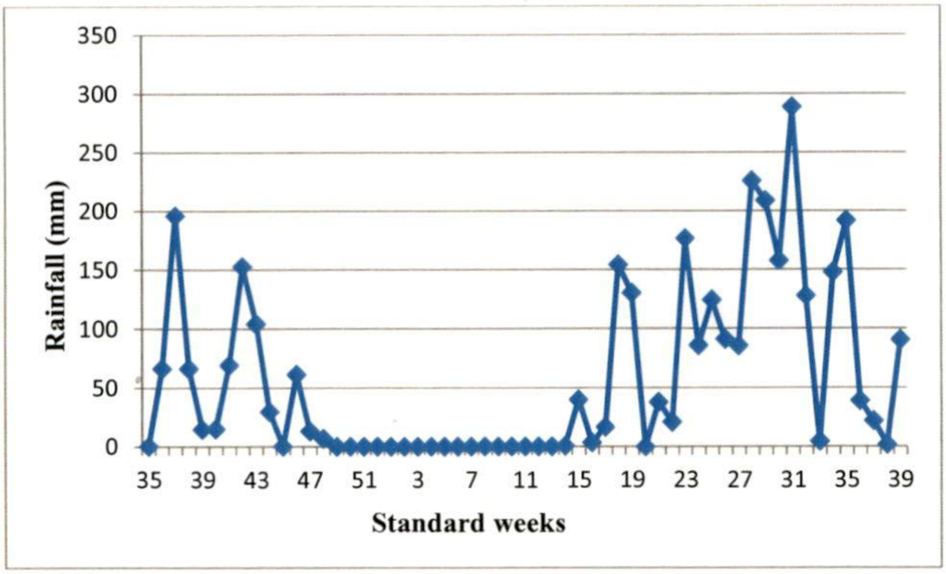

Fig. (e) Rainfall

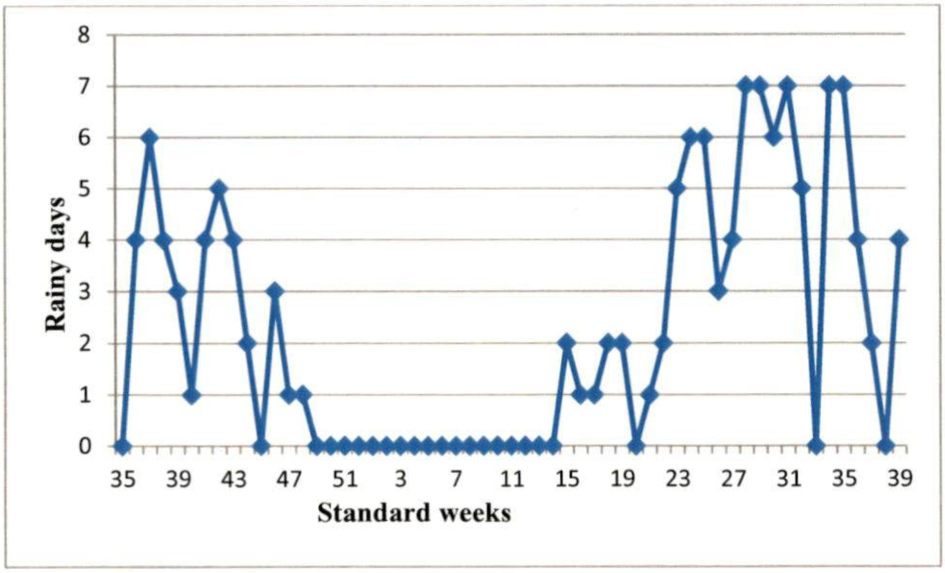

Fig. (f) Rainy Days

Fig. 3.1. Weekly weather parameters during the experiment (contd.)

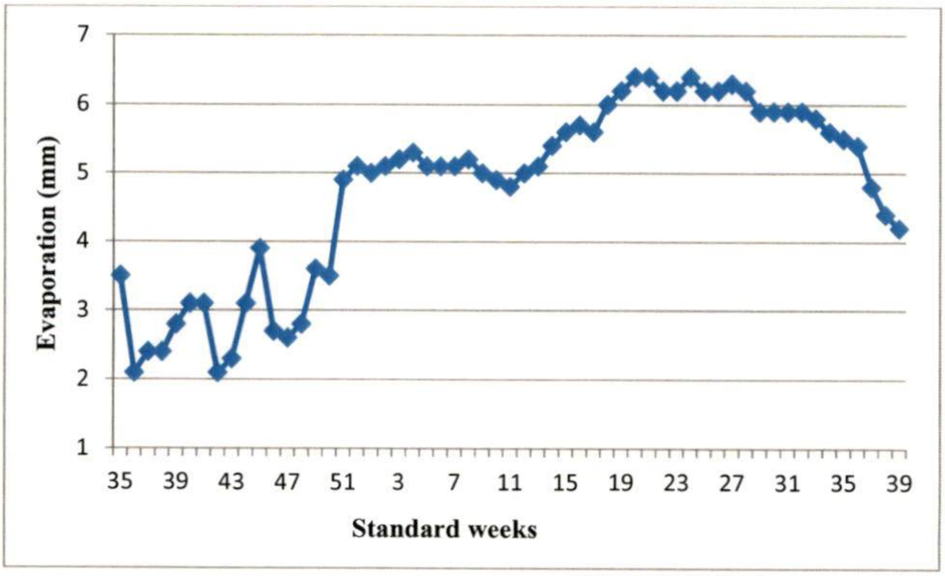

Fig. (g) Evaporation

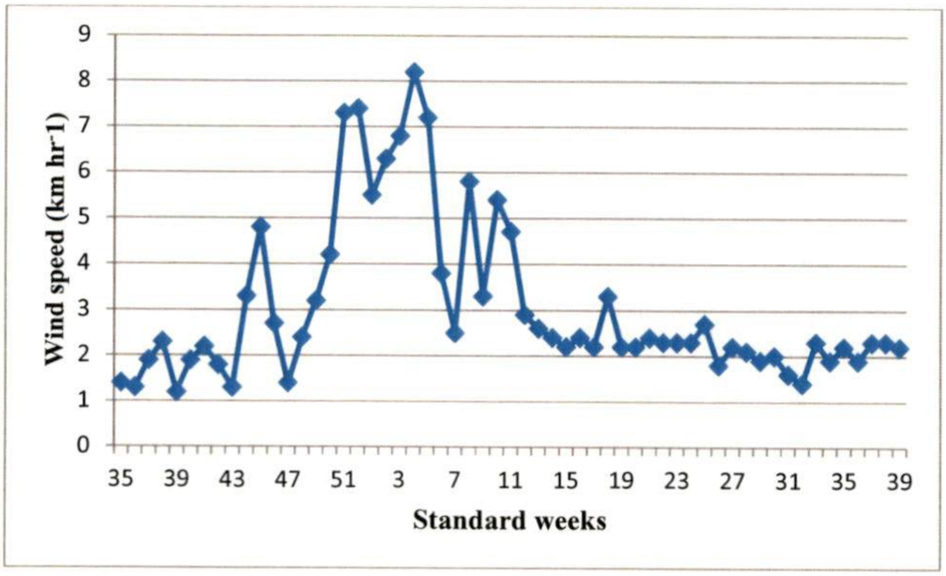

Fig. (h) Wind speed

Fig. 3.1. Weekly weather parameters during the experiment (contd.)

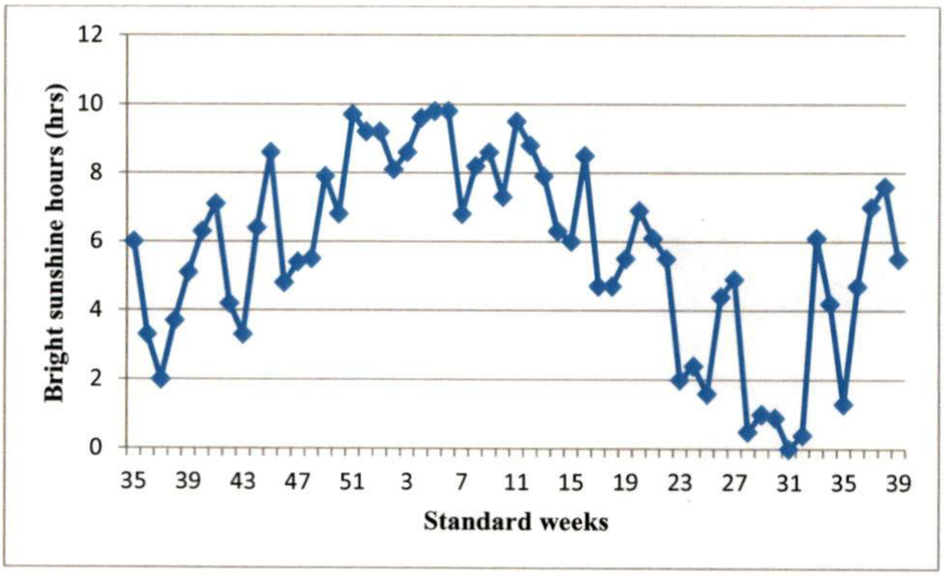

Fig. (i) Sunshine Hours

Fig. 3.1. Weekly weather parameters during the experiment

3.2. EXPERIMENTAL MATERIALS AND METHODS

3.2.1. Variety

The yard long bean variety lola is selected for the experiment. It is a high yielding variety developed by the Kerala Agricultural University and is popular among the farmers of Kerala. Yard long bean is a warm season vegetable and can be grown throughout the year under Kerala conditions. It is a vigorous climbing annual which grows up to a height of three to four meters and produces very long, slender and succulent pods which may be white, light green, dark green or brownish red in colour.

3.2.2. Design and layout

The experiment was laid out in Randomized Block Design (RBD) with three replications. (Fig.3.1). There were 36 plots in the field with a plot size of 25 m^2 accomodating 40 plants per treatment at spacing of 1m x 0.5 m.

3.2.3. Treatment

The treatment comprises of twelve dates of sowing at monthly intervals from September 2013 to August 2014. The treatments are explained in Table 3.2

Table 3.2. Treatments used in the experiment

Treatment	**Sowing time**
D1	September
D2	October
D3	November
D4	December
D5	January
D6	February
D7	March

R1	R2	R3
T2	T4	T1
T5	T3	T6
T4	T2	T5
T1	T6	T4
T3	T5	T2
T6	T1	T3
T8	T10	T7
T11	T9	T12
T10	T8	T11
T7	T12	T10
T9	T11	T8
T12	T7	T9

Fig 3.2. Layout of the field experiment

Plate 3.1. General view of experimental plot

Plate 3.2. (a) Seedling stage

Plate 3.2. (b) Harvested pods

D8	April
D9	May
D10	June
D11	July
D12	August

3.3. CROP MANAGEMENT

The cultural and manurial practices are followed as per the package of practices recommendations of KAU (2011).

3.3.1. Land preparation and Sowing

The land is ploughed three times thoroughly and the weeds and stubbles are removed. Channels at 15 cm depth and 30cm width are made to drain off excess water and the seeds are sown.

3.3.2. Fertilizers and manures

Lime (250 kg ha^{-1}) is applied at the time of the first ploughing. Nitrogen (10 kg ha^{-1}), phosphorus (30 kg ha^{-1}) and potash (10 kg ha^{-1}) is applied at the time of final ploughing. Second dose of nitrogen (10 kg ha^{-1}) is applied 15 days after sowing.

3.3.3. After cultivation

The plots are hand weeded at weekly intervals. Hoeing is done at the time of application of second dose of nitrogen. Pests and diseases are controlled by recommended plant protection measures.

3.4. OBSERVATIONS

The biometric and yield observations were recorded from eight observational plants leaving the border rows. Phenological observations such as days to seedling emergence, days to 50% flowering, days to first harvest, days to 50% pods with fully developed seeds and days to last harvest were noted from all experimental plots.

3.4.1. Biometric observations

3.4.1.1. Plant height

The height of the plant was measured from the ground level to the tip of the main vine at fortnightly intervals.

3.4.1.2. Bio mass

One plant from each plot was uprooted at fortnightly intervals. The various plant parts like leaves, stem and root were separated and weighed to record the fresh weight. The samples were then placed in a hot air oven at 80°C to dry to a constant weight. Biomass was recorded in grams per plant.

3.4.2. Phenological observations

3.4.2.1. Days to seedling emergence

The number of days taken from sowing to emergence of seedlings in each plot was recorded.

3.4.2.2. Days to 50% flowering

The number of days taken from sowing to flowering of 50% of the plants in each plot was recorded.

3.4.2.3. Days to 50% pods with fully developed seeds

The number of days taken from sowing to full maturity of the seeds of 50% of the pods in each plot was recorded.

3.4.2.4. Days to first harvest

The number of days taken from sowing to the first harvest of the fruits at vegetable maturity in each plant was recorded.

3.4.2.5. Number of harvests

The total number of harvest conducted in each plot was recorded.

3.4.3. Yield observations

3.4.3.1. No of pods per plant

The numbers of pods obtained from observational plants in each harvest were recorded.

3.4.3.2. No of seeds per pod

The number of seeds of all the pods harvested from the observational plants was recorded and the mean was worked out.

3.4.3.3. Hundred Seed weight (g)

The weight of hundred randomly selected seeds from each plot was recorded.

3.4.3.3. Length of pod (cm)

The length of all the individual pods harvested from each observational plant was recorded and the mean was worked out.

3.4.3.4. Pod yield/ plant (kg)

The weights of pods from each observational plant were recorded after each harvest. The total weight of pods of each observational plant was calculated and recorded.

3.4.3.5. ***Pod yield/ plot (kg)***

The weight of pods from the plot was recorded after each harvest. The total weight was calculated and recorded.

3.4.4. Soil data

Soil samples were collected from the experimental plot from 5cm, 15cm and 30 cm depth. The samples were then dried separately and respective samples were analyzed for available nitrogen, available phosphorous, available potassium and organic carbon content. The results of soil analysis are presented in Table 3.3.

Table 3.3. Chemical properties of the soil

Sl .No	Parameter	Sampling depth in cm		
		0-5	5-15	15-30
1	Organic carbon (%)	0.81	0.85	1.02
2	Available Phosphorous (kg/ha)	31	53	44
3	Available Potasium (kg/ha)	193	148	147
4	Available Nitrogen (kg/ha)	290	308	336
5	pH	4.8	4.7	4.8
6	EC (Ds/m)	0.08	0.14	0.07

3.4.5. Monitoring of major pests and diseases

The incidence of pests and diseases during the life cycle of crops of all treatments were observed and recorded.

3.4.6. Weather observations

The daily weather data on maximum and minimum temperatures, forenoon and afternoon relative humidity, rainfall and number of rainy days, bright sunshine hours, wind speed and vapour pressure for the entire crop duration were collected from the Principal Agromet Station of the College of Horticulture, Vellanikkara. Soil thermometers were installed in the experimental plot and the observations were recorded. The different weather parameters used in the study are described in Table 3.4

Table 3.4. Weather parameters used in the experiment

Sl. No.	**Weather parameter**	**Unit**
1	Maximum temperature	°C
2	Minimum temperature	°C
3	Mean temperature	°C
4	Diurnal Temperature Range	°C
5	Forenoon relative humidity	%
6	Afternoon relative humidity	%
7	Forenoon vapour pressure	mm Hg
8	Afternoon vapour pressure	mm Hg
9	Rainfall	mm
10	Rainy days	days
11	Bright sunshine	hrs
12	Wind speed	km hr^{-1}
13	Soil temperature	°C

RESULTS

4. RESULTS

The results obtained from the study on "Crop weather relationship of Yard long bean (*Vigna unguiculata* subsp. *Sesquipedalis* (L.) Walp)" are presented below.

