

**EFFECT OF MICROCLIMATE ON PIGEON PEA
(*Cajanus cajan* L.) BASED INTERCROPPING SYSTEM**

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PARBHANI - 431 402 (M.S.) INDIA**

2020

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(*Cajanus cajan* L.) BASED INTERCROPPING SYSTEM**

BY

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B.Sc. (Agri.)

Dissertation

Submitted to the

**Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in Partial fulfillment
of the requirement for the degree**

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COLLEGE OF AGRICULTURE, PARBHANI

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PARBHANI - 431 402 (M.S.) INDIA

2020

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I, hereby declare that this dissertation

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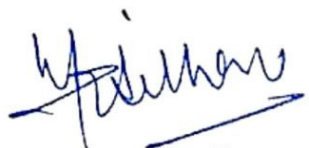
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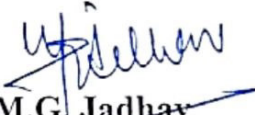

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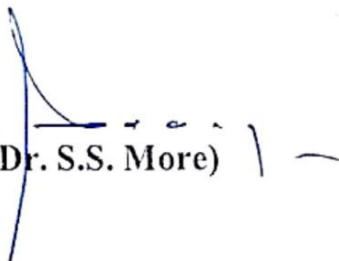

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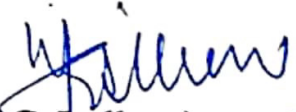
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LIST OF SYMBOL AND ABBREVIATIONS

Avg.	Average
BSS	Bright sunshine hours
$^{\circ}\text{C}$	Degree celcius
CD	Critical difference
cm	Centimeter
DAS	Days after sowing
/	Per
<i>et al</i>	Et alia, and others
<i>etc.</i>	Et cetera (and so on)
EVP	Evaporation
Fig.	Figure
g	Gram
GDD	Growing Degree Days
G. Mean	Geometric Mean
ha^{-1}	Per hectare
hrs	Hours
HTU	Helio Thermal Unit
i.e.	That is
Kg ha^{-1}	Kilogram per hector
Km hr^{-1}	Kilometer per hour
mm day^{-1}	Millimeters per day
MW	Meteorological Week
No.	Number
PAR	Photosynthetically Active Radiation
PTU	Photo Thermal Unit
%	Percentage
RBD	Randomized Block Design
R.D.	Rainy Days
R.F	Rainfall
RH-I	Morning humidity
RH-II	Afternoon humidity
Rs Kg^{-1}	Rupees per kilogram
SE	Standard error
<i>viz</i>	Videlic (namely)
Tmax.	Maximum temperature
Tmin.	Minimum temperature
Tavg.	Average temperature
WS	Wind Speed



Introduction

CHAPTER – I

INTRODUCTION

India is the largest producer (around 25% of global production), it however, consumes 27% and imports around 14% of its pulses requirements (Singh *et al.* 2016). Food legume constitutes an important ingredient of Indian diet as they provide protein and essential amino acids. Pulses are important for their value as human food and for high protein content for livestock. A good amount of lysine is present in pulses. Hence, there is a need for increasing average pulse productivity to fulfill protein requirement. Pulses are suitable in different cropping system as they are varying in maturity period.

Pigeon pea (*Cajanus cajan* L.) is an important pulse crop belongs to family Leguminaceae. Pigeon pea is produced and consumed in India, where it is a key crop for food, nutritional security of the people. The centre of origin is the eastern part of peninsular India, including the state of Orissa, where the closest wild relatives occur. Maharashtra ranks first in both area and production of pigeon pea. Pigeon pea (*Cajanus cajan* L.) is cultivated in the semi-arid areas of tropics and subtropics.

Pigeon pea legume in symbiotic association with Rhizobium bacteria fixes atmospheric nitrogen. When, pigeon pea is intercropped nodules of the root release valuable nitrogen to the other crop. The roots, leaves or stems of the pigeon pea plant that stay in the field also help to improve the soil.

Pigeon pea is the second most important pulse crop of the country after chickpea. It is grown during *kharif* season. It is a long duration crop with initial slow growth rate, so there is ample scope of growing short duration inter crops which help in getting additional yield and income. Intercropping is an advanced agro-technique which involves growing of two or more than two crops in the same field at the same time or also defined as growing two or more crops simultaneously on the same piece of land with a definite row pattern. Mixed or intercropping systems help in protecting the farmer from risks are a good insurance option, since if one crop fails, the other may survive. In India, pigeon pea is generally intercropped with maize, soybean, sesamum, urdbean, mungbean and groundnut. The difficulty and risk of growing sole crops can also be minimized through intercropping.

Micrometeorology can be defined as the meteorology dealing with the study of the atmospheric processes occurring over less than one kilometer horizontal and about ten meters vertical spread.

The term microclimate refers to the climate areas of limited extent or small space. The microclimate including temperature, relative humidity and light intensity in farmland is an important factor in the growth and production of crops. The relative humidity, which played important roles in disease injuries of crops, was promote to present down trend and reducing the number of hours per day with relative humidity $\geq 92\%$ in intercropping. The intercropping can increase the amount of light intercepted of crops in unit planting area so that improve the crop dry matter production, yield and radiation use efficiency (Hanming *et al.* 2012). (Dahmardeh and Khashayar, 2013) showed that variance of microclimate in intercropping system have caused that agreeable environmental condition have ready for growth and yield compared to sole crops.

The principal reasons for farmers to intercrop flexibility, risk minimization against crop failure, profit maximization, soil conservation, maintenance weed control and balanced nutrition (Shetty *et al.* 1995).

Intercropping is the agricultural practice of cultivating two or more crops in the same piece of land at the same time or within the same season. It differs from sole cropping which constrain the cultivation of one crop grown alone in pure stands. All over time and in many parts of the world, intercrop has been used to improve crop utilization of available sun light, water and nutrients. The yield is enhanced if intercropping components have different efficacies in consumption of environmental resources, they will make better use of the resources (Willey, 1979). Intercropping increased the amount of absorption PAR, light interception and shading in intercropping compared to sole (Ghanbari *et al.* 2010). Intercropping helps in variation of microclimate, especially for light intensity, relative humidity and temperature (He *et al.* 2012). In agronomic ecosystems light is an important competition factor since it can't be stored and is lost if not absorbed (Awal *et al.*, 2006). Intercropped plants are of different heights so that shorter species has lower photosynthetic potential and more horizontal leaves, higher level of light can be trapped by the intercropping system and is consumed in better manner and the higher plant is equipped with higher photosynthetic potential and wider leaves. High leaf area index can raise leaf erection, vegetation photosynthesis and finally canopy

growth. It has been noted that leaf area index in intercropping of safflower and bean is higher than that of their monocultures which leads to better use of the absorbed light and increased yield (Tsubo *et al.* , 2001). Higher leaf area index is help to enhance absorption sun light. Thus, leaf area index can reveal its close relation with percentage of light received by the canopy in monoculture and intercropping. (Ahmadvand *et al.*, 2006). Rao, (1982) reported that decrement in pods per plant in intercropping might be due to competition for light, nutrients, and moisture which reduced the growth of component crop. Reported higher cereal grain yield under intercropping system compared to its sole crop (Sikirou and Wydra, 2008).

In Intercropping the production and productivity can be increase by better utilization of available resources and thereby helps to minimize the risks and stability under rainfed conditions. (Triveni *et al.* 2017) It was indicated that under intercropping system such as millet with groundnut the light use efficiency could be an important factor for the yield advantages (Radke and Hagstrom, 1976). (Keating and Carberry, 1993) stated that the by the adoption of a cropping system that either increases the interception of radiation and/or maintains higher radiation use efficiency productivity per unit incident radiation might be improved.

Intercropping of soybean, maize and pigeon pea in 120-cm apart double row strips of cotton proved to be viable as well as convenient for farm operations. Additional production from intercrops obtained from cotton + maize, cotton + soybean and cotton + pigeon pea compensated more than the losses in cotton production. In cereal-legume intercropping systems sub-ordinate legume crops are typically suppressed in their growth and grain yields due to the shading effect of dominant cereal crops or resource competition (Keating and carberry, 1993).