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4.1. WEATHER CONDITIONS EXPERIENCED BY THE CROP

The weather conditions experienced by the crop during the different growth stages of the crop in each date of sowing are presented below.

4.1.1. Weather conditions experienced by the crop from date of sowing to 50% flowering

The various weather parameters experienced by the crop from sowing to 50% flowering are presented in Table 4.1.

4.1.1.1. Surface temperature, relative humidity and vapour pressure

The average maximum temperature from date of sowing to 50% flowering ranged from 29.1°C to 36°C. The highest average maximum temperature was observed in March 2013 planting and the lowest was observed in July 2014. The minimum temperature ranged from 22.2°C to 25.4°C. The lowest minimum temperature was recorded during September 2013 and the highest minimum temperature during April 2014 planting. The DTR was found to be highest in February 2014 and lowest in July 2014 which ranged from 6.1°C to 12.1°C. The forenoon relative humidity ranged from 70 % to 97 %. The highest forenoon relative humidity was observed during August 2014 and lowest relative humidity was observed during January 2014. The highest afternoon relative humidity (80%) was recorded during July 2014 and the lowest (35%) was recorded during February 2014. The forenoon vapour pressure was observed lowest in January 2014 and was observed highest in April 2014 ranging from 15.7 mm Hg to 23.9 mm Hg. The afternoon vapour pressure was observed highest in May and June 2014 (23.4 mm Hg) and lowest during January 2014 (13.7 mm Hg).

4.1.1.2. Rainfall and Rainy Days

The crops sown during January and February 2014 received no rainfall and the highest rainfall of 1087.7 mm during the experiment period was recorded in July 2014 planting. No rainy days were recorded for the crops sown during December 2013 to February 2014.

4.1.1.3. Wind Speed

The wind speed ranged from 1.8 to 5.6 km hr^{-1} during the experiment period and the high wind speed was recorded in December 2013 and January 2014 planting while the lowest during September 2013 planting.

4.1.1.4. Bright Sunshine hours

The crops sown during January 2014 received more BSS hours and those sown during July 2014 received the least BSS hours. The values of BSS hours ranged from 1.6 to 8.7 hrs.

4.1.1.5. GDD

The average GDD ranged from 661.7 to 1167.2. The highest was recorded in March sowing and the lowest in October planting.

4.1.1.6. Soil temperature

The average forenoon soil temperature at 5cm ranged from 24.6°C to 30.3°C, the highest in March 2014 sowing and the lowest during December 2013 sowing, while the lowest at 10cm forenoon was observed in December 2014 sowing and the highest in March 2014 sowing. The lowest average afternoon soil temperature at 5cm (31.3°C)

Table.4.1. Weather conditions experienced by the crop from date of sowing to 50% flowering

		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
Tmax(^oC)		30.3	31.2	32.4	32.2	33.5	35.6	36.0	34.3	32.4	30.4	29.1	29.8
Tmin (^oC)		22.2	23.0	23.3	22.5	22.7	23.5	24.9	25.4	24.8	24.0	23.1	23.2
DTR(^oC)		8.1	8.2	9.1	9.7	10.8	12.1	11.2	9.0	7.6	6.4	6.1	6.6
RH1 (%)		95	92	85	75	70	75	82	89	92	95	96	97
RH2 (%)		72	66	55	42	37	35	45	60	69	77	80	74
VP1(mm Hg)		21.9	21.4	19.7	16.4	15.7	17.9	21.5	23.9	23.6	23.4	22.2	22.5
VP2(mm Hg)		22.0	21.5	19.0	14.7	13.7	14.4	18.5	23.2	23.4	23.4	22.4	22.4
RF(mm)		568.2	371.0	82.5	0.5	0.0	0.0	58.8	345.4	579.9	765.6	1087.7	724.1
RD		26.0	16.0	5.0	0.0	0.0	0.0	4.0	8.0	17.0	32.0	37.0	31.0
WS(km hr^{-1})		1.8	2.5	3.4	5.6	5.6	4.2	3.1	2.4	2.3	2.2	2.0	2.0
BSS (hrs)		4.6	5.9	6.7	8.3	8.7	8.5	7.5	6.1	4.8	2.7	1.6	3.5
GDD(^oC day)		764.2	661.7	827.4	699.8	908.7	1038.0	1167.2	1036.5	843.8	729.8	710.0	759.0
Soil Temp (	5cm	27.5	27.1	26.1	24.6	26.2	28.7	30.3	29.9	28.6	26.6	25.7	26.0
	10cm	28.2	28.3	27.0	25.4	27.0	29.2	30.6	30.0	28.8	27.0	25.5	26.0
	5cm	32.5	33.7	34.6	37.8	40.3	43.4	43.6	40.3	36.4	32.8	31.3	32.9
	10cm	31.4	31.9	32.6	33.8	35.1	37.1	38.2	36.9	33.9	31.1	29.5	30.5

D1- September
D2- October
D3- November
D4- December

D5- January
D6- February
D7- March
D8- April

D9- May
D10- June
D11- July
D12- August

depth was recorded in July 2014 sowing and the highest in March 2014 sowing (43.6°C). The average afternoon temperature at 10cm depth ranged from 30.5°C to 38.2°C, the highest in March 2014 sowing and the lowest in August 2014 sowing.

4.1.2. Weather conditions experienced by the crop from 50% flowering to first harvest

The various weather parameters experienced by the crop from 50% flowering to first harvest is presented in Table 4.2.

4.1.2.1. Surface temperature, relative humidity and vapour pressure

The crops sown during February 2014 experienced the highest maximum temperature (39.3°C) and those sown during May 2014 experienced the lowest maximum temperature (30.6°C). The lowest minimum temperature (22.7°C) was observed in the case of November 2014 planting and the highest (25.8 °C) was observed for April 2014 planting. The forenoon relative humidity ranged from 64.7 % to 96.6 %. The highest and the lowest forenoon relative humidity were recorded in May 2014 and December 2013 plantings respectively. The highest afternoon relative humidity (84.6 %) was recorded in June 2014 planting and the lowest (35 %) in February 2014 planting. The forenoon vapour pressure ranged from 14.9 mm Hg to 24.3 mm Hg. The highest was recorded in May 2014 planting and was low in November and December 2014 planting. The afternoon relative humidity was highest (23.8 mm Hg) in April 2014 planting and the lowest (13.6 mm Hg) was recorded in December 2013 planting.

4.1.2.2. Rainfall and Rainy Days

The crops sown during January 2014 to April 2014 received no rainfall and the crops sown during May 2014 received more rainfall (253.2 mm). No rainy days were recorded in November 2013 to April 2014 sowings.

Table.4.2. Weather parameters experienced by the crop from 50% flowering to first harvest

		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
Tmax(^oC)		30.9	32.4	31.4	33.0	35.5	39.3	35.3	33.4	30.6	29.3	31.7	32.7
Tmin (^oC)		23.3	23.6	22.7	23.5	23.9	24.6	25.6	25.8	24.2	22.8	24.1	23.6
DTR(^oC)		7.6	8.9	8.7	9.5	11.6	14.8	9.7	7.7	6.4	6.5	7.7	9.1
RH1 (%)		96.0	88.6	67.7	64.7	67.0	84.5	86.0	88.5	96.6	95.1	94.5	91.0
RH2 (%)		72.8	61.5	43.9	37.3	35.5	35.0	57.8	60.5	77.3	84.6	69.2	66.5
VP1(mm Hg)		22.2	20.8	14.9	14.9	15.7	21.6	23.8	22.7	24.3	21.9	23.1	22.5
VP2(mm Hg)		22.6	20.5	15.0	13.6	14.5	15.1	23.4	23.8	23.6	22.0	23.7	22.9
RF(mm)		132.4	73.5	1.2	0.5	0.0	0.0	0.0	0.0	253.2	54.3	43.5	1.4
RD		7.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	8.0	2.0	0.0
WS(km hr^{-1})		1.5	2.3	8.2	6.8	7.7	2.9	2.8	2.3	2.7	2.1	2.2	2.3
BSS (hrs)		4.4	5.5	9.4	8.9	9.4	9.7	7.8	6.6	1.4	1.3	6.0	7.4
GDD(^oC day)		192.9	220.9	112.2	172.1	37.4	63.9	77.8	37.2	131.2	120.3	101.5	137.2
Soil Temp (^oC)	5cm	26.8	26.9	24.1	25.9	27.8	30.2	30.4	35.8	26.9	25.3	27.1	26.5
	10cm	27.4	27.8	25.1	26.9	28.7	30.6	29.5	33.5	26.9	25.2	27.3	26.9
	5cm	31.8	32.3	37.8	39.6	43.4	47.5	43.3	34.8	31.9	30.9	36.4	38.0
	10cm	30.6	29.5	33.6	34.6	35.0	39.9	39.3	32.9	30.0	29.0	32.3	34.3

D1- September
D2- October
D3- November
D4- December

D5- January
D6- February
D7- March
D8- April

D9- May
D10- June
D11- July
D12- August

4.1.2.3. Wind Speed

The wind speed ranged from 1.5 to 8.2 km hr^{-1}. The highest wind speed was recorded in November 2014 and the lowest in September 2013.

4.1.2.4. Bright Sunshine Hours

The crop sown during February 2014 received more BSS hours (9.7 hrs) and June 2014 sown crops received the lowest (1.3 hrs).

4.1.2.5. GDD

The average GDD ranged from 37.2 to 220.9. The highest was recorded in October 2013 sowing and the lowest in April 2014 sowing.

4.1.2.6. Soil temperature

The average forenoon soil temperature at 5cm ranged from 24.1°C to 35.8°C and at 10cm depth ranged from 25.1°C to 33.5°C, at 5cm lowest was recorded in November 2013 sowing and the highest in April 2014 sowing. The average afternoon soil temperature at 5cm depth was highest (47.5°C) in February 2014 sowing and lowest (30.9°C) in June 2014 sowing. At 10cm depth the soil temperature during afternoon ranged from 29.0°C to 39.9°C, the highest in February 2014 sowing and the lowest in June 2014 sowing.

4.1.3. Weather parameters experienced by the crop from first harvest to 50% pods with fully developed seeds

The various weather parameters experienced by the crop from first harvest to 50% pods with fully developed seeds is presented in Table 4.3.

4.1.3.1. Surface temperature, relative humidity and vapour pressure

The average maximum temperature ranged from 28.7°C to 35.8°C, the highest was recorded in January 2014 planting and the lowest was recorded in June 2014 planting. The DTR was found to be high (12°C) in December 2013 planting and low (5.6°C) in June 2014 planting. The forenoon relative humidity was recorded more (97.2%) in June and July 2014 plantings and the lowest (66.8%) was recorded in December 2013 planting. The afternoon relative humidity ranged from 32.3% to 81%, the highest was recorded in June 2014 planting and the lowest in December 2013 planting. The forenoon vapour pressure ranged from 14.6 mm Hg to 23.9 mm Hg. December planting recorded the lowest while, February planting recorded the highest. The afternoon vapour pressure was observed highest (23.9 mm Hg) in April 2014 planting and the lowest was recorded (11.9 mm Hg) in December 2013 planting.

4.1.3.2. Rainfall and rainy days

The crops sown during November 2013, December 2013 and January 2014 received no rainfall and those sown during June 2014 received the highest (572.4 mm). There were no rainy days during November 2013, December 2013 and January 2014 sowing.

4.1.3.3. Wind speed

The average wind speed ranged from 1.7 km hr^{-1} to 8.5 km hr^{-1}. The highest wind speed was recorded in January 2014 sowing and June 2014 sowing.

4.1.3.4. Bright Sunshine Hours

The crops sown during December 2013 received more bright sunshine hours (9.3 hrs) and those sown during June 2014 received the lowest (0.5 hrs).

4.1.3.5. GDD

GDD was obtained highest in February 2014 sowing and lowest in May 2014 sowing ranging from 183.6 to 487.2.

4.1.3.6. Soil temperature

The average forenoon soil temperature at 5cm ranged from 25.1 °C in December 2013 sowing to 30 °C in March 2014 sowing and at 10cm depth, temperature ranged from 25.1 °C to 30.3 °C , lowest from June 2014 sowing and highest from February 2014 sowing. The average afternoon soil temperature ranged from 32.7 °C to 43.7 °C at 5cm depth and at 10cm depth, temperature ranged from 30.5 °C to 38.4 °C, lowest from July 2014 sowing and highest from February 2014 sowing.

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Table.4.3.Weather parameters experienced by the crop from first harvest to 50% pods with fully developed seeds

		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
Tmax(°C)		32.3	32.6	32.2	34.1	35.8	35.4	32.9	31.2	31.1	28.7	29.9	32.3
Tmin (°C)		23.8	23.8	22.4	22.1	24.2	25.5	25.0	24.5	24.3	23.0	23.1	23.8
DTR(°C)		8.5	8.8	9.8	12.0	11.6	9.9	7.9	6.7	6.8	5.6	6.7	8.5
RH1 (%)		81.4	87.3	69.7	66.8	71.5	88.1	90.3	94.1	93.6	97.2	97.2	93.7
RH2 (%)		58.5	56.8	37.1	32.3	33.0	56.3	64.5	75.1	71.7	81.0	74.4	69.3
VP1(mm Hg)		19.8	20.4	15.2	14.6	17.7	23.9	23.5	23.8	23.6	22.1	22.3	22.7
VP2(mm Hg)		19.8	19.6	13.2	11.9	13.8	22.6	23.1	23.9	22.9	22.2	22.7	23.1
RF(mm)		62.5	7.4	0.0	0.0	0.0	44.2	284.4	322.6	109.3	572.4	346.4	232.9
RD		3.0	1.0	0.0	0.0	0.0	3.0	4.0	15.0	5.0	18.0	17.0	13.0
WS(km hr^{-1})		4.1	2.7	6.5	6.0	8.5	6.9	2.4	2.3	2.0	1.7	2.0	4.1
BSS (hrs)		6.7	5.8	8.8	9.3	8.5	6.9	5.4	3.3	4.8	0.5	3.7	4.8
GDD (°C day)		289.9	206.5	244.6	290.1	418.3	487.2	431.3	388.2	183.6	297.2	325.8	358.1
Soil Temp (°C)	5cm	27.2	26.9	25.6	25.1	27.0	29.1	30.0	29.2	28.1	26.1	25.9	26.2
	10cm	27.1	26.7	25.5	26.6	29.7	30.3	29.4	27.4	26.8	25.1	26.0	26.7
	5cm	32.7	32.7	38.3	40.1	43.7	42.8	37.2	34.2	34.5	30.8	32.8	34.4
	10cm	32.0	31.6	253.8	34.7	37.4	38.4	34.5	31.8	31.9	28.5	30.5	31.8

D1- September
D2- October
D3- November
D4- December

D5- January
D6- February
D7- March
D8- April

D9- May
D10- June
D11- July
D12- August

4.1.4. Weather parameters experienced by the crop from sowing to last harvest

The various weather parameters experienced by the crop from sowing to last harvest is presented in Table 4.4.