The amendment of utilization plant resources depend on microclimate modification created by two crops selected for intercropping. The effect of temperature, light interception, evapotranspiration, soil moisture storage, and water use efficiency under intercropping system were varied according to crop combination and row arrangements within a combination. The light use efficiency could be an important factor for the yield advantages in intercropping system such as potato with corn. (Sharaiha and Battikhi, 2002). A microenvironmental factor depends on intercropping combinations and row arrangements. The more work of this nature is needed to provide more information in order to improve the intercropping system. The population of different insect pests is reduced in the presence of associated plants

in crop-crop diversity which is brought mainly profitable if suitable intercrop is selected. The intercrops produced substantially smaller fresh weights in either planting patten compared to the yields of sole crop. However, intercropping system as a whole resulted in higher economic returns as compared to the sole crop.

In view of above, an experiment entitled, “Effect of microclimate on pigeon pea (*Cajanus cajan* L.) based intercropping system” will be conducted on following objectives.

Objectives:

- 1) To study the effect of different Pigeon pea based intercrops on microclimate.
- 2) To study the effect of weather parameters on growth and yield of Pigeon pea based intercropping system.



*Review
of
Literature*

CHAPTER – II

REVIEW OF LITERATURE

1. To study the effect of different Pigeon pea based intercrops on microclimate

Ali (1990) stated that in intercrop during early stages the increase in PAR intercepted by soybean after planting was slow but the rate increased during later sample periods. Over the same period monocrop/sole soybean approached 95% PAR interception and the rate of increase slowed as the monocrop approached a critical LAI of about 4.0. In the amount of PAR intercepted per unit LAI alternate narrow rows were more efficient than wide rows.

Lanfontaine *et al.* (1997) explained two models empirical and mechanistic for partitioning of radiation and transpiration within a maize-sorghum intercrop were evaluated against measurements of canopy, radiative balance, ecophysiological and micrometeorological parameters.

Jaya *et al.* (1998) reported that maize plant density and row orientation affected within-canopy temperature and light transmission. Maize planted with N-S orientation at medium density (7.1 plant m⁻²) reduced within-canopy maximum temperatures at 40 cm above the ground by 1.2 °C. The temperature reduction was related with a reduction of irradiance up to 70 %.

Patel *et al.* (1999) stated that in the early growth stage of pigeon pea the growing habitat was very slow and hence more soil near stem portion remained exposed to solar radiation, resulting in higher soil temperatures, whereas in the intercropping system, groundnut achieved leaf area for covering the soil, thereby preventing the increase in soil temperature. This was real till the harvest of groundnut therefore; the temperature was higher in the intercropped system because of elimination of the intercepting medium. At 15 cm depth but with lower magnitude also, similar variations were observed.

Polthane and Vidhaya (2003) observes that there was no significant difference in light penetration (%) through the corn canopy between single corn cropping (60 cm above ground) and corn-peanut, corn-mungbean, corn-soybean intercropping (top of legumes canopy). The light penetration through the corn canopy in corn-peanut, corn-mungbean and corn-soybean intercropping ranged from 46-73% depending on corn growth stage.

Wolfswinkel (2003) showed that when soil cover provided by intercrop and high plant density, a relative low temperature will be maintained within the crop canopy, providing a favourable microclimate for the associated crop.

Awal *et al.* (2006) stated that the planting patterns of maize-peanut intercropping systems can induce changes in the microclimate environment within canopy of the crop, particularly in the light intensity and the spectral properties of the soybean canopy with its lower layer. Suggested that through the efficient utilization of solar energy in maize/peanut intercropping would help to increase production.

Shamim *et al.* (2008) reported that the microclimate of crop stands was largely influenced by air temperature within and above the crop canopy. Temperature profiles were drawn at four phenophases indicated that temperature inside the canopy was lower than that above the canopy in all the treatments (i.e. temperature profiles showed an inversion throughout the day) but slope of the air temperature profiles was greater at vegetative stage than that of later growth phase of crops. There was no significant difference found in temperature profiles of different treatments.

Zhang *et al.* (2008) explained the objectives are measurements during the intercropping phase helps to characterize the spatial distribution of PAR in a cotton-wheat intercrop system, and by using a model for light interception in a row crop helps to estimate PAR interception by component crops and by both monocultures over a growing season,.

Jena *et al.* (2010) reported that the absorption of PAR by canopy of sesame was increased in case of intercropping and the maximum amount of absorption was recorded in 4:1 row ratio; the reverse was true for greengram crop. Under the intercropping of sesamum and greengram reflection from canopy declined which might be due to complex scattering of radiation by both the crops thus the canopy temperatures of both the crops were reduced under intercropping.

Pablo *et al.* (2010) concluded that the enormous effects of shade trees on the microclimate experienced by coffee plants can be summarized as a reduction in transmitted light and betterment in microclimatic conditions through a reduction of air and coffee leaf temperature extremes.

Knorzer *et al.* (2011) studied on analyzing and modeling competitive relationships in a wheat/maize relay intercropping system with regard to yield, solar radiation and microclimate effects.

Hanming *et al.* (2012) analyzed microclimate of maize field including temperature, RH and light intensity in both monocropping and intercropping were continuously investigated by using Multi-channel Data Logger (Hobo H8) analyzed and compared. The results show that the microclimatic condition was improved significantly. Showed the variation in microclimate, including increasing the radiation duration and light intensity at different height position in intercropping field significantly, and remarkable correlation between light intensity and photosynthetic rate implied the variation of light intensity play important role for improving the yield component of maize.

Dahmardeh and Khashayar (2013) showed that the maximum of soil moisture was obtained at sole green gram and in intercropping of 75% green gram + 25% maize. The maximum of soil temperature was obtained at sole maize and in intercropping of 75% maize + 25% green gram.

Emefiene *et al.* (2013) reported that pigeon pea remains one of the most drought tolerant legumes and is the only crop that gives some grain yield during dry spells when other legumes such as field bean will have wilted and dried up. It maintains photosynthetic functions during stress compared to other drought tolerant legumes such cowpea. Its initial slow growth reduces competition for light, water and soil nutrient. Benefits of pigeon pea is moisture storage, its intercropping system provides insurance against total crop failure in droughty prone areas. A few example of suitable intercropping systems under drought are sorghum and pigeon pea; pearl millet and cowpea; sunflower and horse gram.

Xiaobang *et al.* (2015) reported that intercropping systems were improving field microclimatic conditions (e.g. reduced atmospheric temperature, increased RH). Associated climate extremes and given climate change conditions, in a dry year, enhanced RH above the understory crop canopy and lower atmospheric temperature may contribute to less evapotranspirative loss from the understory crop. However, CO₂ concentrations and PAR measured in the intercropping systems were significantly lower than the same parameters measured in the monocropping system, these two parameters had a positive correlation with the net assimilation (NA) of soybeans, and this negatively influenced the final soybean above ground biomass and crop yield.

Dwivedi *et al.* (2015) stated that intercropping maize with cowpea has been reported to increase light interception in the intercrops, improve conservation of the soil moisture and reduce water evaporation compared with maize grown alone.

Koocheki *et al.* (2016) reported that the maximum radiation use efficiency obtained in weed-free intercropping of 75% sesame - 25% mung bean. The results of sesame RUE in weedy intercropping systems also showed that, amount of RUE was improved in all intercropping systems in comparison with sole cropping system. Leaf area index decreased with various weeds because of increasing competition and shared resources. The light extinction coefficient of sesame and mung bean was estimated 0.68 and 0.56 respectively.

Oroka and Frank (2016) evaluated the variation in on-farm soil microclimate, nitrogen mineralization and foliage attributes of cassava as the influenced of intercropping, chemical fertilizer and vermicomposts.

Xin *et al.* (2017) evaluate the intercepted PAR and RUE in maize and soybean under different intercropping systems, tested different strip intercropping configurations and a row intercropping configurations in comparison to monoculture. Results showed that the intercepted PAR and RUE of intercropping systems were all higher than those of monoculture. The soybean intercepted PAR in strip intercropping was 1.35 times greater than that in row intercropping. In row intercropping, the lack of soybean intercepted PAR resulted in a significant reduction of soybean dry matter.

Kresnatita *et al.* (2018) concluded that at monoculture planting the intensity of radiation and air temperature above the canopy of cauliflower is higher than the intercropping system. Arrangements when planting and spacing of sweet corn affect the behavior of microclimate on the canopy of cauliflower plants. The microclimate change corresponding to the growth stage of the cauliflower plant was obtained at arrangement when planting sweet corn two weeks before planting cauliflower and planting distance in sweet corn line 60 cm, which is able to reduce the intensity of radiation and high temperature so that suitable for cultivation of cauliflower at the intensity and high temperature.