4.1.4.1. Surface temperature, relative humidity and vapour pressure

The average maximum temperature ranged from 29.8°C to 35.3°C. The highest temperature was recorded in February planting and the lowest in July planting. The lowest minimum temperature (22.8°C) was recorded in September 2013 planting and the highest minimum temperature (24.8°C) was observed in March and April 2014 planting. The DTR values ranged from 6.3 °C to 11.3°C and it was found to be highest during January and lowest during June planting. The forenoon relative humidity ranged from 73% to 96 % and the afternoon relative humidity ranged from 38% to 76%. The highest forenoon relative humidity was observed in June 2014 planting and the lowest in December 2013 planting. The lowest afternoon relative humidity was observed in January 2014 and the highest in June 2014 planting. The morning vapour pressure ranged from 16.6 mm Hg to 23.7 mm Hg and it was highest in April 2014 planting and lowest in December 2013 planting. The highest afternoon vapour pressure (23.3 mm Hg) was recorded in April 2014 planting and the lowest (14.5 mm Hg) in December 2013 planting.

4.1.4.2. Rainfall and rainy days

The crops sown during December 2013 received less rainfall (1mm) and there were no rainy days during this period whereas those sown during June 2014 received the maximum rainfall (1633.5 mm) and those sown during June 2014 received more number of rainy days (62).

4.1.4.3. Wind speed

The maximum wind speed (5.3 km hr^{-1}) was recorded during December 2013 and low wind speed (2 km hr^{-1}) was observed during July 2014.

Table.4.4.Weather parameters experienced by the crop from sowing to last harvest

		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
Tmax(^oC)		31.3	31.8	32.7	33.6	34.9	35.3	34.3	32.6	31.2	30.0	29.8	30.9
Tmin (^oC)		22.8	22.9	22.9	23.0	23.6	24.4	24.8	24.8	24.2	23.6	23.2	23.4
DTR(^oC)		8.5	8.9	9.8	10.7	11.3	10.9	9.4	7.8	7.0	6.3	6.6	7.4
RH1 (%)		91	85	76	73	74	81	87	92	93	96	95	95
RH2 (%)		65	56	45	39	38	46	57	67	73	78	76	72
VP1(mm Hg)		21.0	19.4	17.3	16.6	17.8	20.5	22.5	23.7	23.2	22.9	22.3	22.4
VP2(mm Hg))		20.8	18.9	16.0	14.5	15.1	18.2	20.9	23.3	23.1	22.9	22.5	22.6
RF(mm)		796.4	452.3	82.5	1	40.7	345.4	776.6	1105.0	1437.8	1633.5	1492.3	1018.8
RD		38.0	21.0	5.0	0.0	2.0	8.0	25.0	40.0	50.0	62.0	57.0	48.0
WS(km hr^{-1})		2.4	3.7	4.9	5.3	4.7	3.4	2.8	2.3	2.3	2.1	2.0	2.1
BSS (hrs)		5.4	6.7	8.0	8.5	8.4	7.5	6.1	4.7	3.5	2.5	3.1	4.2
GDD(^oC day)		1751.1	1636.0	1815.8	1901.7	1859.8	1918.6	2095.7	1860.8	1504.2	1343.1	1334.0	1420.9
Soil Temp (^oC)	5cm	26.6	26.0	25.7	26.4	28.0	29.3	29.4	28.6	27.4	26.2	25.9	26.1
	10cm	27.3	27.0	26.6	27.1	28.7	29.5	29.6	28.7	27.5	26.3	25.9	26.3
	5cm	33.1	34.7	37.2	40.3	42.4	42.1	40.0	37.0	34.3	32.5	32.7	33.8
	10cm	31.7	32.1	33.6	35.2	36.6	37.1	36.0	34.2	32.1	30.3	30.4	31.0

D1- September
D2- October
D3- November
D4- December

D5- January
D6- February
D7- March
D8- April

D9- May
D10- June
D11- July
D12- August

4.1.4.4. Bright Sunshine Hours

The bright sunshine hours ranged from 2.5 hrs to 8.5 hrs. The highest was observed during December 2013 planting and the lowest during June 2014 planting.

4.1.4.5. GDD

The average GDD ranged from 1334 to 2095.4, highest was obtained in March 2014 sowing and lowest in July 2014 sowing.

4.1.4.6. Soil temperature

Soil temperature at 5cm depth ranged from 25.7°C to 29.4°C at forenoon and at 10cm ranged from 25.9°C to 29.6°C. The lowest soil temperature at 5cm depth was recorded in November 2013 sowing and the highest in March 2014 sowing. The average afternoon soil temperature at 5cm depth ranged from 32.5 °C to 42.4 °C, highest was recorded in January 2014 sowing and the lowest in June 2014 sowing. At 10cm depth in the afternoon temperature ranged from 30.3 °C to 37.1 °C, the highest was recorded in February 2014 sowing and the lowest in June 2014 sowing.

4.2. BIOMETRIC OBSERVATIONS

4.2.1. Plant height

Analysis of Variance was done for plant height at fortnightly intervals (up to sixth fortnight), and the results are presented in Appendix II- page iii and it was found that date of sowing had a significant effect on plant height on all fortnights. The analysis between dates of planting for plant height at different weeks after sowing is provided in Table 4.5.

4.2.1.1. Plant height at 15 DAS

Crop sown during October (23.6cm) and December (23.4cm) were on par and recorded high plant heights at 15 DAS followed by November (21.08cm), January (20.50cm) and February (20.45cm) sown crops which were on par. Plant height at 15 DAS was observed low for April (10.08cm) and August (9.50cm) sown crops and these were on par.

4.2.1.2. Plant height at 30 DAS

October (66.31cm) and November (62.91cm) sown crops were on par and recorded high plant heights at 30 DAS which was followed by December (51.65cm), January (50.83cm) and February (50.62cm) sown crops which were on par and the plant heights of July (21.21cm), August (21.25cm), March (27.41cm) and May (21.74cm) sown crops were on par at 30 DAS and these recorded the low plant heights.

4.2.1.3. Plant height at 45 DAS

At 45 DAS plant height was observed high for October (177.58cm), November (161.95cm) and June (159.93cm) sown crops which were on par and was closely followed by December (152.91cm) sown crop. Plant height at 45 DAS was recorded low for March (66.10cm), April (68.96cm), May (70.40cm) and August (86.29cm) sown crops which were on par.

4.2.1.4. Plant height at 60 DAS

High plant height at 60 DAS were recorded for September (289.73cm), October (290.10cm) and December (274.87cm) sown crops which were on par and closely followed by November (261.37cm) sown crop whereas March (141.50cm), April (137.25cm) and August (131.21cm) sown crops were on par and recorded low plant heights.

4.2.1.5. Plant height at 75 DAS

October (430.00cm) and September (412.42cm) sown crops were on par and recorded high plant heights at 75 DAS which was closely followed by November (364.91cm) and December (378.58cm) sown crops and these were on par. Lowest plant height was observed for August (193.29cm) sown crop.

4.2.1.6. Plant height at 90 DAS

September (540.29cm) and October (550.20cm) crops recorded high plant heights and were on par followed by November (485.58cm) and December (487.75cm) sown crops and these were on par. Heights of March (287.58cm) and August (257.62 cm) sown crops were on par and these recorded low plant heights.

4.2.2. Biomass

Analysis of variance was done for biomass at fortnightly intervals (upto sixth fortnight) and are presented in Appendix- II- page . It was found that date of sowing had significant effect on biomass on all fortnights. Biomass at various time intervals for the different dates of sowing is given in Table 4.6.

4.2.2.1. Biomass at 15 DAS

The October (1.01g) sown crop recorded the highest biomass and July (0.39g) and August (0.52g) sown crops recorded low biomass and these were on par.

4.2.2.2. Biomass at 30DAS

April (12.72g) and May (12.92g) sown crops were on par and recorded high biomass whereas September (3.44g) sown crop recorded low biomass.

4.2.2.3. Biomass at 45 DAS

October (32.72g) sown crops recorded the highest biomass and the lowest was recorded by September (7.04g) sown crop.

4.2.2.4. Biomass at 60 DAS

At 60 DAS high biomass was recorded for October (35.10g) and June (34.50g) sown crops which were on par and September (11.08g) sown crop recorded the lowest.

4.2.2.5. Biomass at 75 DAS

October (57.14g) sown crop recorded the highest biomass at 75DAS and September (17.87g) and November (19.41g) sown crops were on par recording low biomass.

4.2.2.6. Biomass at 90 DAS

February (54.12g), October (53.53g) and January (52.03g) sown crops were on par recording high biomass and September (27.06g) and November (29.37g) sown crops recorded low biomass.

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Table.4.5. Effect of date of sowing on plant height (cm) at fortnightly intervals

Treatments	Weeks after sowing					
	2	4	6	8	10	12
D1	18.49^{c}	32.25^{cd}	128.37^{c}	289.73^{a}	412.41^{ab}	540.29^{a}
D2	23.58^{a}	66.30^{a}	177.58^{a}	290.00^{a}	430.00^{a}	550.20^{a}
D3	21.08^{b}	62.91^{a}	161.95^{ab}	261.37^{ab}	364.91^{bc}	485.58^{b}
D4	23.413^{a}	51.56^{b}	152.91^{abc}	274.87^{a}	378.58^{abc}	487.75^{b}
D5	20.50^{b}	50.83^{b}	132.83^{c}	233.20^{bc}	327.66^{cd}	428.24^{c}
D6	20.45^{b}	50.62^{b}	$135.5b^{c}$	218.66^{cd}	327.95^{cd}	429.29^{c}
D7	11.33^{de}	27.41^{d}	66.10^{d}	141.50^{f}	204.70^{gh}	287.58^{f}
D8	10.08^{e}	33.20^{cd}	68.96^{d}	137.25^{f}	227.95^{fgh}	307.91^{ef}
D9	10.66^{de}	21.74^{d}	70.40^{d}	167.71^{ef}	269.16^{ef}	351.37^{de}
D10	12.45^{d}	43.33^{bc}	159.93^{ab}	219.67^{cd}	$299.32d^{e}$	385.41^{cd}
D11	11.08^{de}	21.21^{d}	125.77^{c}	190.79^{de}	254.35^{efg}	299.63^{ef}
D12	9.50^{e}	21.25^{d}	86.29^{d}	131.21^{f}	193.29^{h}	257.62^{f}

Means bearing the same superscript do not differ significantly

D1- September
D2- October
D3- November
D4- December

D5- January
D6- February
D7- March
D8- April

D9- May
D10- June
D11- July
D12- August

Table.4.6. Effect of date of sowing on biomass at fortnightly intervals

Treatments	Weeks after sowing					
	2	4	6	8	10	12
D1	0.75^{bc}	3.44^{e}	7.04^{d}	11.08^{g}	17.87^{f}	27.06^{f}
D2	1.01^{a}	6.64^{c}	32.72^{a}	35.10^{a}	57.14^{a}	53.53^{ab}
D3	0.73^{bc}	3.87^{de}	8.34^{cd}	14.07^{fg}	19.41^{ef}	29.37^{f}
D4	0.72^{bc}	6.28^{c}	10.11^{cd}	14.88^{fg}	22.40^{e}	37.20^{e}
D5	0.75^{bc}	5.28^{cde}	10.19^{cd}	16.27^{efg}	21.99^{e}	52.03^{ab}
D6	0.63^{bc}	5.45^{cd}	12.46^{c}	21.22^{cde}	22.86^{e}	54.12^{a}
D7	0.83^{ab}	9.28^{b}	12.62^{c}	23.33^{cd}	27.79^{d}	43.33^{cd}
D8	0.70^{bc}	12.72^{a}	18.32^{b}	19.30^{def}	21.89^{e}	45.44^{cd}
D9	0.62^{bcd}	12.92^{a}	20.56^{b}	26.62^{bc}	35.71^{c}	39.94^{de}
D10	0.65^{bc}	10.27^{b}	19.80^{b}	34.50^{a}	38.41^{bc}	47.88^{bc}
D11	0.39^{d}	6.26^{c}	21.29^{b}	31.65^{ab}	41.25^{b}	52.09^{ab}
D12	0.52^{cd}	5.93^{c}	20.29^{b}	29.73^{ab}	38.33^{bc}	48.09^{abc}

Means bearing the same superscript do not differ significantly

D1- September
D2- October
D3- November
D4- December

D5- January
D6- February
D7- March
D8- April

D9- May
D10- June
D11- July
D12- August

4.3. PHENOLOGICAL OBSERVATIONS

Analysis of variance was performed for the phenological observations and are presented in Appendix II- page.It was found that date of sowing had high significant effects on days to 50% flowering, days to 50% pods with fully developed seeds, days to first harvest, days to last harvest and number of harvests.

4.3.1. Days to seedling emergence

There was no significant difference between dates of sowing and the days taken for seedling emergence.

4.3.2. Days to 50% flowering

Date of planting had significant effect on days to 50% flowering in yard long bean. March (60.00) sown crops more number of days for 50% flowering and December (44.60) and June (45.37) took less number of days.

4.3.3. Days to 50% pods with fully developed seeds

March (88.00) sown crops took more number of days and the least was observed for October (66.00) sown crop.

4.3.4. Days to first harvest

March (63.70) and September (61.70) sown crops took more number of days for commencation of harvest whereas October (54.00), June (53.00) and July (53.30) sown crops took only less number of days.

4.3.5. Days to last harvest

The crops sown during December 2013 (112.30) and March 2014 (113.00) took more number of days to last harvest which was followed by September 2013 sowing (108.70) and November (108.00). The least number of days (85.00) was recorded for the June 2014 planting.

4.3.6. Number of harvests

The October sown crops recorded more number of harvests (12.30) followed by September 2013 (11.00) and December 2013 (10.30) planting. March 2014 sown crops recorded the least number of harvests (6.30).

Table.4.7. Effect of sowing dates on phenological observations with respect to different sowing dates

Dates of sowing	Days to seedling emergence	Days to 50% flowering	Days to 50% pods with fully developed seeds	Days to first harvest	Days to last harvest	Number of harvests
D1	5.00	49.70^{c}	79.00^{cd}	61.70^{a}	108.70^{b}	11.00^{b}
D2	5.00	41.30^{g}	66.00^{h}	54.00^{def}	100.00^{e}	12.30^{a}
D3	4.00	48.70^{cd}	71.00^{g}	56.30^{bcd}	108.00^{b}	9.70^{bcd}
D4	5.00	44.60^{f}	74.00^{f}	55.30^{cdef}	112.30^{a}	10.30^{bc}
D5	5.00	53.30^{c}	77.00^{e}	55.30^{cdef}	101.70^{de}	8.00^{ef}
D6	6.00	56.00^{b}	83.00^{b}	58.00^{b}	102.30^{d}	7.30^{fg}
D7	6.00	60.00^{a}	88.00^{a}	63.70^{a}	113.00^{a}	6.30^{g}
D8	6.00	55.00^{bc}	80.00^{c}	57.00bc	104.70^{c}	7.30^{fg}
D9	6.00	48.00^{cd}	67.00^{h}	55.70^{bcde}	89.70^{f}	8.70^{def}
D10	5.00	45.37^{ef}	73.00^{f}	53.00^{f}	85.00^{h}	9.00^{cde}
D11	5.00	47.00^{de}	74.00^{f}	53.30^{ef}	85.70^{gh}	9.00^{cde}
D12	5.00	49.37^{c}	78.00^{de}	57.30^{bc}	88.00^{fg}	9.30^{cde}

4.4. YIELD OBSERVATIONS

The yield parameters recorded are summarized in Table.4.3.