2. To study the effect of weather parameters on growth and yield of Pigeon pea based intercropping system

Marshall and Willey (1983) reported that in pearl millet/groundnut intercropping per row, the millet intercepted 2.1 times more PAR in the intercrop than in the monocrop and used it with a similar efficiency to produce twice as much dry matter. Per row in the intercrop, the groundnut intercepted 27% less PAR than in the monocrop but used it with 46% greater efficiency to yield the same.

Keating and Carberry (1993) stated that in sorghum-groundnut intercropping system, intercropped sorghum had 20% lower RUE than sole cropped sorghum, through by contrast intercropped groundnut had about 20% higher RUE than sole cropped groundnut. The RUE of sorghum decreased and the RUE of groundnut increased resulted in no intercrop yield advantage under that situation.

Soetedjo *et al.* (1998) indicated that higher evapotranspiration of peas and canola intercropped system was related to their higher yield production as compared to their sole crop.

Selvaraju and Balasubramanian (2001) concluded that in low rainfall year during which rainfall was lower, compartmental bunding stored higher moisture and it led to favourable micro-climate and higher yield of component crops in both sorghum + pigeonpea and pearl millet + cowpea intercropping systems.

Tsubo *et al.* (2001) investigated that the production efficiency of intercrop with production efficiency of sole crop in terms of the fraction of radiation intercepted, Radiation use Efficiency (RUE) and Harvest Index (HI) considering the effect of row orientation. Concluded that the more PAR energy intercepted by intercrop than sole maize, and was equivalent to sole beans. Radiant energy more efficiently utilized by sole maize than the intercrop and had greater RUE than sole beans and finally no differences in HI were found among cropping system. The higher radiation interception of intercrop resulted from the high LAI, and the higher RUE of sole maize resulted from the greater energy conversion by C₄ plant Species.

Rodrigo *et al.* (2001) stated that the additional radiation captured by the intercrop canopy facilitates large dry matter accumulation and may lead to more seed yields in rubber/banana intercropping system.

Sharaiha R.K. and Hadidi N.A. (2002) Studied that the effect of light intensity, evapotranspiration, air and soil temperature, soil moisture storage, and water

use efficiency on the yield of okra and pea as they were grown under sole cropping and intercropping systems with four row arrangements (1:1 ,1:2 ,2:1 ,2:2).

Reynolds *et al.* (2006) examined tree competition significantly reduced PAR , net assimilation and growth and yield of individual soybean or corn plants growing nearer (2m) to tree rows.

Lingaraju *et al.* (2007) concluded that intercropping system of maize and pigeon pea (50%) at 4:2 row ratio is more remunerative and productive than sole crop of maize or pigeon pea and other intercropping system under rainfed conditions of northern transitional zone of karnataka.

Dudhade *et al.* (2009) showed that sole pigeon pea gave significantly higher grain yield per hectare followed by pigeon pea + mungbean (1:3). All other intercropping treatments gave comparatively minimum grain yield of pigeon pea because of severe completion for light, water, space and nutrient. Among sole crop pigeon pea was more remunerative followed by soybean.

Ghanbari (2010) observed that intercropping achieved the highest light interception, soil moisture, soil temperature and yield, compared to sole crops. Furthermore, microclimatic variation exerted by intercropping caused favourable environmental conditions, conducive for growth and high yield compared to sole crops.

Lott *et al.* (2009) observed a reduction in biomass and grain yield in maize when incident radiation was reduced under combined canopy of forest and maize.

Yahuza (2011) indicated that the impact of both intercepted photosynthetically active radiation and radiation use efficiency for growth and yield of crops and intercrops. Growth and final yields of crops is mainly dependant on the amount of intercepted photosynthetically active radiation and the radiation use efficiency by crops and/or intercrops.

Wang *et al.* (2015) reported that the yield, either decrease of intercropped cabbage due to more shade from maize or increase of intercropped maize due to more PAR being obtained, was a positive linear function of PAR which was concern to the number of intercropping rows of two crops with a negative linear function for maize and a positive logarithmic function for cabbage, respectively.

Thimmegowda *et al.* (2016) concluded that in an assessment of different intercropping systems in red soils of Ramanagara and Bengaluru Rural

districts, groundnut + pigeon pea (8:2), finger millet + pigeon pea (8:2) and pigeon pea + field bean/cowpea (1:1) were found to be economical and climate resilient in dryland situations. Hence, solution to obtain higher productivity diversified food products and reduced risk of crop failure under rainfed conditions offered by intercropping system.

Liu *et al.* (2017) concluded that in maize soybean intercropping system the changes in the light environment led to increased internode length, plant height and specific leaf area, but reduced branching. These morphological changes enabled relatively more light interception and increased light use efficiency of soybean due to the shading effect caused by maize. However, these positive responses could not compensate the effect of reduced leaf area and total light interception, leading to reduced biomass and grain production.

Nandini *et al.* (2017) examine the response of three cluster bean genotypes viz, RGC-1003, RGC-936 and HG-365 with four planting densities viz, 45cm×15cm, 30cm×15cm, 45cm×10cm and 30cm×10cm. The spacing 30cm×10cm planting density was recorded higher total dry matter, leaf area, leaf area index and interception of light during most of the growth period and attained full radiation interception at 90 DAS than other planting densities. The intercepted PAR, extinction coefficient and RUE increased with higher planting density. Dry matter production was significantly correlated with RUE. The RUE higher value obtained were for RGC-1003 compared to other genotypes. It was noticed that the conversion efficiency of incident PAR to dry matter production varied much with three genotypes and four levels of spacing. The production of dry matter productivity of cluster bean is corresponding to solar radiation.

Barthwal *et al.*(2018) pointed out that, the competition between pigeonpea and maize for sunlight, space, water, nutrients etc. was more as compared to urdbean which resulted in poor growth and development of pigeonpea under pigeonpea + maize intercropping system.

Iqbal *et al.* (2018) found that improvement of field microclimate including temperature, relative humidity and light intensity is considered a key factor for increased yield in maize-soybean intercropping systems. High temperature, light intensity and low humidity in intercropping systems raise the photosynthetic rate of leaves and improve the biological characters of maize plant. Maize is a dominant crop

capturing more sunlight as compared to soybean in maize soybean intercropping system.

Karale *et al.* (2018) revealed that, among different intercropping systems safflower + linseed (2:2) intercropping systems recorded altogether higher light interception which was comparable to safflower + linseed (1:2) in 30 cm row proportion. The growth indices like number of primary and secondary branches, plant height, TDMP (Total Dry Matter Production) were significantly higher observed in sole safflower and linseed this might be owing to there is no inter and intraspecific computation between two different species whereas, the leaf area and leaf are index was recorded significantly higher in safflower + linseed in 1:2 rows proportions. The safflower + linseed (1:2) intercropping systems recorded significantly higher safflower equivalent yield (1686 kg ha^{-1}) followed by safflower + linseed (1:1) row proportion (1450 kg ha^{-1}). Higher B : C and net returns was recorded in safflower + linseed in 1:2 row ratio (2.22 and 23.212 ha^{-1}) followed by sole linseed (19.376 ha^{-1}) and sole safflower (1:1) ($18,979 \text{ ha}^{-1}$).



*Material
and
Methods*

CHAPTER – III

MATERIALS AND METHODS

A field experiment “Effect of microclimate on Pigeon pea (*Cajanus cajan* L.) based intercropping system” was conducted during the *kharif* season of 2019-20 at experimental farm of the Department of Agricultural Meteorology located at College of Agriculture, Vasant Rao Naik Marathwada Krishi Vidyapeeth, Parbhani.

The details of the materials used and methods adopted during the present investigation, on different crops are narrated under following heads are briefly presented in this chapter.

3.1 Details of experimental site

The investigation carried out at Experimental Farm, Department of Agricultural Meteorology, V. N. M. K. V., Parbhani. Agro climatically Parbhani situated at latitude, longitude and altitude of, 19°16’N, 76°47’E and 409 m above M.S.L. (Mean Sea Level), respectively.

3.1.1 Soil type

The field selected for experiment is uniform with typical black cotton soil having medium fertility and fairly good drainage.

3.2 Agro climatic situation

The climate of Marathwada region on annual basis can be classified as semi arid type. The region experiences hot and dry summer, cold dry winter and wet humidity with medium rainfall in monsoon season.

3.2.1 Climatic condition during 2019-20

The weather data for the relevant period of experiment recorded at central Meteorological Observatory, Department of Agricultural Meteorology, Vasant Rao Naik Marathwada Krishi Vidyapeeth, Parbhani are presented in Table. 4.1.

3.3 Experimental and treatment details

In the present investigation single sowing date at the nine treatments of different crops with varieties were tried and the details of treatment and experiment are listed below.

Experimental details:

The experimental details about design, number of treatments, number of replications, total number of plots, plots size, replications, plot to plot, varieties, spacing of crops are given below.

Design	Randomized Block Design (RBD)
Number of treatments	9
Number of replications	3
Total number of plots	27
Plot size	4.5 m × 5.4 m
Replications	0.5 m
Plot to plot	1.0 m
Varieties	Pigeon pea – BDN-711 Sorghum – Parbhani Shakti Maize – Dekalb Soyabean – MAUS-158 Sesamum – JLT- 408
Spacing	Pigeon pea – 90 cm × 20 cm Sorghum – 45 cm × 15 cm Maize – 60cm × 30 cm Soyabean – 45 cm × 5cm Sesamum – 30 cm × 15 cm

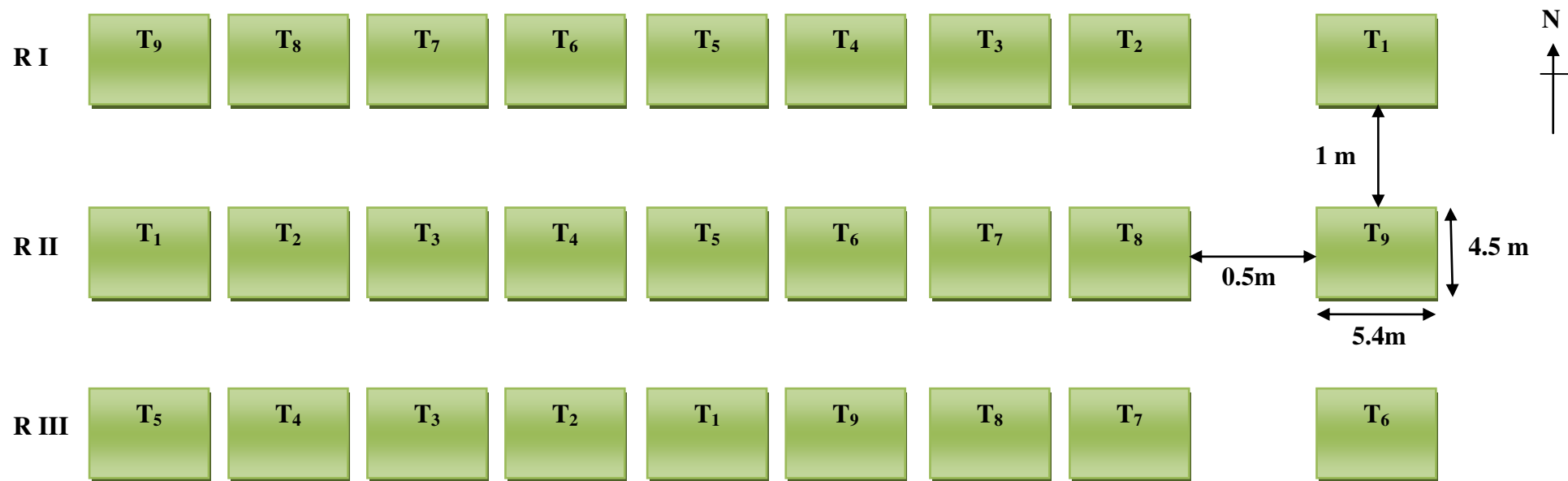
Treatment details:

The treatment details about date of sowing, season, crops, different treatments, ratio of component crops, fertilizer dose, soil type and irrigation is given below.

- 1) Date of sowing 2 July 2019
- 2) Season *Kharif* 2019
- 3) Crops
Pigeon pea - (*Cajanus cajan* L.)
Sorghum - (*Sorghum bicolor*)
Maize - (*Zea mays*)
Soybean - (*Glycine max* L.)
Sesamum - (*Sesamum indicum*)
- 4) Treatments
T₁: (Pigeon pea + Sorghum)
T₂: (Pigeon pea + Maize)
T₃: (Pigeon pea + Soybean)
T₄: (Pigeon pea + Sesamum)
T₅: (Pigeon pea)
T₆: (Sorghum)
T₇: (Maize)
T₈: (Soybean)
T₉: (Sesamum)
- 5) Ratio of component crop 4:2
- 6) Fertilizer dose
(NPK kg ha⁻¹)
Pigeon pea - (25:50:25)
Sorghum - (80:40:40)
Maize - (150:75:75)
Soybean - (30:60:30)
Sesamum - (30:60:60)
- 7) Soil Medium
- 8) Irrigation Rainfed

Table.3.1 Experimental and treatment details

Experimental details:		
1)	Design	Randomized Block Design (RBD)
2)	Number of treatments	9
3)	Number of replications	3
4)	Total number of plots	27
5)	Plot size	4.5 m × 5.4 m
6)	Replications	0.5 m
7)	Plot to plot	1.0 m
8)	Varieties	Pigeon pea – BDN-711 Sorghum – Parbhani Shakti Maize – Dekalb Soyabean – MAUS-158 Sesamum – JLT- 408
9)	Spacing	Pigeon pea – 90 cm × 20 cm Sorghum – 45 cm × 15 cm Maize – 60cm × 30 cm Soyabean – 45 cm × 5cm Sesamum – 30 cm × 15 cm
Treatment details:		
1)	Date of sowing	2 July 2019
2)	Season	<i>Kharif</i> 2019
3)	Crops	Pigeon pea (<i>Cajanus cajan</i> L.) Sorghum (<i>Sorghum bicolor</i>) Maize (<i>Zea mays</i>) Soybean (<i>Glycine max</i> L.) Sesamum (<i>Sesamum indicum</i>)
4)	Treatments	T ₁ : Pigeon pea + Sorghum T ₂ : Pigeon pea + Maize T ₃ : Pigeon pea + Soybean T ₄ : Pigeon pea + Sesamum T ₅ : Pigeon pea T ₆ : Sorghum T ₇ : Maize T ₈ : Soybean T ₉ : Sesamum
5)	Ratio of component crop	4:2
6)	Fertilizer dose (NPK kg ha ⁻¹)	Pigeon pea (25:50:25) Sorghum (80:40:40) Maize (150:75:75) Soybean (30:60:30) Sesamum (30:60:60)
7)	Soil	Medium
8)	Irrigation	Rainfed



Design – RBD

Replication – 3

Treatment – 9

Plot size – 4.5 m × 5.4 m

Fig. 3.1 Plan of Layout



Plate.1. Overall performance of Pigeon pea + Sorghum (T₁) intercropping



Plate.2. Overall performance of Pigeon pea + Maize (T₂) intercropping



Plate.3. Overall performance of Pigeon pea + Soybean (T₃) intercropping



Plate.4. Overall performance of Pigeon pea + Sesamum (T₄) intercropping



Plate.5. Overall performance of sole Pigeon pea (T₅)



Plate.6. Overall performance of sole Sorghum (T₆)



Plate.7. Overall performance of sole Maize (T₇)



Plate.8. Overall performance of sole Soybean (T₈)



Plate.9. Overall performance of sole Sesamum (T₉)

3.4 Cropping history of the experimental field

The cropping pattern followed in the experimental plot during preceding three years and present experimentation is given in Table 3.2.

Table.3.2 Cropping history of the experimental plot (field trial)

Sr. No.	Year	Sequence of crop grown		
		<i>Kharif</i>	<i>Rabi</i>	<i>Summer</i>
1	2016-2017	Soybean	Fallow	Fallow
2	2017-2018	Finger millet	Fallow	Fallow
3	2018-2019	Present investigation	-	-

The data presented in above revealed that residual effect of previous cropping on soil fertility.

3.5 Agronomical practices

3.5.1 Preparatory cultivation

The experimental area was ploughed once and harrowed once to obtain the good tilth. The experimental field was laid out as per the plan of layout. The schedule of cultural operations undertaken is prescribed in Table 3.3.

3.5.2 Fertilizer application

The recommended dose of fertilizer (RDF) for pigeon pea is 25:50:25 NPK kg ha⁻¹, 80:40:40 NPK kg ha⁻¹ for sorghum, maize 150:75:75 NPK kg ha⁻¹, soybean 30:60:30 NPK kg ha⁻¹ and sesamum 30:60:30 NPK kg ha⁻¹. Sorghum, maize required split dose of N. Accordingly, the fertilizer requirement was calculated as per the treatment for each plot.

3.5.3 Seeds and sowing

Pure seed of pigeon pea variety BDN- 711, sorghum- Parbhani Shakti, maize- Dekalb, soybean- MAUS-158 and sesamum- JLT 408 were used. The sowing was done by dibbling seeds at proper depth. The emergence of seedling was started 5 days after sowing and completed by 8-10 days.