4.4.1. No of pods per plant

The number of pods per plant was recorded high for the September 2013 (24.30) and October 2013 (24.50) sown crops. Low number of pods was recorded for May (12.05), July (11.90) and August (12.90) sown crops

4.4.2. *No of seeds per pod*

The crop sown during September (17.50) and October (17.70) recorded more number of seeds per pod and January (13.70), February (13.90), April (14.20), May (14.20) and June (13.30) sown crops recorded less number of seeds per pod.

4.4.3. Hundred Seed weight (g)

The hundred seed weight was recorded high for September (19.20) and October (19.85) sown crops followed by November (17.56) and April (17.50) sowings. It was recorded low (16.06) for February sown crops

4.4.4. Length of pod (cm)

The length of pods was observed more for September (45.40), October (45.10), November (45.30) and March (45.40) sown crops and was observed low for July (37.00) sown crop.

4.4.5. Pod yield/ plant (kg)

The September (0.40) and October (0.39) sown crops recorded high pod yield per plant and the low was recorded in May (0.18), July (0.18) and August (0.19) sown crops.

4.4.6. Pod yield/ plot (kg)

The September (24.40) and October (23.50) sown crops recorded high pod yield per plot. May (12.40) and July (12.97) sown crops recorded the low pod yield per plot.

Table.4.8. Effect of sowing dates on yield observations with respect to different sowing dates

Date of sowing	Number of pods per plant	Number of seeds per pod	Length of pods (cm)	Pod yield per plot (kg)	Pod yield per plant (kg)	Hundred seed weight (g)
D1	24.30^{a}	17.50^{ab}	45.40^{a}	24.40^{a}	0.40^{a}	19.20^{a}
D2	24.50^{a}	17.70^{a}	45.10^{a}	23.50^{ab}	0.39^{a}	19.85^{a}
D3	21.90^{b}	16.00^{bc}	45.30^{a}	21.20^{bcd}	0.34^{b}	17.56^{b}
D4	21.80^{b}	14.90^{cd}	42.90^{ab}	19.60^{cde}	0.33^{b}	17.30^{bcd}
D5	18.50^{c}	13.70^{e}	43.30^{ab}	17.20^{ef}	0.27^{c}	17.20^{bcd}
D6	18.40^{c}	13.90^{e}	43.80^{ab}	15.70^{fg}	0.26^{c}	16.16^{e}
D7	19.10^{c}	14.40^{cd}	45.40^{a}	18.00^{ef}	0.28^{c}	16.60^{cde}
D8	21.70^{b}	14.20^{e}	41.20^{bc}	21.80b^{c}	0.32^{b}	17.50^{bc}
D9	12.05^{d}	14.20^{e}	39.20^{cd}	12.40^{h}	0.18^{d}	16.40^{de}
D10	19.40^{c}	13.30^{e}	43.70^{ab}	18.90^{de}	0.28^{c}	16.70^{bcde}
D11	11.90^{d}	14.60^{cd}	37.00^{d}	12.97^{h}	0.18^{d}	16.70^{bcde}
D12	12.90^{d}	14.80^{cd}	44.20^{ab}	13.40^{gh}	0.19^{d}	16.50^{de}

D1- September
D2- October
D3- November
D4- December

D5- January
D6- February
D7- March
D8- April

D9- May
D10- June
D11- July
D12- August

4.5. MONITORING OF MAJOR PESTS AND DISEASES

Incidence of major pests and diseases of yard long bean were experienced in the experimental field during the course of investigation. There were variations in the pests and diseases observed during different planting times. The pests and diseases observed during the experimental period are presented in table 4.9.

Table.4.9. Major Pests and diseases observed in the field

Sl. No	Dates of planting	Pests	Diseases
1	September 1	Aphids, Pod borer, Pod bug	Mosaic
2	October 1	Aphids, Pod borer, Pod bug	Mosaic
3	November 1	Leaf miner	Rust, Mosaic
4	December 1	Aphids, Leaf miner	Rust, Mosaic
5	January 1	Aphids, Pod borer, Stem fly	Anthracnose
6	February 1	Aphids, Pod borer	Rust
7	March 1	Aphids, Pod borer	Mosaic
8	April 1	Aphids, Pod borer	Cercospora leaf spot
9	May 1	Pod fly, tussak caterpillar, Pod bug	Cercospora leaf spot
10	June 1	Tussak caterpillar, Aphids	Nil
11	July 1	Aphids, Pod borer	Nil
12	August 1	Pod borer	Anthracnose

4.6. CROP WEATHER RELATIONSHIPS

Simple linear correlations between weather elements and important growth and yield characters of yard long bean were worked out and are presented below.

4.6.1. Correlation between pod yield per plot and weather parameters at different growth stages of the crop

The results of the correlation analysis between weather parameters and pod yield per plot are presented in Table 5.0.

4.6.1.1. Days to 50% flowering

Positive correlation was found with maximum temperature, DTR and bright sunshine hours, while minimum temperature, relative humidity, forenoon vapour pressure, rainfall, GDD, evaporation and afternoon soil temperature at 5cm depth showed negative correlation, however these were not significant.

4.6.1.2. 6 Weeks after sowing

Bright sunshine hours showed significant positive correlation with pod yield per plot and rainy days exhibited significant negative correlation with pod yield per plot.

4.6.1.3. From 50% flowering to first harvest

Maximum temperature, Minimum temperature, DTR, relative humidity, vapour pressure, evaporation and soil temperature at 10cm depth showed negative correlation, while GDD showed significant positive correlation with pod yield per plot.

4.6.2. Correlation between pod yield per plant and weather parameters at different growth stages of the crop

The results of the correlation analysis between weather parameters and pod yield per plant are presented in Table 5.1.

4.6.2.1. Days to 50% flowering

Significant positive correlation was found with DTR, bright sunshine hours and forenoon soil temperature at 10cm depth while minimum temperature, afternoon relative humidity, forenoon vapour pressure, rainfall and rainy days showed significant negative correlation with pod yield per plant.

Table.5.0. Correlation between pod yield per plot and weather parameters

Crop stages	Tmax	Tmin	DTR	RH1	RH2	VP1	VP2	RF	EVP	BSS	WS	GDD	RD	Soil Temperature			
														FN		AN	
														5 cm	10 cm	5 cm	10 cm
S2	0.064	-0.183	0.164	-0.018	-0.070	-0.048	0.004	-0.312	-0.085	0.249	0.011	-0.079	-0.218	0.067	0.228	-0.049	0.064
S3	0.197	-0.097	0.223	-0.178	-0.187	-0.154	-0.068	-0.217	-0.046	0.394*	0.199	-0.066	-0.416*	0.058	0.149	0.012	0.119
S6	-0.150	-0.166	-0.104	-0.182	-0.081	-0.293	-0.139	0.102	-0.062	0.053	0.081	0.338*	0.118	0.071	0.099	-0.277	-0.237

Table.5.1. Correlation between pod yield per plant and weather parameters

Crop	Tmax	Tmin	DTR	RH1	RH2	VP1	VP2	RF	EVP	BSS	WS	GDD	RD	Soil Temperature			
														FN		AN	
														5 cm	10 cm	5 cm	10 cm
S2	0.092	-0.268**	0.240**	-0.113	-0.168*	-0.166*	-0.121	-0.373**	-0.001	0.322**	0.111	-0.079	-0.276**	0.012	0.175*	0.001	0.083
S3	0.268**	-0.123	0.299**	-0.272**	-0.288**	-0.254**	-0.182**	-0.322**	0.086	0.469**	0.296**	-0.168*	-0.483**	0.059	0.160*	0.088	0.169*
S6	-0.048	-0.182**	0.021	-0.247**	-0.185**	-0.341**	-0.241**	0.032	0.042	0.142*	0.134*	-0.019	0.054	0.020	0.074	-0.155*	-0.131

**- Significant at 1% level

*- Significant at 5% level

S2- Days to 50% flowering
S3-6 weeks after sowing
S6- From 50% flowering to first harvest

4.6.2.2. 6 Weeks after sowing

Maximum temperature, DTR, bright sunshine hours, wind speed and soil temperature at 10cm depth exhibited significant positive correlation and relative humidity, vapour pressure, GDD, rainfall and rainy days exhibited significant negative correlation with pod yield per plant.

4.6.2.3. From days to 50% flowering to first harvest

Bright sunshine hours and wind speed exhibited significant positive correlation with pod yield per plant while minimum temperature, relative humidity, vapour pressure and afternoon soil temperature at 10cm depth showed significant negative correlation with pod yield per plant.

4.6.3. Correlation between number of seeds per pod and weather parameters at different growth stages of the crop

4.63.1. Days to 50% flowering

Significant negative correlation with number of seeds per pod was obtained with GDD and minimum temperature, whereas DTR, Bright sunshine hours and relative humidity exhibited positive correlation with number of seeds per pod, however it was not significant.

4.6.3.2. 6 Weeks after sowing

BSS and wind speed exhibited significant positive correlation with number of seeds per pod while rainfall and rainy days exhibited significant negative correlation with number of seeds per pod.

4.6.3.3. From days to 50% flowering to first harvest

GDD exhibited significant positive correlation with number of seeds per pod while maximum temperature, minimum temperature and rainfall exhibited negative correlation with pod yield plant.

Table.5.2. Correlation between number of seeds per pod and weather parameters at different growth stages of the crop

Crop stages	Tmax	Tmin	DTR	RH1	RH2	VP1	VP2	RF	EVP	BSS	WS	GDD	RD	Soil Temperature			
														FN		AN	
														5 cm	10 cm	5 cm	10 cm
S2	-0.082	-0.194**	0.005	0.047	0.019	-0.040	0.000	-0.051	-0.109	0.050	-0.025	-0.168**	-0.026	-0.077	-0.018	-0.114	-0.093
S3	0.019	-0.010	0.021	-0.105	-0.069	-0.097	-0.050	-0.157*	0.021	0.171*	0.160*	-0.113	-0.174*	-0.037	-0.007	-0.061	-0.048
S6	-0.037	-0.127	0.011	-0.038	0-.056	-0.094	-0.077	-0.011	-0.052	0.053	-0.010	0.292**	0.024	-0.075	-0.038	-0.096	-0.086

Table.5.4. Correlation between number of pods per plant and weather parameters at different growth stages of the crop

Crop stages	Tmax	Tmin	DTR	RH1	RH2	VP1	VP2	RF	EVP	BSS	WS	GDD	RD	Soil Temperature			
														FN		AN	
														5 cm	10 cm	5 cm	10 cm
S2	0.166*	-0.208**	0.293**	-0.179**	-0.229**	-0.197**	-0.169*	-0.414**	0.079	0.363**	0.166*	-0.020	-0.327**	0.043	0.202**	0.079	0.153*
S3	0.322**	-0.084	0.327**	-0.333**	-0.331**	-0.287**	-0.222**	-0.314**	0.142*	0.464**	0.342**	0.078	-0.500**	0.099	0.196**	0.144*	0.220**
S6	0.012	0-.133	0.070	-0.275**	-0.224**	-0.347**	-0.274**	0.010	0.097	0.164*	0.154*	0.262**	0.017	0.066	0.118	-0.095	-0.080

**- Significant at 1% level

*- Significant at 5% level

S2- Days to 50% flowering

S3-6 weeks after sowing

S6- From 50% flowering to first harvest

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4.6.4. Correlation between number of pods per plant and weather parameters at different growth stages of the crop

The results of the correlation analysis between weather parameters and number of pods per plant are presented in Table 5.3.

4.6.4.1. Days to 50% flowering

Significant positive correlation with found with maximum temperature, BSS, DTR, wind speed and soil temperature at 10cm depth and number of pods per plant. Minimum temperature, relative humidity, vapour pressure, rainfall and rainy days exhibited negative correlation with number of pods per plant.

4.6.4.2. 6 Weeks after sowing

Maximum temperature, DTR, BSS, wind speed, evaporation and soil temperature at 10cm depth exhibited significant positive correlation with number of pods per plant, whereas relative humidity, vapour pressure, rainfall and rainy days exhibited significant negative correlation with number of pods per plant.

4.6.4.3. From days to 50% flowering to first harvest

Bright sunshine hours and GDD exhibited significant positive correlation with number of pods per plant while significant negative correlation was found with number of pods per plant and relative humidity and vapour pressure.

4.6.5. Correlation between length of pods and weather parameters at different growth stages of the crop

The results of the correlation analysis between weather parameters and number of pods per plant are presented in Table 5.4

4.6.5.2. Days to 50% flowering

Rainfall exhibited significant negative correlation with length of pods and significant positive correlation was obtained with forenoon soil temperature at 10cm depth and length of pods.

4.6.5.3. 6 Weeks after sowing

Significant positive correlation was obtained with maximum temperature, DTR, BSS and soil temperature at 10cm depths while, significant negative correlation was found with length of pods and rainfall and rainy days.

4.6.5.6. From days to 50% flowering to first harvest

Minimum temperature exhibited significant negative correlation with length of pods and GDD exhibited significant positive correlation with length of pods.

4.6.6. Correlation between hundred seed weight and weather parameters at different growth stages of the crop

The results of the correlation analysis between weather parameters and number of pods per plant are presented in Table 5.5

4.6.6.1. Days to 50% flowering

Significant negative correlation was obtained with minimum temperature, evaporation, GDD and afternoon soil temperature at 5cm depth and hundred seed weight.

4.6.6.2. 6 Weeks after sowing

Bright sunshine hours exhibited significant positive correlation with hundred seed weight and significant negative correlation was found with hundred seed weight and rainy days.

4.6.6.3. From days to 50% flowering to first harvest

Significant positive correlation was obtained with GDD and significant negative correlation was found with afternoon soil temperature and hundred seed weight.

Table.5.4. Correlation between length of pods and weather parameters at different growth stages of the crop

Crop stages	Tmax	Tmin	DTR	RH1	RH2	VP1	VP2	RF	EVP	BSS	WS	GDD	RD	Soil Temperature			
														FN		AN	
														5 cm	10 cm	5 cm	10cm
S2	0.043	-0.105	0.103	0.058	-0.023	0.017	0.016	-0.171*	-0.048	0.108	-0.093	0.035	-0.066	0.078	0.158*	-0.037	0.007
S3	0.178**	-0.073	0.194**	0.000	-0.103	-0.004	0.019	-0.287**	-0.016	0.282**	0.000	-0.072	-0.259**	0.127	0.179**	0.076	0.140*
S6	-0.009	-0.134*	0.046	-0.054	-0.036	-0.092	-0.036	-0.018	-0.021	0.116	0.010	0.185**	-0.014	-0.052	-0.035	-0.039	0.013

Table.5.5. Correlation between hundred seed weight and weather parameters at different growth stages of the crop

Crop	Tmax	Tmin	DTR	RH1	RH2	VP1	VP2	RF	EVP	BSS	WS	GDD	RD	Soil Temperature			
														FN		AN	
														5 cm	10 cm	5 cm	10cm
S2	-0.255	-0.368*	-0.108	0.201	0.178	0.040	0.166	-0.026	-0.355*	0.017	-0.155	-0.387*	0.048	-0.098	0.054	-0.341*	-0.250
S3	0.197	-0.097	0.223	-0.178	-0.187	-0.154	-0.068	-0.217	-0.046	0.394*	0.199	-0.066	-0.416*	-0.151	-0.072	-0.241	-0.202
S6	-0.279	-0.272	-0.210	0.009	0.082	-0.161	0.018	0.184	-0.281	-0.100	-0.050	0.594**	0.265	-0.116	-0.059	-0.452**	-0.469**

**- Significant at 1% level

*- Significant at 5% level

S2- Days to 50% flowering
S3-6 weeks after sowing
S6- From 50% flowering to first harvest

4.6.7. Correlation between weather parameters and phenological stages

The results of the correlation analysis between weather parameters and phenological stages are presented in Table 5.6

4.6.7.1. Surface temperature, relative humidity and vapour pressure

Maximum temperature showed significant positive correlation with days to last harvest and days to 50% flowering. Minimum temperature showed significant positive correlation with days to 50% pods with fully developed seeds and days to first harvest. DTR exhibited significant positive correlation with days to last harvest and days to 50% pods with fully developed seeds. Forenoon and afternoon relative humidity showed significant negative correlation with days to last harvest. The afternoon vapour pressure showed significant negative correlation with days to last harvest.