3.5.4 Inter cultivation

Two weeding at 30 DAS and 45 DAS were carried out to control weeds and conserve soil moisture.

Table.3.3 Date wise schedule of cultural operations carried out in experimental plot during Kharif 2019-20

Sr. No.	Particulars	Frequency	Date of operation
A) Pre sowing cultural operation			
1	Ploughing	1	25/04/2019
2	Harrowing	1	07/06/2019
3	Cleaning of field	1	17/06/2019
4	Layout of experiment	1	20/06/2019
B) Sowing operation			
1	Sowing and fertilizer Application	1	02/07/2019
C) Inter cultural operation			
1	Hand weeding	2	17-18/07/2019 12-13/08/2019
2	Gap filling	1	11/07/2019
D) Plant protection measures			
1	Spraying of insecticide	2	13/08/2019 28/08/2019
E)	Harvesting	1	Sesamum (03/10/2019) Soybean (10/10/2019) Maize (16/10/2019) Sorghum (29/10/2019) Pigeon pea (19/12/2019)
F)	Threshing	1	Sesamum (09/10/2019) Soybean (18/10/2019) Maize (27/10/2019) Sorghum (08/11/2019) Pigeon pea (29/12/2019)

3.5.5 Plant protection

One to two spraying carried out for each plot for controlling the insect pest disease.

3.5.6 Harvesting and threshing

Harvesting was done at maturity, the crop plants in each net plot were cut to ground level with the help of sickle. The plot wise harvested plants were collected and dried separately for a week. Then threshing and cleaning was done. Weight of biological, seed and straw yield were recorded separately for each net plot.

3.6 Bio-metric observation

Details of biometric observations recorded during the course of study. Plant height, number of leaves, dry matter accumulation per plant was recorded at each 15 days interval for short duration crop and 30 days interval for long duration

crop up to harvest of the crop. The details of observations along with frequency are presented in Table 3.4.

3.6.1 Sampling technique

From each sole crop plot five plants and in intercrop plot three of main and two of inter crop were selected at random. Bamboo pegs were fixed near the observational plants and were labeled with tags for identifying their location. The various biometric observations were recorded from selected plants from each net plot, these plants were separately harvested at maturity for assessing their yield and yield attributes.

3.6.2 Pre harvest studies

3.6.2.1 Emergence count and final plant count

The number of emerged plants from each net plot was recorded on 10 DAS. Final plant stand per net plot was recorded at harvest.

3.6.2.2 Height of plant (cm)

Height of the randomly selected five plants was measured in cm from ground level to the base of last fully opened leaf of sesamum, soybean, maize and sorghum at various dates of observation starting from 15 DAS, and long duration crop that is pigeon pea observation dates starting from 30 DAS.

3.6.2.3 Number of functional leaves plant⁻¹

The total number of functional leaves plant⁻¹ (Trifoliolate as one in case of soybean and pigeon pea) from five observational plants were counted and recorded at 15 DAS for short duration crop and 30 DAS for long duration crop up to till harvest. All the fully opened leaves from each plant were recorded as functional leaves.

3.6.2.4 Dry matter plant⁻¹ (g)

One representative sample from each net plot was selected randomly and uprooted at each observation dates for dry matter studies, roots were discarded for any dry matter studies and the rest of the plant was kept in well labeled brown paper bags for drying. Initially, plant samples were sun dried for two to three days followed by oven drying at a constant temperature of $62^{\circ}\text{C} \pm 2^{\circ}\text{C}$ until constant dry weight was obtained. After, air cooling the dry weight plant⁻¹ was recorded.

Table.3.4 Details of bio-metric and other observations recorded during present investigation

Sr. No.	Particulars	Frequency	DAS	Sampling index
A) Pre-harvest studies				
1	Emergence count	1	10	Net plot
2	Final plant stand	1	At harvest	Net plot
3	Height of plant (cm)	-	15 DAS – (Sorghum, Maize, Soybean and Sesamum) 30 DAS – (Pigeon pea)	Five plants net plot ⁻¹
4	No. of functional leaves plant ⁻¹	-	15 DAS – (Sorghum, Maize, Soybean and Sesamum) 30 DAS – (Pigeon pea)	Five plants net plot ⁻¹
5	Dry matter plant ⁻¹ (g)	-	15 DAS – (Sorghum, Maize, Soybean and Sesamum) 30 DAS – (Pigeon pea)	Five plants net plot ⁻¹
6	Days to maturity	1	-	-
B) Post harvest studies				
1	Grain yield plot ⁻¹	1	At harvest	Net plot
2	Stalk yield plot ⁻¹	1	At harvest	Net plot
3	Biological yield plot ⁻¹	1	At harvest	Net plot
4	Land Equivalent Ratio (LER)	1	At harvest	Net plot
C) Meteorological Observations				
1	Weekly Weather observations	-	Total period	27 MW to 51 MW
2	Micrometeorological observations	-	30 DAS	Net plot
3	Agro meteorological indices	-	-	At each phenophase stage

3.6.3 Post harvest studies

3.6.3.1 Seed Yield (Kg ha⁻¹)

Biomass from each plot was threshed and seeds were separated by winnowing and seed yield recorded in kg net plot⁻¹. From this, seed yield per hectare was calculated by using the following formula.

$$\text{Seed yield (Kg ha}^{-1}\text{)} = \frac{\text{Seed yield of net plot}}{\text{Net plot size (m}^2\text{)}} \times 10000$$

3.6.3.2 Pigeon pea Equivalent Yield (PEY)

On the basis of Govt. minimum support price (MSP) of pigeon pea, sorghum, maize, soybean and maize seed the yield of each treatment for both component crops converted into crop equivalent yield of pigeon pea crop. The pigeon pea equivalent (PYE) (Kg ha⁻¹) is calculated as follows:

$$\text{PEY} = P_{ab} + \frac{N_{ab} \times N_{mp}}{P_{mp}}$$

Where,

PEY = Pigeon pea equivalent yield (Kg ha⁻¹)

P_{ab} = Yield of pigeon pea in intercropping system (Kg ha⁻¹)

N_{ab} = Yield of intercrop (sorghum, maize, soybean and sesamum) in intercropping system (Kg ha⁻¹)

N_{mp} = Market price of intercrop (sorghum, maize, soybean and Sesamum) (Rs Kg⁻¹)

P_{mp} = Pigeon pea market price (Rs Kg⁻¹)

3.6.3.3 Stalk yield (Kg ha⁻¹)

After harvesting, the sun dried produce was weighed from each treatment plot. This biological yield per plot was then converted on hectare basis.

3.6.3.4 Biological yield (Kg ha⁻¹)

The figures of biological yield were calculated by the addition of seed yield and straw yield of net plots. Finally it was converted on hectare basis.

3.6.3.5 Land Equivalent Ratio (LER)

The intercropping efficiency was assessed using the Land Equivalent Ratio according to Mead and Willey (1980) using the formula:

$$\text{LER} = \frac{\text{YA}}{\text{SA}} + \frac{\text{YB}}{\text{SB}}$$

Where,

YA and YB = individual crop yields in intercropping and

SA and SB = the crop yields as sole crops

LER > 1 indicates intercrop advantage

3.7 Meteorological observations

The daily observations of air temperature rainfall (mm), temperature ($^{\circ}\text{C}$), relative humidity (%), bright sunshine hours, wind speed (km hr^{-1}), rainy days are recorded at the observatory of Agriculture meteorology Department situated in V.N.M.K.V. Parbhani. The daily observations converted on weekly basis and used for analysis.

3.8 Microclimatic studies

3.8.1 Available soil moisture

The soil moisture content at 0-15 cm, 15-30 cm, and 30-45 cm soil depths was determined by gravimetric method at 30 days interval *i.e.* 30, 60, 90,120 and 150 days after sowing. Conversion of soil moisture into volumetric content was done using the following formula.

$$\text{Moisture content} = \frac{W_1 - W_2}{W_2} \times 100$$

Where,

W_1 = Weight of moist soil sample (g)

W_2 = Weight of oven dry soil sample (g)

3.8.2 Canopy temperature ($^{\circ}\text{C}$)

The canopy temperature was recorded in a day *i.e.* at afternoon hours by using infrared thermometer at 30 days interval *i.e.* 30, 60, 90,120 and 150 days after sowing.

3.8.3 Relative humidity (%)

The relative humidity was recorded in a day *i.e.* at afternoon hours by using 4-in-1 precision humidity and temperature meter at 30 days interval *i.e.* 30, 60, 90,120 and 150 days after sowing.

3.9 Computation of Agrometeorological indices

3.9.1 Growing Degree Days (GDD) ($^{\circ}\text{C day}$)

Growing Degree Days is defined as “the sum over the growing season of a crop of the difference between the daily temperature and a reference



Plate.10. Infrared Thermometer



Plate.11. 4-in-1 Precision Humidity and Temperature Meter

temperature”. GDD was expressed in terms of $^{\circ}\text{C}$ day. The total GDD for different phenophases were determined by the following formula. (Nuttonson, 1955).

The base temperature (8°C) for all the crops in the study, following Schenkler and Roberts, (2009). This is because the literature indicates that the base temperature for most crops ranges between 5 to 10°C (Luo, 2011).

$$\text{GDD } (^{\circ}\text{C day}) = \sum [(T_{\text{max}} + T_{\text{min}})/2] - T_b$$

Where,

T_{max} = Daily maximum air temperature ($^{\circ}\text{C}$)

T_{min} = Daily minimum air temperature ($^{\circ}\text{C}$)

T_b = Base temperature ($^{\circ}\text{C}$)

3.9.2 Helio Thermal Units (HTU) ($^{\circ}\text{C}$ day hrs)

The HTU may be defined as “the accumulated product of GDD and bright sunshine hours between the developmental thresholds for each day” and HTU was expressed in terms of $^{\circ}\text{C}$ day hrs.

The HTU is the product of GDD and mean daily hours of bright sun shine. The sum of HTU for each phenophase was worked out by following equation which was given by Singh *et al.* (1990).

$$\text{HTU} = \text{GDD} \times \text{Mean BSS}$$

Where,

BSS = Bright Sunshine Hours

3.9.3 Photo Thermal Units (PTU) ($^{\circ}\text{C}$ day hrs)

PTU may be defined as “the product of growing degree days and the day length” expressed in terms of $^{\circ}\text{C}$ day hrs.

PTU was computed by using following formula. This was proposed by Gudadhe *et al.* (2013).

$$\text{PTU} = \text{GDD} \times \text{Day length}$$

Day length for sorghum, soybean, sesamum and pigeon pea (10 hrs) and for maize (12 hrs) Qiang *et al.* (2015).

3.10 Correlation studies

Simple correlation between weather parameters i.e. Rainfall, Rainy days, Maximum temperature, Minimum temperature, Relative humidity, Evaporation, Bright sun shine hours and wind velocity on the development of crop was estimated to know the correlation between these weather parameters and seed yield of pigeon pea.

The procedure and formula described by Snedecor and Cochran (1968) were adopted and significance was test

$$r = \frac{\sum xy}{\sqrt{(\sum x)(\sum y)}}$$

Where,

r = Correlation coefficient

x = Independent variables (attributed)

y = Dependent variable (attributed)

A decorative gold frame with intricate floral and scrollwork motifs at the corners and along the sides. The frame is L-shaped, with the top and left sides being vertical and the bottom and right sides being horizontal. The text is centered within the frame.

*Results and
Discussion*

CHAPTER – IV

RESULTS AND DISCUSSION

A field experiment entitled “Effect of microclimate on pigeon pea (*cajanus cajan* l.) based intercropping system.” was conducted during the *Kharif* season of 2019-20 in the Experimental farm of the Department of Agricultural Meteorology V.N.M.K.V. Parbhani.

4.1 Weather condition during crop growth period

The weather conditions prevailed during the crop growing season i.e. *kharif* 2019-20 were presented graphically depicted by plotting different meteorological elements observed mean values over standard meteorological week. The weather elements discussed viz., rainfall and rainy days, air temperature, relative humidity, evaporation, bright sunshine hours and wind velocity. The meteorological data (Table 4.1) for the corresponding period of experiment are recorded at central agro meteorological observatory. Department of Agricultural Meteorology, V.N.M.K.V., Parbhani.

4.1.1 Rainfall (mm day⁻¹) and Rainy days

The data of rainfall and rainy days are given in Table 4.1 and depicted in Fig 4.1 (a) which revealed that total rainfall received during period (26 MW to 51 MW) was 918.4 mm in 49 rainy days. The first rain shower 6.0 mm was received in 25 MW and 46.9 mm rainfall as a monsoon was received in 26 MW. Rainfall was received 46.9 mm during a span of 8 days which was sufficient to undertake sowing operation. Therefore sowing of crop was undertaken during 27 MW (2nd July).

Sufficient rains for initial crop growth and development and which was recorded to the 10.6, 34.2, 11.2 and 64.3 mm in 27th, 28th, 29th and 30th MW respectively, which resulted in better germination of seed and emergence of crops in the experimental field. The rainfall received during 29th MW was observed advantageous to initial crop growth. Cumulatively 738.2 mm rainfall and 34 rainy days were received during 31 to 43 MW, which helped for better growth and yield of crops.

4.1.2 Air Temperature ($^{\circ}\text{C}$)

Data given in Table 4.1 and graphically depicted in Fig. 4.1 (b) showed that the temperature prevailed during different phenological stages of crop. The data showed that, the minimum and maximum temperature during crop growing period (July to December) range between 13.2°C and 34.2°C respectively.

During 27th MW i.e. at the time of sowing the highest maximum temperature was recorded 33.2°C , the maximum temperature range a from 29.5°C to 36°C and the minimum temperature range from 22.5°C to 24.2°C .

Highest minimum temperature was recorded at 27th MW (23.1°C) and the lowest minimum temperature recorded in 51th MW (14.9°C) during crop growing period. However, the highest maximum temperature was recorded during 51th MW (28.3°C).

4.1.3 Relative humidity (%)

Weekly weather data presented in Table 4.1 and graphically depicted in Fig. 4.1 (b). It showed that weekly mean relative humidity of morning (RH-I) and afternoon (RH-II) hours during the crop growing period (July to December) was ranged between 84 percent and 57 percent for respectively.

Fig 4.1 (b) showed that RH-I ranged from 76 percent to 94 percent and RH-II ranged from 44 percent to 85 percent.

Highest RH-I was recorded in 38th MW (94 %) and lowest in 27th MW (76 %). While, highest RH-II was recorded in 31th MW (85 %) and lowest in 47th MW (44 %).

4.1.4 Evaporation (mm)

The data given in Table 4.1 and graphically depicted in Fig. 4.1 (c) revealed that the weekly mean evaporation 3.9 mm day^{-1} was recorded during crop growing period. This was ranged between 2.0 to 7.0 mm day^{-1} .

During crop growing season evaporation values were lowest and highest in 31th MW and 29th MW, 2.1 mm day^{-1} and 6.6 mm day^{-1} respectively.

The lowest values of evaporation were recording during 31th MW (2.1 mm day^{-1}) due to continuous rainfall and lowest temperature during this week while,

highest evaporation was recorded during 29 MW (6.6 mm day^{-1}) because maximum temperature during this week.

4.1.5 Bright sunshine hours (hrs day^{-1})

The data given in Table 4.1 and graphically depicted in Fig. 4.1 (c) showed that during crop growing period (26 MW to 51 MW) weekly mean BSS were recorded 5.8 hrs which was ranged between 1.0 to 9.0 hrs.

The highest BSS was recorded during 45th MW (8.6 hrs). Lowest BSS was recorded during 31th MW (1.2 hrs) when 855.4 mm of rainfall was recorded.

4.1.6 Wind velocity (Km hr^{-1})

The data on mean wind velocity during crop growing period are given in Table 4.1 and graphically depicted in Fig. 4.1 (c) it observed that, the weekly mean wind velocity during crop growing period was recorded 4.3 Km hr^{-1} .

It was observed that highest weekly wind velocity (8.3 Km hr^{-1}) was recorded in 27th MW and lowest wind velocity (1.6 Km hr^{-1}) was recorded during in 45th MW. Lower wind velocity seems to be helpful for decrease in ET.