4.6.7.2. Rainfall and rainy days

The total rainfall received during the crop season exhibited significant negative correlation with days to last harvest. Rainy days also showed significant negative correlation with days to last harvest and days to 50% pods with fully developed seeds but were not significant.

4.6.7.3. Sunshine hours

Sunshine hours showed significant positive correlation with days to last harvest. Sunshine hours exhibited positive correlation with days to 50% flowering, days to first harvest and days to 50% pods with fully developed seeds.

4.6.7.4. Wind speed and evaporation

Wind speed exhibited significant positive correlation with days to last harvest, and also showed positive correlation with days to 50% flowering and days to 50% pods with fully developed seeds but these correlations were not significant. Evaporation exhibited significant positive correlation with days to last harvest and days to 50% flowering.

4.6.7.5. Growing degree days

GDD exhibited significant positive correlation with days to last harvest, days to 50% flowering, days to first harvest and days to 50% pods with fully developed seeds.

4.6.7.6. Soil temperature

The forenoon soil temperature at 5cm and 10cm exhibited significant positive correlation with days to 50% flowering, days to first harvest and days to 50% pods with fully developed seeds. The afternoon soil temperature at 5cm showed significant positive correlation with days to last harvest, days to 50% flowering and days to 50% pods with fully developed seeds. At 10cm depth, the afternoon soil temperature showed significant positive correlation with days to 50% flowering.

Table.5.6. Correlation between weather parameters and phenological stages

Weather parameters		DLH 1	D50F	DFH 2	DFDS 2	DFDS 3	DFH 1	DLH 2	DFDS 1
Tmax (°C)		0.705*	0.773**	0.323	0.406	0.339	0.492	0.545	0.560
Tmin(°C)		0.050	0.455	0.448	0.607*	0.558	0.234	0.187	0.367
RH1(%)		-0.665*	-0.410	0.124	0.081	0.088	-0.063	-0.583*	-0.176
RH2(%)		-0.714**	-0.530	-0.046	0.008	0.066	-0.244	-0.583*	-0.301
Rainfall(mm)		-0.724**	-0.433	0.017	0.020	0.173	-0.501	-0.391	-0.196
VP1(mm Hg)		-0.508	-0.104	0.304	0.313	0.325	0.095	-0.397	0.030
VP2(mm Hg)		-0.586*	-0.323	0.216	0.256	0.280	-0.062	-0.458	-0.143
Wind speed (km hr^{-1})		0.635*	0.171	-0.218	0.153	0.064	-0.126	0.545	0.011
Sunshine hours		0.763**	0.439	0.182	0.121	0.024	0.300	0.560	0.210
DTR(°C)		0.735**	0.658*	0.187	0.144	0.069	0.445	0.511	0.449
GDD(°C day)		0.928**	0.692*	-0.079	0.746**	0.881**	0.798**	0.894**	0.899**
Epan (mm)		0.630*	0.692*	0.098	0.087	0.021	0.320	0.525	0.461
Rainy Days		-0.740**	-0.462	-0.122	-0.121	0.069	-0.244	-0.504	-0.222
Soil temp (°C)	5cm	0.383	0.683*	0.343	0.695*	0.693*	0.614*	0.345	0.597*
	10cm	0.560	0.632*	0.341	0.647*	0.664*	0.642*	0.460	0.548
	5cm	0.624*	0.784**	0.286	0.412	0.331	0.447	0.489	0.597*
	10cm	0.417	0.780**	0.499	-0.201	-0.219	0.522	0.328	-0.116

**- Significant at 1% level

*- Significant at 5% level

DLH 1- Days to last harvest (From sowing)
DLH2- Days to last harvest (From 50% flowering)
D50F- Days to 50% flowering
DFH1- Days to first harvest (From sowing)
DFH2 – Days to first harvest (From 50% flowering)
DFDS1- Days to 50% pods with fully developed seeds (From sowing)
DFDS2- Days to 50% pods with fully developed seeds (From 50% flowering)
DFDS3 – Days to 50% pods with fully developed seeds (From first harvest)

4.6.8. Correlation between yield attributes and yield

The results of the correlation analysis between yield attributes and yield are presented in Table 5.7. Pod yield per plant exhibited significant positive correlation with the entire yield attributes such as pod yield plot, number of pods per plant, length of pods, number of seeds per pod and hundred seed weight.

Table.5.7. Correlation between yield attributes and yield

	Number of pods per plant	Number of seeds	Hundred seed weight	Pod yield per plot	Length of pods
Pod yield per plant	0.975**	0.623**	0.725**	0.952**	0.550**

4.7. MODEL FOR THE PREDICTION OF POD YIELD

Multiple linear regression equations were fitted for predicting the pod yield using mean weather variables experienced by the crop during the different stages of crop growth. Some of the prediction equations developed are given in Table.5.8.the models could predict the yield satisfactorily with an adjusted R^2 between yield and weather variables.

Table.5.8. Yield prediction model for Lola

Sowing time	Regression equation	R^2	Adj. R^2
Full Year	Yield= 284.305-16.565*RD-112.703**TMAX+ 52.369**ST10FN+ 134.842**DTR+134.943**WS+77.818**VP2+0.803**RF-82.431**VP1+8.980**RH1-10.458BSS	78.7	77.7
June - Sept	Yield= -3577.189+151.568**ST10FN-33.002**BSS	80.9	80.3
March - May	Yield= -5940.130+250.925** TMIN	79.6	79.2
Sep- Oct	Yield= -603.052+37.005ST5FN	33.2	32.2

DISCUSSION

5. DISCUSSION

The present experiment was conducted with an objective to find the best month for cultivation of yard long bean in Kerala and also to determine the crop weather relationship. The results of the present attempt to ascertain the crop weather relationships in yard long bean are discussed below.

5.1. EFFECT OF WEATHER ON GROWTH AND DEVELOPMENT OF YARD LONG BEAN

5.1.1. Plant height

The results obtained from the experiment indicate that the plant height is influenced by dates of sowing. Maximum height of 550.2 cm and 540.3 cm was recorded in October 2013 and September 2013 sown crops respectively and minimum height of 257.6 cm and 287.9 cm are recorded in August 2014 and March 2014 sown crops respectively. The increase in plant height of early September sown cowpea crop was also reported by Kamara and Godfrey-Sam-Aggrey (1979). The decrease in plant height of March sown crop may be due to an increase in maximum temperature beyond 32°C and that of August sown crop may be due to decrease in the maximum temperature beyond 32°C. (Table.3.9.). DTR was also observed more in March sown crop and lower in August sown crop. It was also observed from the correlation studies that an increase in minimum temperature during 50% flowering negatively influenced plant height. (Table.5.9. and Fig. 5.1.).

Table.5.9. Correlation between minimum temperature and plant height

	Plant height at different weeks after sowing				
	2	6	8	10	12
Minimum temperature	-.663*	-.679*	-.743**	-.663*	-.619*

Table.6.0. Correlation between pod yield per plant and plant height

	Plant height at different weeks after sowing					
	2	4	6	8	10	12
Pod yield per plant	.614**	.604**	.446**	.656**	.688**	.753**

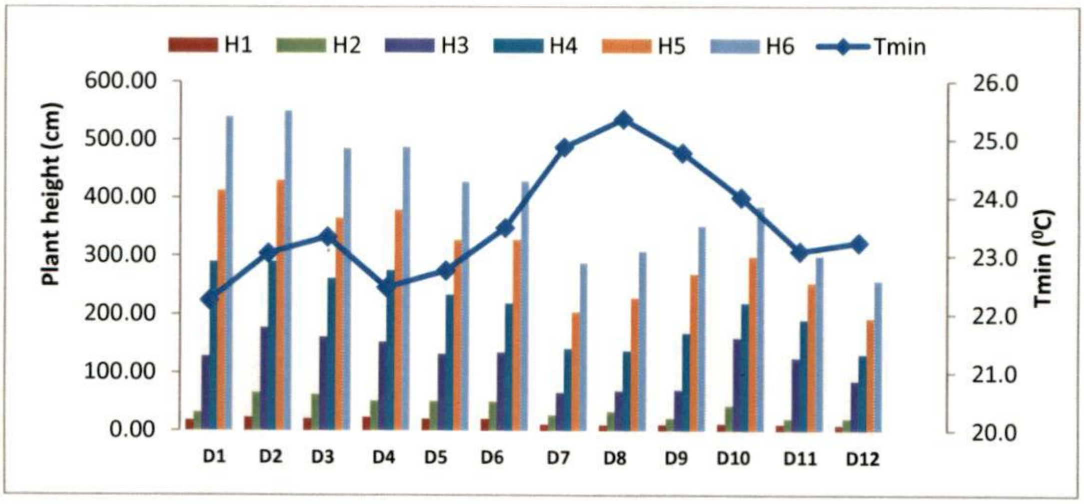


Fig.5.1. Influence of minimum temperature on plant height at fortnightly intervals with respect to different sowing dates

5.1.2. Biomass

The influence of sowing time on biomass was evident from the study. Biomass was recorded high for February 2014, October 2013, July 2014 and January 2014 sown crops and was recorded low for September 2013 and November 20013 sown crops. The increase in plant biomass of January and February 2014 sown crops may be attributed to an increase in bright sunshine hours coupled with an increase in DTR during the period from sowing to maturity of 50% of the pods. No rainfall was received during this period. Positive influence of increased sunshine hours per day on growth and yield of cowpea was reported by Kiari *et al.* (2011).

5.1.3. Number of pods per plant

The date of sowing had significant effect on number of pods per plant. Number of pods per plant was observed more in October and November sown crops and was observed low in May, July and August sown crops. Maximum temperature, DTR, BSS and soil temperature at 10cm depth positively influenced the number of pods per plant (Table.4.8.) (Fig.5.2.) Low number of pods per plant in May, July and August sown crops may be due to an increase in relative humidity, vapour pressure and rainfall experienced from sowing of these crops to maturity of 50% of the pods. Banik *et al.*, (2000) has also reported that very low and very high rainfall has caused poor yields in cowpea. Cowpea grown during high rainfall periods will result to low yield was also reported by Singh (2003).

5.1.4. Number of seeds per pod

Number of seeds per pod was influenced by dates of sowing. High minimum temperature during the various stages of crop growth negatively influenced the number of seeds per pod. The importance of optimum temperature on number of seeds per pod was reported by Shaukat *et al.*, (2012). Significant negative correlation was obtained with minimum temperature and GDD during sowing to 50% flowering

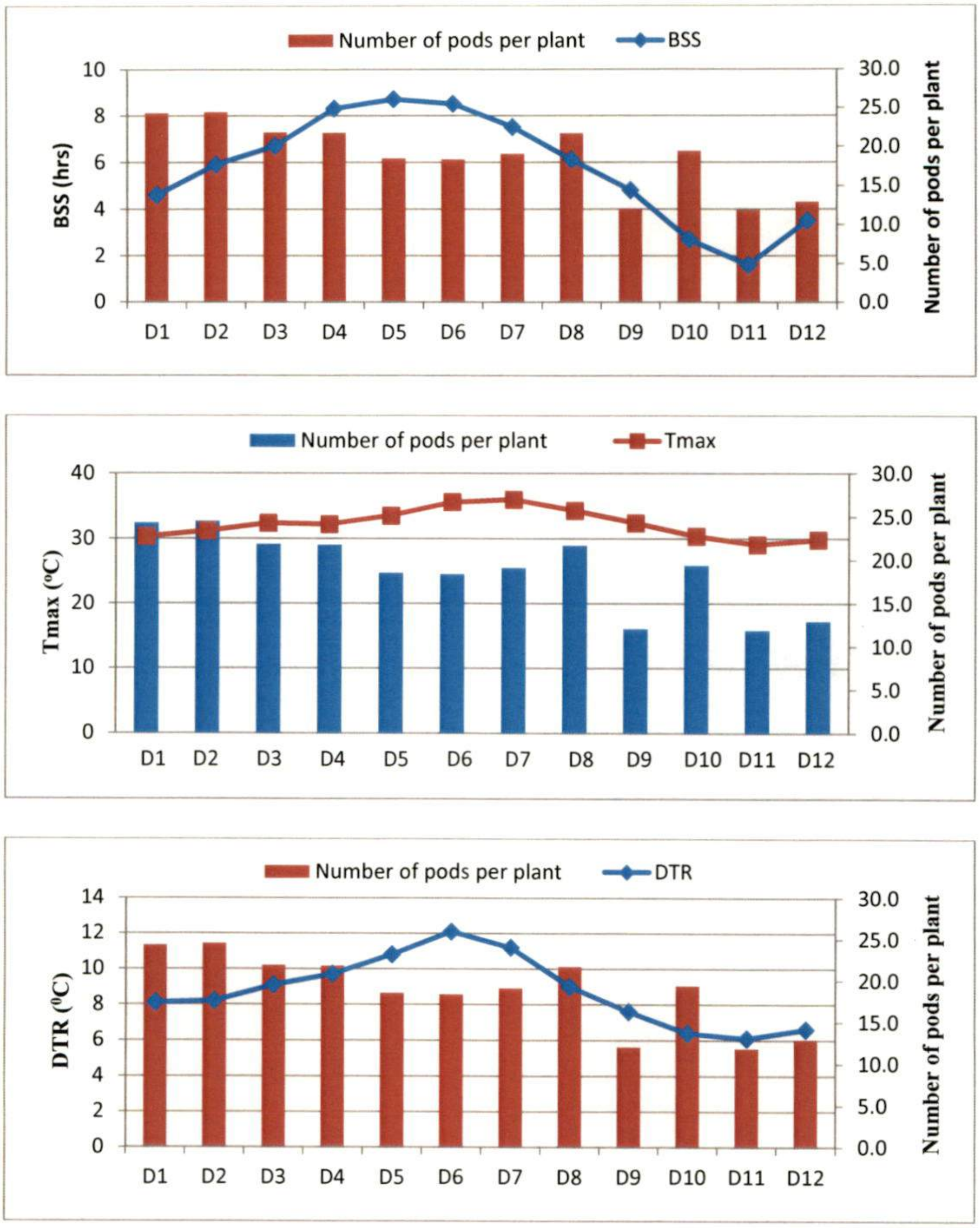
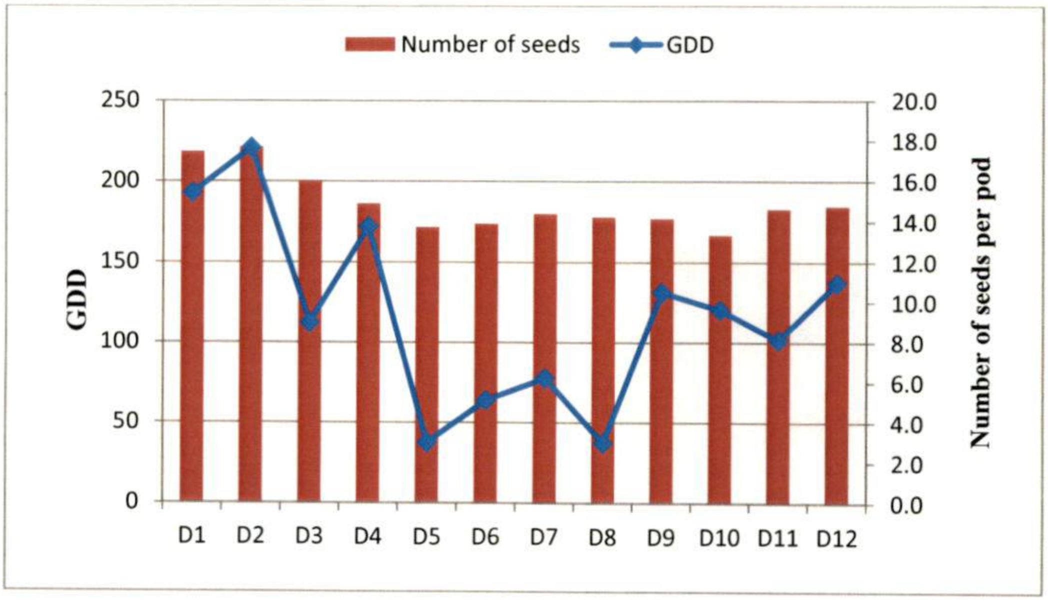


Fig.5.2. Influence of weather parameters on number of pods per plant with respect to different sowing dates



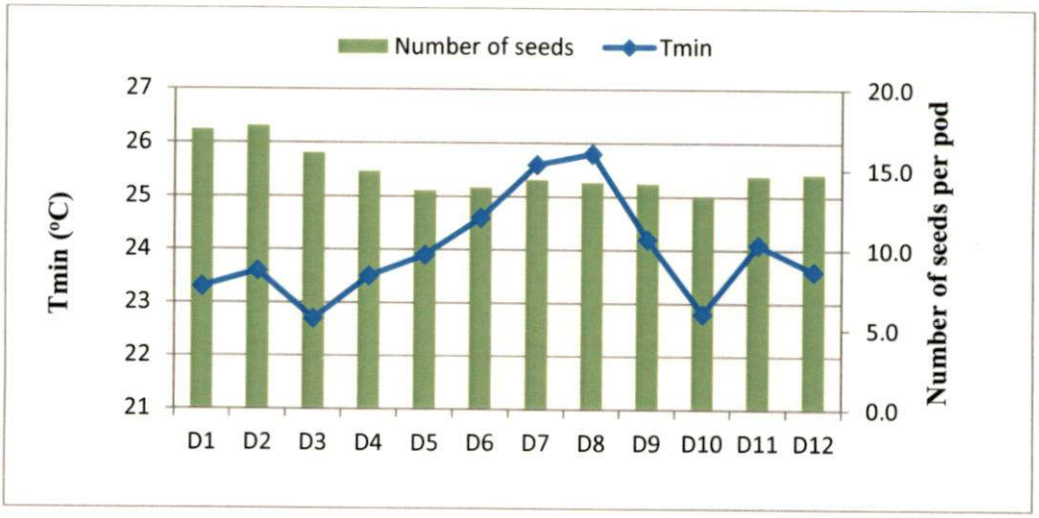


Fig.5.3. Influence of weather parameters to number of seeds with respect to different dates of sowing

of the crops (Table.4.7.) and (Fig.5.3.) which might have influenced the variations in number of seeds per pod during different time of sowing.

5.4.5. Hundred Seed weight

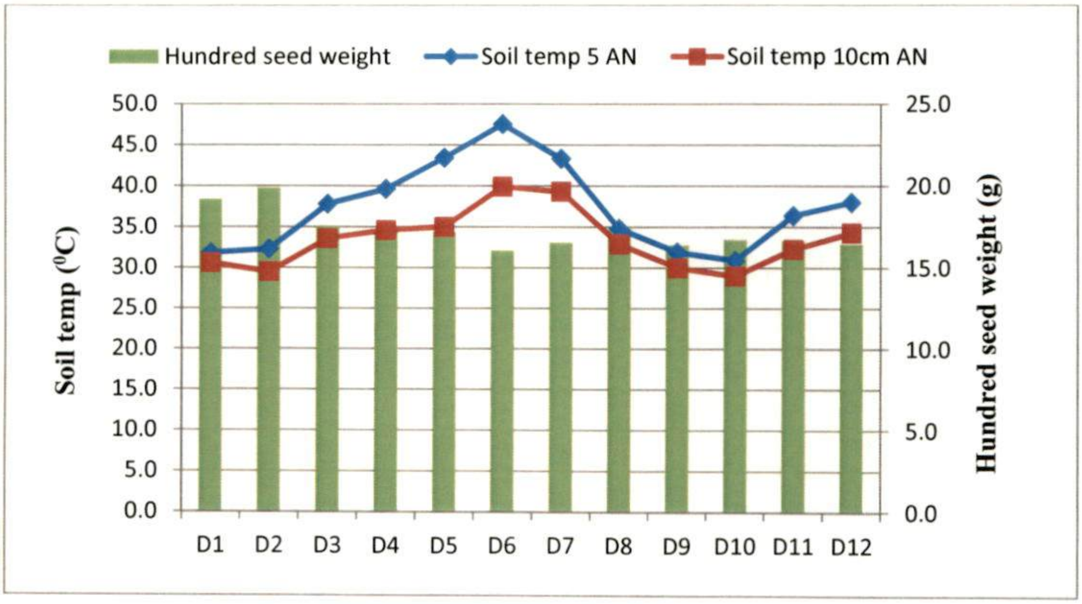
There were variations in hundred seed weight with variations in date of sowing. In September and October sown crop the hundred seed weight was more and was observed low in January, February, April, May and June. Minimum temperature and afternoon soil temperature had influenced the hundred seed weight negatively. (Fig.5.4.). The decrease in hundred seed weight with increase in air temperature was also reported by Puteh *et al.,* (2013). High maximum temperature i.e. above 35°C was recorded in January and February sown crops from sowing to first harvest, which might have also contributed to the decrease of hundred seed weight in those sowing. This is in agreement with the findings of Puteh *et al.,* (2013).

5.4.6. Length of pods

The length of pods was significantly influenced by dates of sowing. Pod length was recorded low in July (37.0cm) and May (39.2cm) sown crops. The decrease in maximum temperature coupled with a decrease in DTR, BSS and soil temperature at 10cm depths at forenoon and afternoon during flowering to maturity of 50% of the pods might have caused the reduction of pod length in July and May sown crops. Davis (1996) also reported the positive effect of BSS to fruit length in bitter gourd.

5.4.7. Pod yield

Pod yield per plant and pod yield per plot was estimated. It was found that dates of sowing had significant effects on pod yield. Pod yield was recorded high in September and October sowing. Low pod yield was observed in May and July sown crops. Maximum temperature, DTR, BSS and soil temperature at 10cm depth positively influenced the pod yield (Fig.5.5.). A combination of optimum weather parameters experienced by the September and October sown crops might have



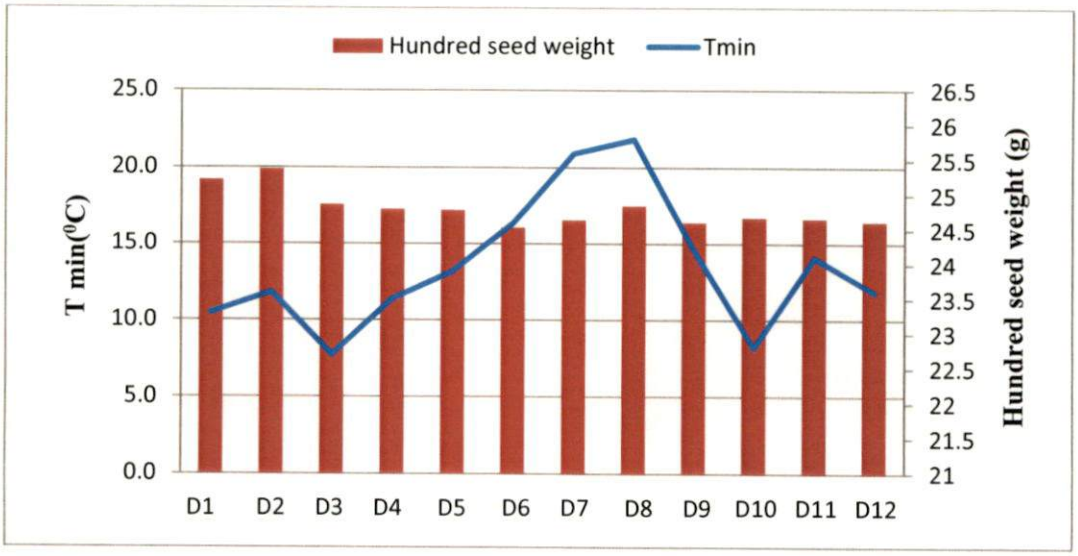
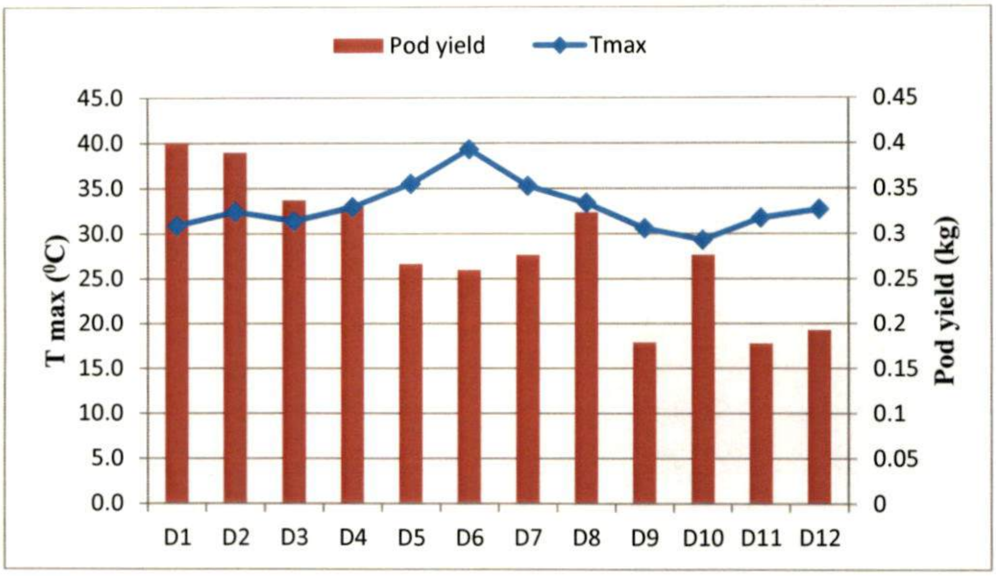


Fig.5.4. Influence of weather parameters on hundred seed weight with respect to different sowing dates



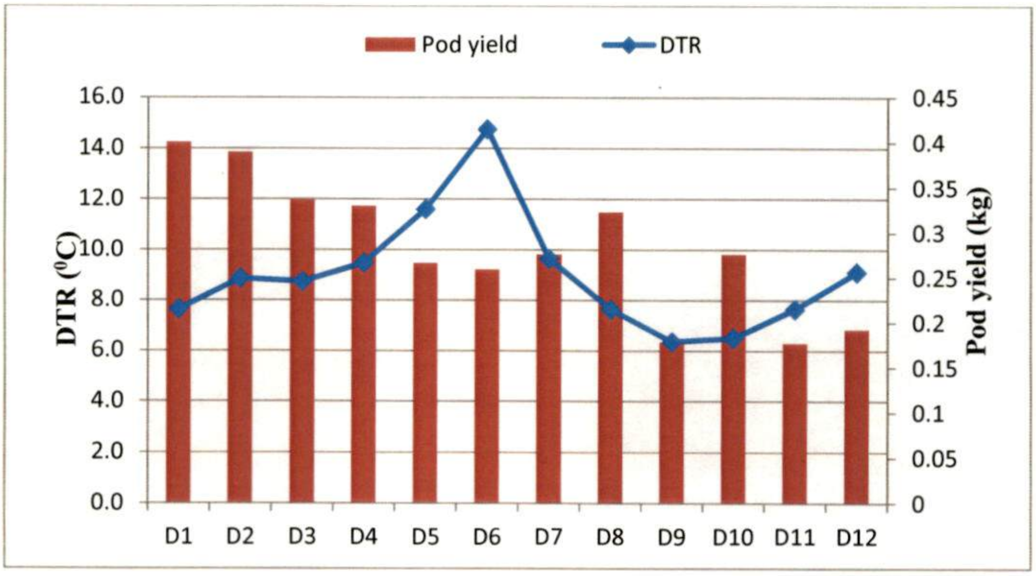
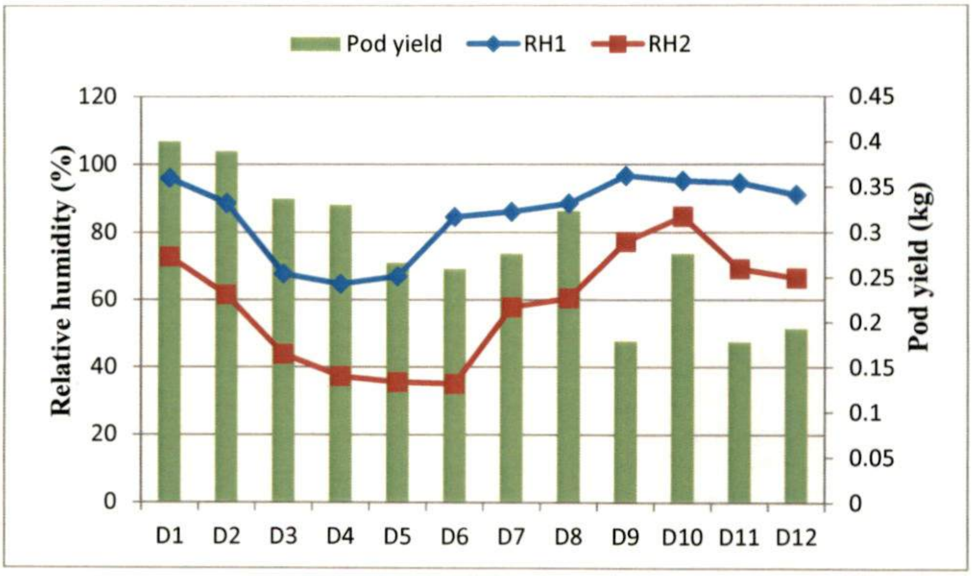


Fig. 5.5. Influence of weather parameters on pod yield with respect to different sowing dates



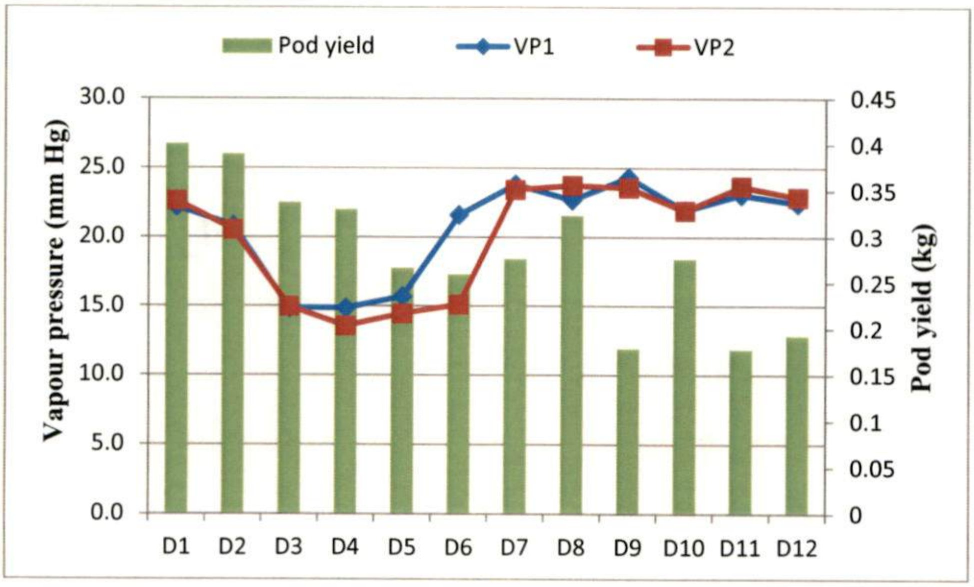


Fig.5.5. Influence of weather parameters on pod yield with respect to different sowing dates (cont.)

contributed to high yield. May and July sown crops experienced an increase in rainfall (Banik *et al.,* 2000 and Singh, 2003) and decrease in BSS (Kiari *et al.*, 2011).