Table.4.1 Weekly weather data during crop growing period 2019-20

Sr.no.	MW	RF (mm)	RD	Temperature (°C)		Relative Humidity (%)		EVP (mm)	BSS (hrs)	WS (Km/hr)
				Max.	Min.	RH I	RH II			
1	26	46.9	4	33.2	22.7	85	59	4.9	4.8	5.6
2	27	10.6	1	33.2	23.1	76	58	5.1	2.7	8.3
3	28	34.2	3	33.5	22.6	83	49	5.5	6.7	7.0
4	29	11.2	2	34.2	22.9	79	46	6.6	7.7	5.8
5	30	64.3	3	30.6	22.6	81	62	4.5	4.1	6.3
6	31	85.4	5	28.1	21.8	92	85	2.1	1.2	6.6
7	32	62.2	3	30.5	22.0	89	65	4.0	3.5	6.2
8	33	9.7	1	32.3	21.5	80	57	4.6	5.4	4.6
9	34	1.2	0	32.2	22.0	80	56	5.6	6.5	6.0
10	35	78.0	3	31.2	21.5	88	59	4.6	5.6	4.7
11	36	13.2	1	30.1	21.6	83	70	2.9	2.0	4.7
12	37	86.4	3	30.0	21.2	88	68	2.8	4.7	5.4
13	38	118.8	5	30.9	21.9	94	67	2.3	5.1	3.5
14	39	35.6	3	31.3	21.1	92	62	3.7	6.5	3.3
15	40	21.2	2	31.4	20.5	88	60	3.8	7.3	2.8
16	41	5.1	1	31.5	20.1	87	53	4.1	7.0	2.7
17	42	121.4	3	30.1	18.6	82	55	3.5	5.9	4.1
18	43	100.0	4	29.7	20.6	82	63	2.4	4.3	3.6
19	44	13.0	2	30.4	20.7	84	62	3.2	6.9	3.8
20	45	0.0	0	31.4	18.4	89	48	3.4	8.6	1.6
21	46	0.0	0	30.0	14.7	77	45	3.7	8.3	2.7
22	47	0.0	0	30.0	13.2	81	44	3.4	8.5	2.1
23	48	0.0	0	30.1	15.4	80	46	3.8	7.9	2.6
24	49	0.0	0	28.9	14.8	76	46	4.2	7.4	3.5
25	50	0.0	0	30.0	15.6	86	44	3.6	7.1	2.5
26	51	0.0	0	28.3	14.9	88	44	3.3	6.1	2.9
Total / Avg.		918.4	49	30.9	19.9	84	57	3.9	5.8	4.3

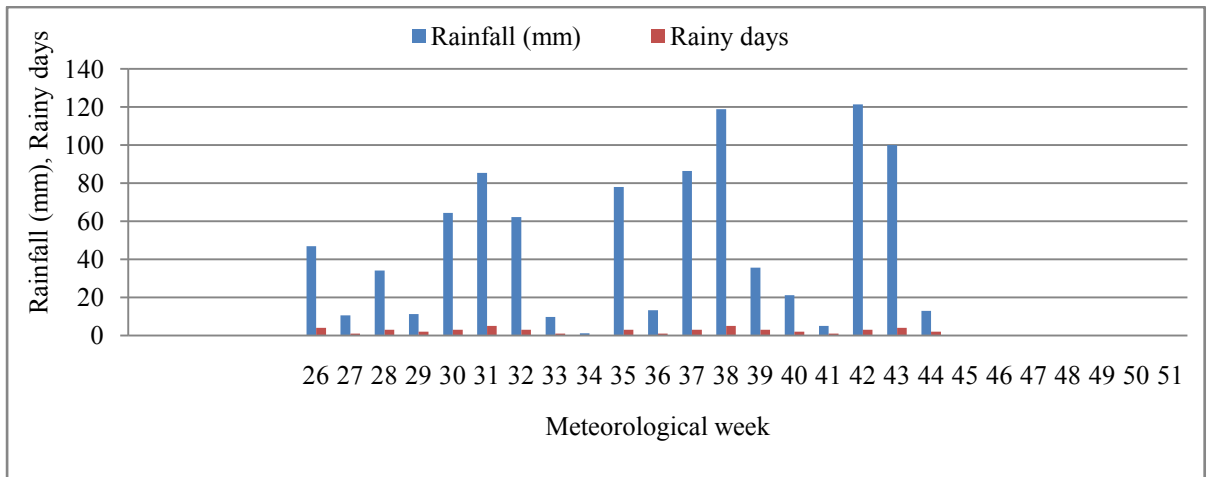


Fig.4.1 (a) Weekly Rainfall (mm) and Rainy days during crop growing period

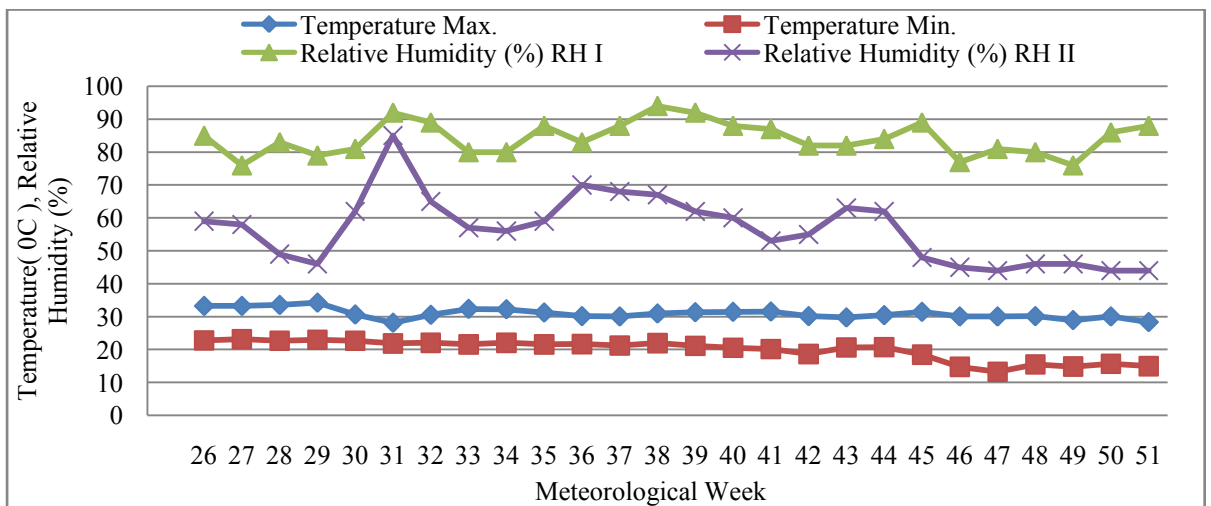


Fig.4.1 (b) Weekly Temperature (°C) and Relative humidity (%) during crop growing period

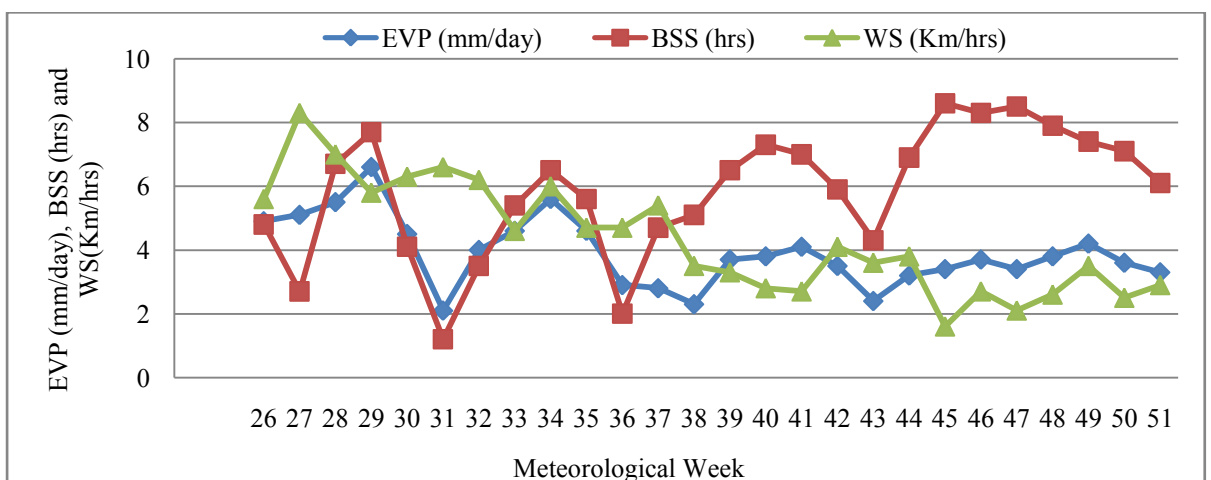


Fig.4.1 (c) Weekly EVP (mm/day), BSS (hrs) and WS (Km/hrs) during crop growing period

4.2 Phenophase wise weather condition prevailed during different treatment

The effect of weather parameters on crop physiology was expressed directly on the phenology. The duration required for each phenophase as influenced by different treatments.