5.2. EFFECT OF WEATHER ON THE DURATION OF PHENOLOGICAL STAGES

5.2.1. Days to seedling emergence

The number of days taken for seedling emergence was not affected by the dates of sowing.

5.2.2. Days to 50% flowering

The crops sown during October 2013 took less number of days for flowering of the 50% of the plants. March sown crops took the highest number of days to achieve 50% flowering. Increase in maximum temperature coupled with minimum temperature and soil temperature might have attributed to an increase in the number of days for 50% flowering. Hall (1992) also reported that high night temperature damages floral development and pod set in cowpea. GDD and DTR were also observed more with increased days to 50% flowering.

5.2.3. Days to 50% pods with fully developed seeds

March sown crops took more number of days to attain maturity for 50% of the pods. This can be attributed to the delay to attain 50% flowering which might be due to the increased maximum, minimum and soil temperature. Baloch (1994) also reported that hot weather interferes with the seed set in peas.

5.2.4. Days to first harvest

From the correlation analysis, it was observed that there is a significant correlation with GDD and forenoon soil temperature with days to first harvest. March sown crops took more number of days to first harvest. Therefore increase in GDD and

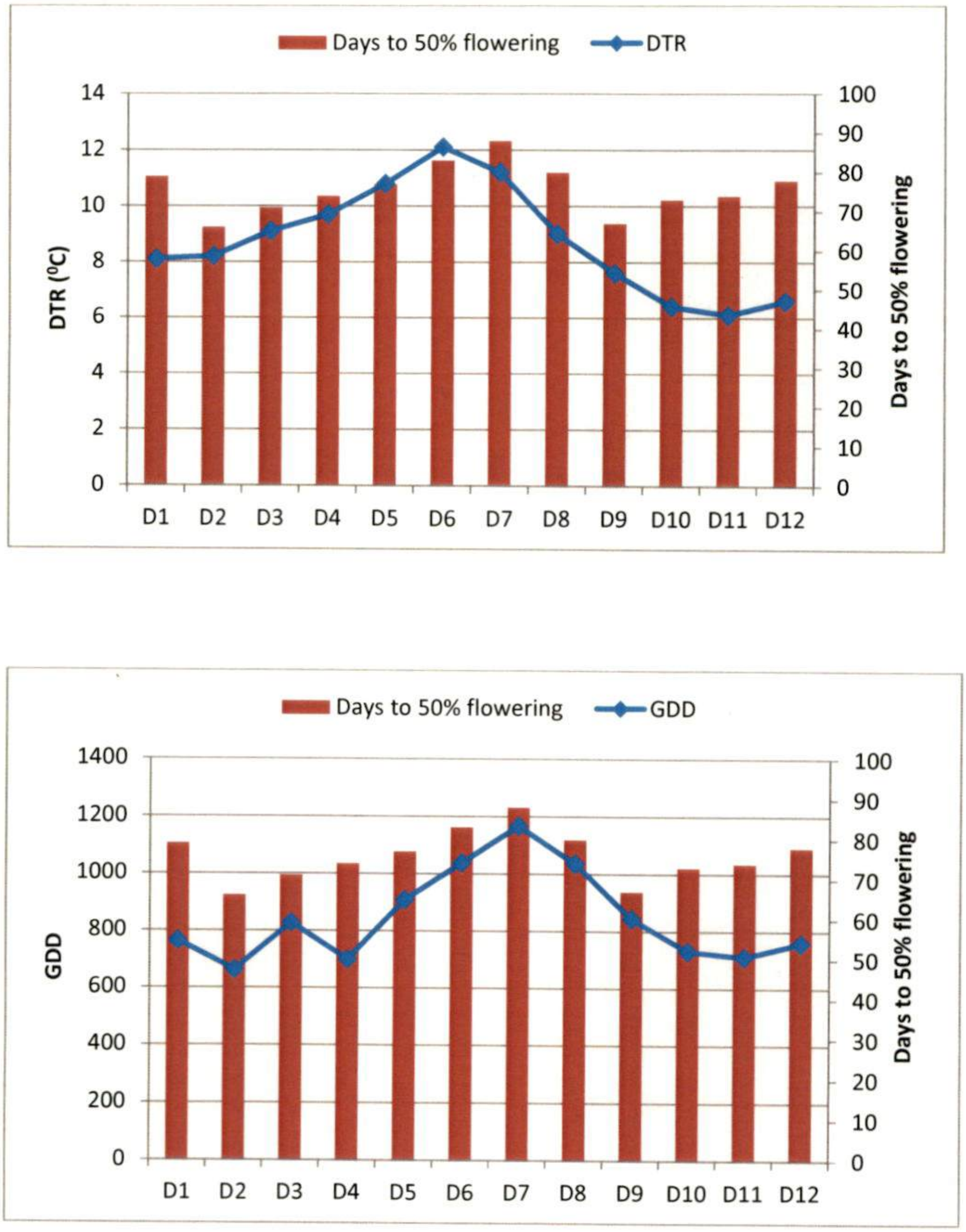


Fig.5.6. Influence of weather parameters on days to 50% flowering with respect to different sowing dates

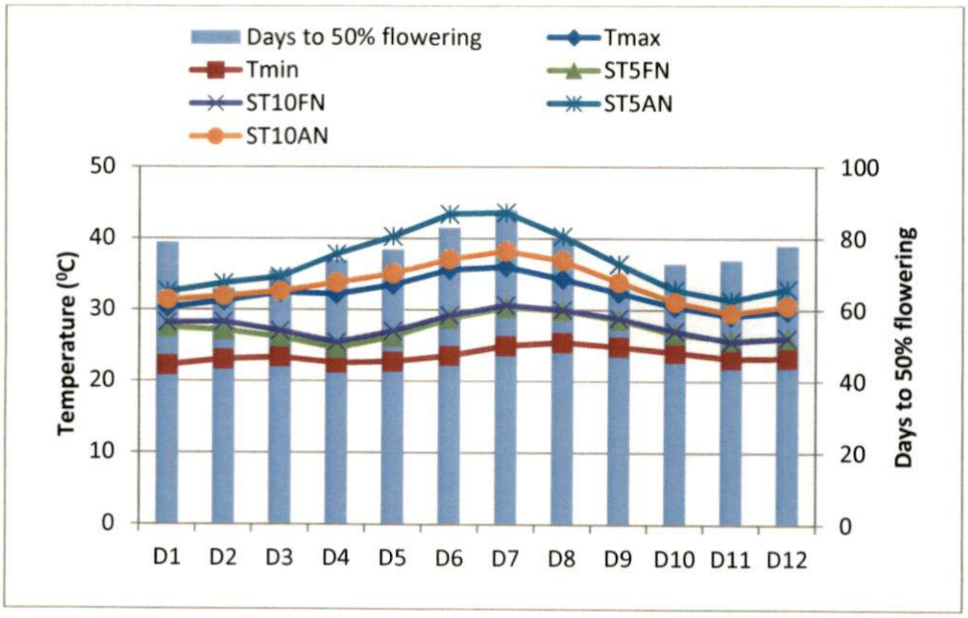


Fig.5.6. Influence of weather parameters on days to 50% flowering with respect to different sowing dates

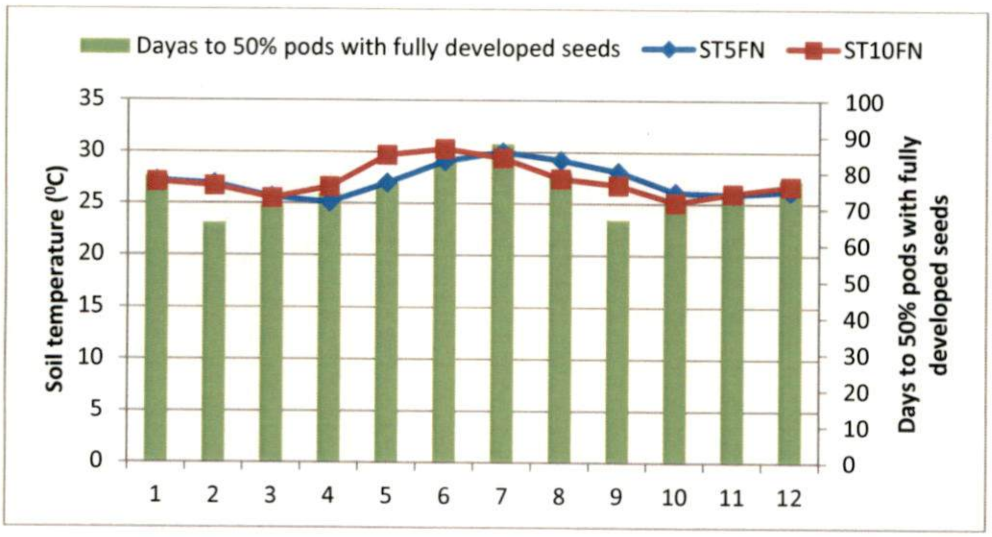
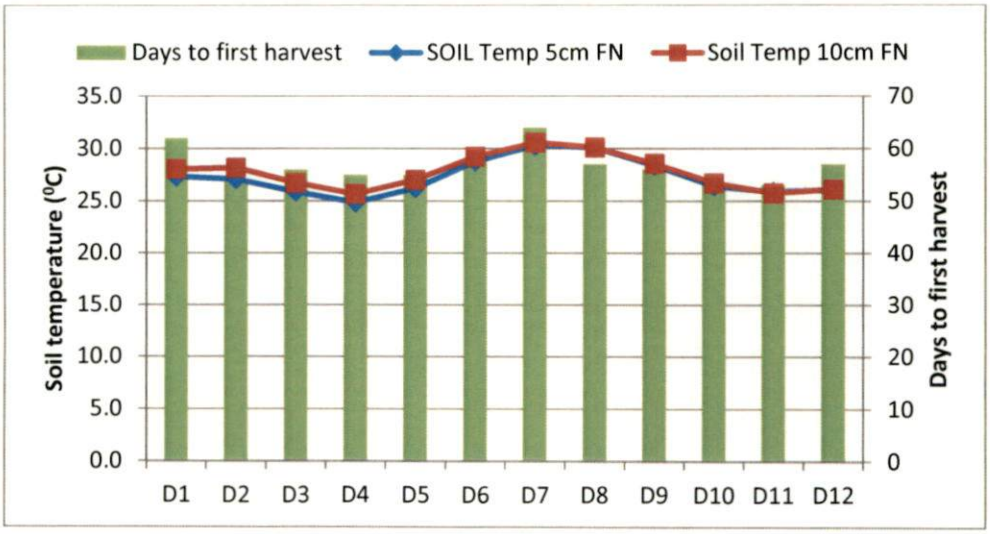


Fig.5.7. Influence of soil temperature on days to 50% pods with fully developed seeds with respect to different sowing dates



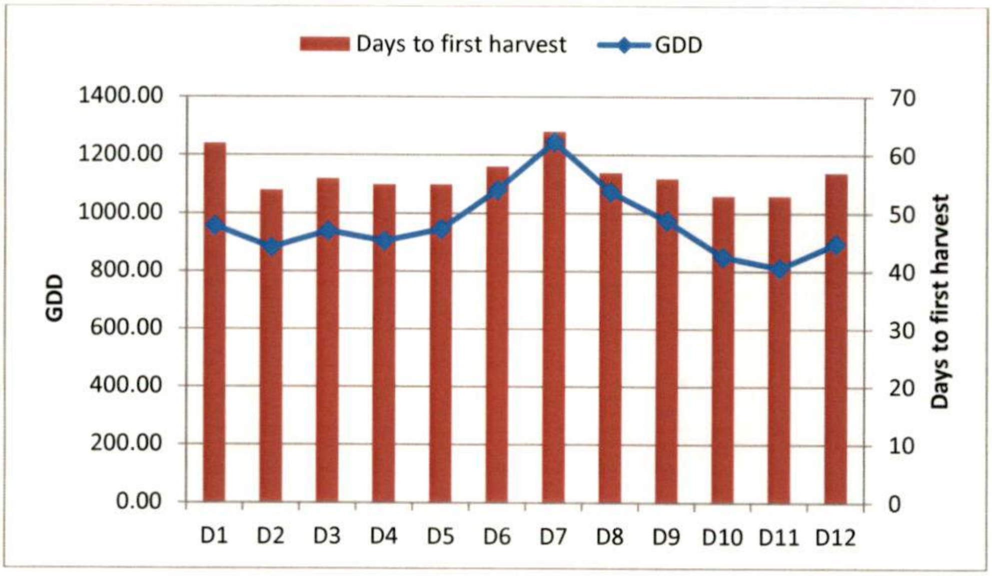


Fig.5.8. Influence of weather parameters on days to first harvest with respect to different sowing dates

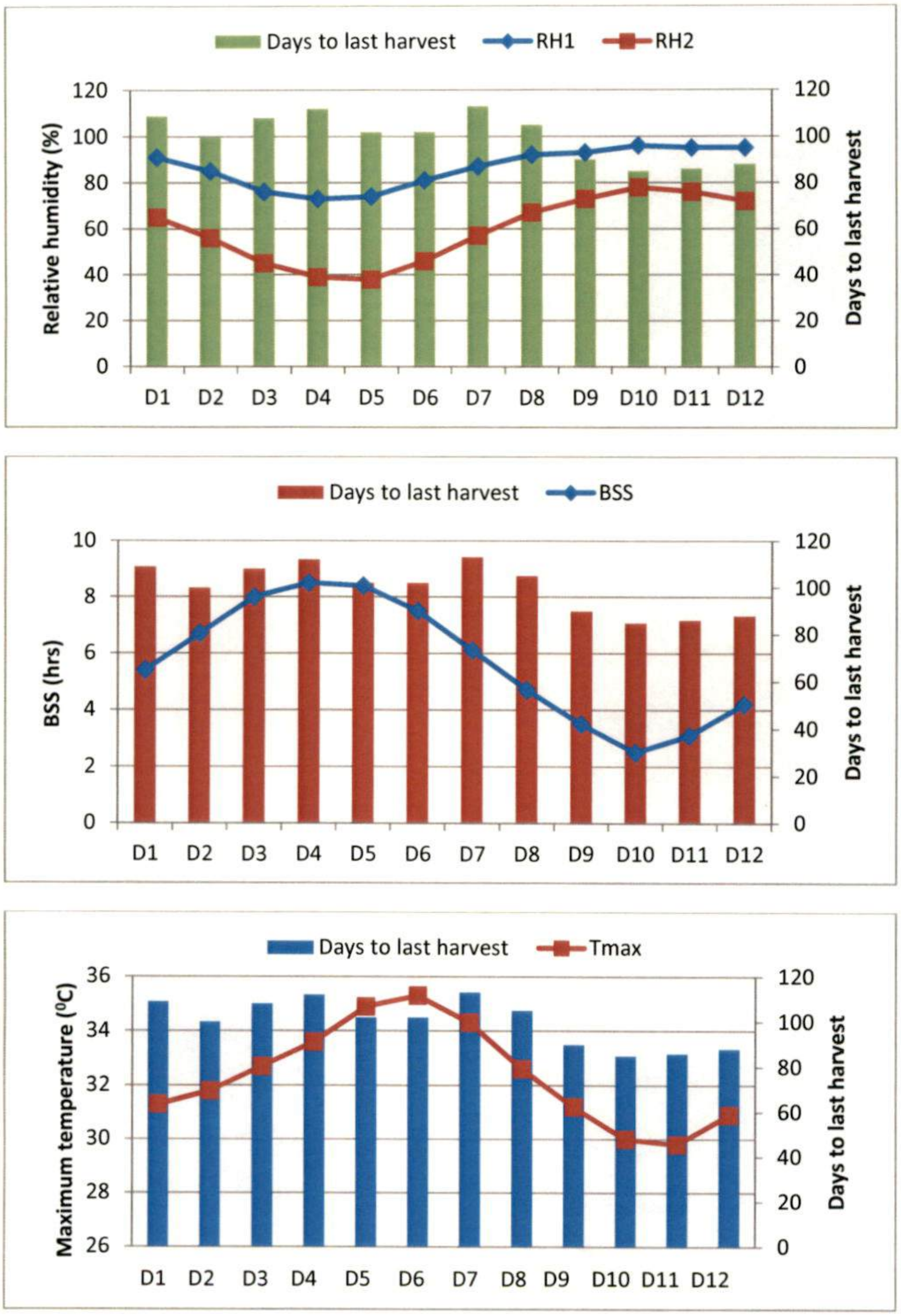


Fig.5.9. Influence of weather parameters on days to last harvest with respect to different sowing dates

forenoon soil temperature may be the reason for increase in the number of days to first harvest.

5.2.5. Days to last harvest

Crop duration was also observed more for March sown crops followed by December sown crops. It was observed from the correlation analysis that, an increase in maximum temperature, BSS and GDD will lead to increase in crop duration, whereas increase in relative humidity and rainfall will lead to decrease in crop duration.

5.2.6. Number of harvests

October sown crops recorded more number of harvests which might be attributed to more number of pods per plant and pod yield in the same crop.

5.3. PREDICTION MODEL FOR LOLA

Multiple linear regression equations were fitted for predicting the pod yield by stepwise regression method using mean weather variables experienced by the crop during the different stages of crop growth. The regression equation with R^2 value 0.77, fitted using the weather parameters experienced by the crops during the experimental period is given below.

Pod Yield = 284.305-16.565*RD-112.703**TMAX+52.369**ST10FN+ 134.842**DTR+ 134.943**WS+77.818**VP2+0.803**RF-82.431**VP1+8.980**RH1-10.458BSS

This equation could predict the yield of lola with a precision of 77.7 % (Fig. 6.0.)

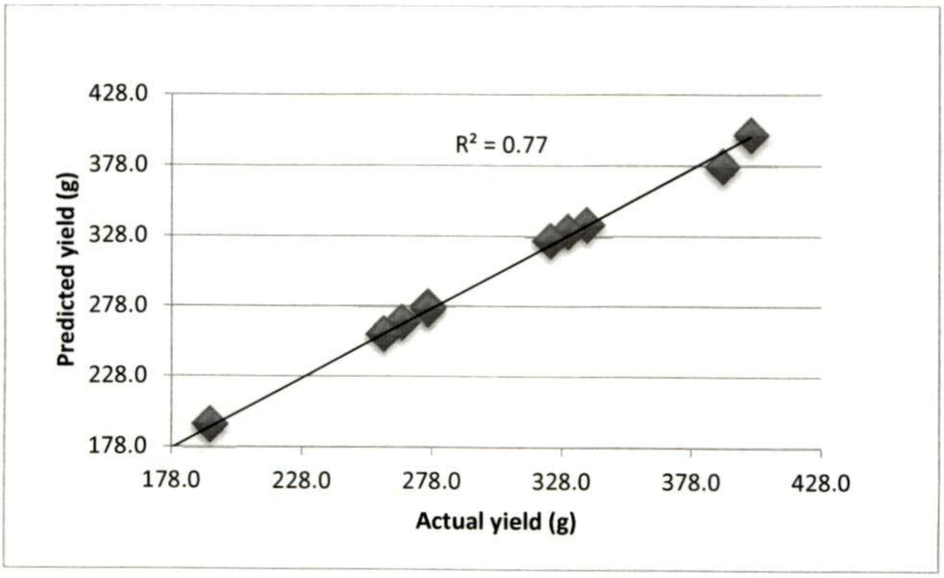


Fig.6.0. Actual and predicted pod yield of lola

SUMMARY

6. SUMMARY

The experiment on "Crop weather relationship of Yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Walp)" was carried out at the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara, Thrissur during 2013-2014. The experiment was conducted to study the effect of weather on growth and yield of yard long bean and to determine the optimum sowing time for yard long bean in the central zone of Kerala. The salient findings of the study are summarized as follows.

- The plant height at different weeks after sowing was highly variable among the different sowing dates. The high plant height was recorded in September 2013 and October 2013 sowing. Minimum temperature showed negative correlation with plant height during the different stages of plant growth. The crops sown during March 2014 and August 2014 recorded low plant heights.
- The biomass (dry weight) was also significantly influenced by the different sowing dates. The crops sown during October 2013 and February 2014 recorded high biomass and was observed low in the crops sown during September 2013 and November 2013.
- The phenological stages of the crop also showed variations with different dates of sowing. The duration from sowing to 50% flowering was observed different in different dates of sowing. The crops sown during March 2014 took more number of days to attain 50% flowering while those sown during December 2013 took less number of days for 50% flowering. The increase in days for 50% flowering was observed with an increase in maximum temperature, GDD and soil temperature. The crops sown during June 2014 took less number of days for commencation of harvest whereas the crops sown during September 2013 and March 2014 took more number of days for first harvest. It was observed that an increase in GDD and forenoon soil temperature prolonged the days for first harvest. The number of days taken for

50% of the pods to attain seed maturity was influenced by the minimum temperature positively. GDD, forenoon soil temperature at 5cm and 10cm depth and afternoon soil temperature at 5cm depth also exhibited significant positive correlation with days taken for 50% of the pods to attain seed maturity. The days to 50% of the pods with fully developed seeds was recorded highest in March 2014 sowing and lowest in October 2013 sowing. The crops sown during December 2013 and March 2014 took more number of days for the last harvest and the crop duration was found lowest in June 2014 sown crops. Maximum temperature, DTR, BSS, relative humidity, vapour pressure, wind speed, rainfall and rainy days exhibited significant positive correlation with crop duration.

- The yield and yield attributes also varied among different dates of sowing. The number of pods per plant was recorded high in September 2013 and October 2013 sown crops whereas it was recorded low in May, July and August 2014 sown crops. Maximum temperature, DTR and BSS during 50% flowering and also from 50% flowering to first harvest, positively influenced the number of pods per plant. It was observed that an increase in relative humidity, vapour pressure, rainfall and rainy days decreased the number of pods per plant.
- January, February, April, May and June 2014 sown recorded low number of seeds per pod and September and October 2013 sown crops recorded the high. GDD exhibited significant positive correlation with number of seeds per pod when the weather during 50% flowering to first harvest was calculated.
- The length of pods was found high in September 2013, October 2013, November 2013 and March 2014 sown crops while it was recorded low in July 2014 sown crops. Significant positive correlation was obtained with maximum temperature, DTR, BSS and soil temperature at 10cm depths while,

significant negative correlation was found with length of pods and rainfall and rainy days during six weeks after sowing.

- Hundred seed weight was recorded high in September 2013 and October 2013 sown crops and it was recorded low in February 2014 sown crop. In correlation analysis using the weather from 50% flowering to first harvest, it was found that, GDD influenced the hundred seed weight positively and significant negative correlation was found with afternoon soil temperature and hundred seed weight.
- The pod yield per plot and pod yield per plant was estimated. It was found that the pod yield per plant and per plot was high in September 2013 and October 2013 sown crops whereas it was recorded low in May, July and August 2014 sown crops. During 50% flowering, significant positive correlation was found with DTR, bright sunshine hours and forenoon soil temperature at 10cm depth while minimum temperature, afternoon relative humidity, forenoon vapour pressure, rainfall and rainy days showed significant negative correlation with pod yield.
- The major pests noticed in the study are aphids, pod borer and pod bug and the major diseases noticed are rust, mosaic and anthracnose during the different crop growth stages.
- Multiple linear regression equations were fitted for predicting the pod yield using mean weather variables experienced by the crop during the different stages of crop growth. The regression equation with R^2 value 0.80, fitted using the weather parameters from September 2013 to June 2014 is given below.

  Yield= -3577.189+151.568**ST10FN-33.002**BSS

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APPENDICES

Appendix I

Abbreviations and units used

Weather parameters

Tmax : Maximum temperature

Tmin : Minimum temperature

BSS : Bright sunshine hours

DTR : Diurnal Temperature Range

RH 1 : Forenoon relative humidity

RH 2 : Afternoon relative humidity

VP 1 : Forenoon vapour pressure

VP 2 : Afternoon vapour pressure

RF : Rainfall

RD : Rainy days

SR : Solar radiation

WS : Wind speed

Heat units

GDD : Growing Degree Days

Units

g : gram

kg : kilogram

mm : millimetre

cm : centimeter

Km hr^{-1} : kilometre per hour

°C : degree Celsius

% : per cent

ha : hectare

APPENDIX II

ANOVA of different plant growth characters of the experiment

Number of pods per plant, number of seeds per pod, length of pods, pod yield per plot, pod yield per plant and hundred seed weight

Source of variation	Degrees of freedom	MEAN SQUARES					
		Number of pods per plant	Number of seeds per pod	Length of pods	Pod yield per plot	Pod yield per plant	Hundred seed weight
		4.212*	0.272	8.964	2.162	1051.435	0.711
DOP	11	59.419**	5.966**	21.091**	50.168**	17203.823**	3.976**
Error	22	1.207	0.86	3.532	1.892	322.158	0.251

**- Significant at 1% level

*- Significant at 5% level

DF – Degrees of Freedom

Days to 50% flowering, Days to 50% pods with fully developed seeds, Days to first harvest, Day to last harvest, Number of harvests

SOURCE OF VARIATION	DF	MEAN SQUARES				
		Days to 50% flowering	Days to 50% pods with fully developed seeds	Days to first harvest	Day to last harvest	Number of harvests
Replication	2	1.028	4.083*	0.528	4.083*	0.194
DOP	11	85.24**	122.977**	30.717**	311.939**	8.513**
Error	22	1.119	0.811	1.649	1.114	0.588

**- Significant at 1% level

*- Significant at 5% level

Plant height at different weeks after sowing

Source of variation	DF	MEAN SQUARES					
		Plant height at different weeks after sowing					
		2	4	6	8	10	12
Replication	2	1.421	38.091	336.564	524.038	703.003	161.306
DOP	11	95.123**	789.257**	4721.594**	10517.507**	18950.915**	30805.414**
Error	22	1.072	40.11	210.673	401.898	947.766	943.8

DF – Degrees of Freedom

**- Significant at 1% level

*- Significant at 5% level

Dry weight at different weeks after sowing

SOURCE OF VARIATION		MEAN SQUARES					
		Dry weight at different weeks after sowing					
		2	**4**	**6**	**8**	**10**	**12**
Replication	2	0.04	1.839	1.648	3.05	1.056	2.553
DOP	11	0.07*	30.583**	162.949**	207.653**	418.997**	251.155**
Error	22	0.017	1.146	5.826	10.948	4.6	10.545

**- Significant at 1% level

*- Significant at 5% level

DF – Degrees of Freedom

Crop weather relationship of Yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Walp)

By

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ABSTRACT OF THE THESIS

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Abstract

Yard long bean is an important leguminous vegetable crop cultivated in Kerala. It is a highly relished vegetable crop which can be cultivated throughout the year. However, weather and climate are considered to be the most limiting factors in crop production. Since weather conditions experienced by a crop play a major role in its growth and yield, the study of the influence of weather on crop is very much important.

The present investigation on "Crop weather relationship of Yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Walp) was carried out in the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara during 2013-2014 to determine the crop weather relationship and to study the effect of date of sowing on the growth and yield of yard long bean. The experiment was laid out in randomized block design with three replications at Instructional farm, Vellanikkara from September 2013 to August 2014. The treatment comprises of twelve dates of sowing at monthly intervals from September 2013 to August 2014. Yard long bean variety lola was used for the experiment.

The different growth and yield characters like plant height, biomass, number of pods per plant, number of seeds per pod, hundred seed weight, length of pod, pod yield per plot, pod yield per plant and duration of different growth phases were recorded along with monitoring of major pests and diseases. The daily weather parameters like maximum and minimum temperature, forenoon and afternoon relative humidity, forenoon and afternoon vapour pressure, rainfall and rainy days, bright sunshine hours, evaporation, wind speed and soil temperature were also recorded.

The maximum temperature was found highest in February 2014 sowing and was recorded lowest in July 2014 sowing whereas the highest minimum temperature was recorded in March and April 2014 sowing. The crops sown during December 2013 and January 2014 received no rainfall and those sown during June 2014 received the maximum rainfall. The bright sunshine hours was recorded more in December 2013 sowing and was low in June 2014 sowing. Plant height, biomass, phenological stages, yield and yield attributes were highly variable among the different sowing dates. The March 2014 sown crops took more number of days to attain 50% flowering followed by February 2014 sown crops. The crop duration was also observed more for

March sown crops which was on par with December 2014 sown crops. Yield and yield attributes were influenced by various weather parameters experienced during the different crop growth stages. Pod yield was highest from September and October 2013 sown crops and lowest from May and July 2014 sown crops. Yield attributes such as number of pods per plant, number of seeds, length of pods and hundred seed weight were also recorded more in September and October 2014 sown crops. Pests such as aphids, pod borer, pod bug and diseases such as mosaic, rust and anthracnose were observed in the crop during the study.

To determine the critical weather elements affecting the crop growth, correlation analysis was done and it was found that maximum temperature, diurnal temperature range, soil temperature at 10cm depth, wind speed and bright sunshine hours exhibited positive influence on the pod yield, whereas increase in minimum temperature, growing degree days, relative humidity, vapour pressure, rainfall and rainy days negatively influenced the yield. Multiple linear regression models were fitted, to predict the pod yield based on the weather variables..