In the present investigation, the whole life cycle of crops (from sowing to physiological maturity) was divided into various distinct phenophases on the basis of external morphological characteristics.

4.2.1 Phenophase wise weather parameters in Pigeon pea

The data given in Table 4.2 and graphically depicted in Fig. 4.2 revealed that average weather condition observed at different phenophases of pigeon pea.

The data revealed that the rainfall received during each phenophases and the total rainfall received at each phenophases from emergence to maturity was recorded 893.9 mm. The highest rainfall (359.6 mm) was received during branching to flowering (P_3) stage, while lowest rainfall (14.3 mm) was received during sowing to emergence (P_1) stage of pigeon pea.

The total rainy days at each phenophase during the pigeon pea crop sown in 27th MW was recorded 46 rainy days. The highest rainy days (18) were recorded during emergence to branching (P_2) and branching to flowering (P_3) stage, while, the lowest rainy days (1) recorded during sowing to emergence (P_1) stage.

The diurnal temperature variation during the pigeon pea sowing in 27th MW showed the average maximum temperature (T_{max}) 31.3 °C, minimum temperature (T_{min}) 20.5 °C and mean temperature ($T_{avg.}$) 25.9 °C. The highest maximum temperature (33.5 °C) and the lowest minimum temperature (16.7 °C) were recorded respectively at sowing to emergence (p_1) and pod formation to physiological maturity (P_5) stage.

The diurnal relative humidity variation during the pigeonpea sowing in 27th MW showed that the mean morning relative humidity (RH-I) 83 %, evening relative humidity (RH-II) 57 % and average relative humidity (RH avg.) 70 %. The highest RH-I (87 %) and RH-II (62 %) recorded at emergence to branching (P_2) and

branching to flowering (P₃) stage. While, lowest RH-I (76 %) and RH-II (50 %) recorded at sowing to emergence (P₁) and pod formation to physiological maturity (P₅) stage, respectively.

The data on average evaporation recorded at each phenophase showed that evaporation at each phenophase was observed 4.2 mm day⁻¹. The highest evaporation 5.3 mm day⁻¹ was recorded during sowing to emergence (P₁) stage and the lowest evaporation 3.5 mm day⁻¹ was recorded during pod formation to physiological maturity (P₅) stage of pigeon pea.

The average bright sunshine hours recorded in pigeon pea during 27th MW was 5.3 hrs day⁻¹. The highest BSS (7.4 hrs day⁻¹) was recorded during pod formation to physiological maturity (P₅) and lowest BSS (3.4 hrs day⁻¹) was recorded during sowing to emergence (P₁) stage of pigeon pea.

The average wind velocity observed during 27th MW from sowing to physiological maturity was 5.0 Km hr⁻¹. The highest wind velocity (8.2 Km hr⁻¹) was recorded during sowing to emergence (P₁) stage and lowest (2.9 Km hr⁻¹) during pod formation to physiological maturity (P₅) stage of pigeon pea.

Table 4.2 Phenophase wise weather parameters in Pigeon pea

Weather Parameters	Phenophases of pigeon pea					Total	Mean
	P ₁	P ₂	P ₃	P ₄	P ₅		
Rainfall (mm)	14.3	283.6	359.6	103.8	132.6	893.9	-
Rainy days	1	18	18	3	6	46	-
T max (°C)	33.5	31.3	31.2	30.4	30.0	-	31.3
T min (°C)	23.1	22.3	21.3	19.1	16.7	-	20.5
T Mean (°C)	28.3	26.8	26.2	24.7	23.4	-	25.9
R.H. – I (%)	76	85	87	83	82	-	83
R.H. – II (%)	55	62	62	56	50	-	57
R.H. Mean (%)	66	74	74	70	66	-	70
Evp. (mm day⁻¹)	5.3	4.6	3.9	3.8	3.5	-	4.2
B.S.S. (hrs day⁻¹)	3.4	4.4	5.7	5.7	7.4	-	5.3
W.V. (km hr⁻¹)	8.2	6.2	4.2	3.6	2.88	-	5.0

P₁ – Sowing to emergence

P₂ – Emergence to branching

P₃ – Branching to flowering

P₄ – Flowering to pod formation

P₅ – Pod formation to physiological maturity

4.2.2 Phenophase wise weather parameters in Sorghum

The data given in Table 4.3 and graphically depicted in Fig. 4.3 revealed that average weather condition observed at different phenophases of sorghum.

The data revealed that the rainfall received during each phenophases and the total rainfall received at each phenophases from emergence to maturity was recorded 824.0 mm. The highest rainfall (273.6 mm) was received during emergence to penical initiation (P_2) stage, while lowest rainfall (5.2 mm) was received during sowing to emergence (P_1) stage of sorghum whereas, low rainfall during P_6 stage may reduced flowering or cause spikes to dry out.

The total rainy days at each phenophase during the sorghum crop sown in 27th MW was recorded 42 rainy days. The highest rainy days (17) were recorded during emergence to penical initiation (P_2), while, the lowest rainy days (1) recorded during sowing to emergence (P_1) stage of sorghum.

The diurnal temperature variation during the sorghum sowing in 27th MW showed the average maximum temperature (T_{max}) 31.2 °C, minimum temperature (T_{min}) 21.6 °C and mean temperature ($T_{avg.}$) 26.5 °C. The highest maximum temperature (33.3 °C) and the lowest minimum temperature (20.1 °C) were recorded respectively at dough stage to physiological maturity (P_7) stage.

The diurnal relative humidity variation during the sorghum sowing in 27th MW showed that the mean morning relative humidity (RH-I) 86 %, evening relative humidity (RH-II) 62 % and average relative humidity (RH avg.) 74 %. The highest RH-I (92 %) recorded at boot stage to flowering (P_5), Flowering to dough (P_6) stage and RH-II (70 %) at flag leaf stage to boot stage (P_4) stage. While, lowest RH-I (75 %) recorded at sowing to emergence (P_1) stage and RH-II (59 %) at sowing to emergence (P_1), penical initiation to flagg leaf (P_3) stage, respectively.

The data on average evaporation recorded at each phenophase showed that average evaporation at each phenophase was observed 4.0 mm day⁻¹. The highest evaporation 5.3 mm day⁻¹ was recorded during sowing to emergence stage (P_1) and the lowest evaporation 3.0 mm day⁻¹ was recorded during boot stage to flowering (P_5) stage of sorghum.

The average bright sunshine hours recorded in sorghum during 27th MW was 4.9 hrs day⁻¹. The highest BSS (7.2 hrs day⁻¹) was recorded during flowering to dough stage (P₆) and lowest BSS (3.0 hrs day⁻¹) was recorded during flag leaf stage to boot stage (P₄) stage.

The average wind velocity observed during 27th MW from sowing to physiological maturity was 5.1 Km hr⁻¹. The highest wind velocity (8.7 Km hr⁻¹) was recorded during sowing to emergence (P₁) stage and lowest (3.2 Km hr⁻¹) during flowering to dough (P₆) stage of sorghum.

Table 4.3 Phenophase wise weather parameters in Sorghum

Weather Parameters	Phenophases of sorghum							Total	Mean
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇		
Rainfall (mm)	5.2	273.6	78.5	98.2	118.3	43.6	206.5	824.0	-
Rainy days	1	17	3	4	5	4	8	42	-
T max (°C)	33.3	31.7	31.4	30.1	30.7	31.5	30.2	-	31.2
T min (°C)	23.2	22.2	21.7	21.3	21.8	21.2	20.1	-	21.6
T Mean (°C)	28.3	27.0	26.5	25.7	26.3	26.3	25.1	-	26.5
R.H. – I (%)	75	83	86	87	92	92	85	-	86
R.H. – II (%)	59	60	59	70	68	61	61	-	62
R.H. Mean (%)	67	72	73	78	80	76	73	-	74
Evp. (mm day⁻¹)	5.3	4.7	4.9	3.1	3.0	3.7	3.5	-	4.0
B.S.S. (hrs day⁻¹)	3.3	4.7	5.8	3.0	5.1	7.2	5.7	-	4.9
W.V. (km hr⁻¹)	8.7	6.10	5.2	5.2	3.9	3.2	3.5	-	5.1

P₁ – Sowing to emergence
P₃ – Penical initiation to flag leaf stage
P₅ – Boot stage to flowering
P₇ – Dough stage to physical maturity

P₂ – Emergence to penical initiation
P₄ – Flag leaf stage to boot stage
P₆ – Flowering to dough stage

4.2.3 Phenophase wise weather parameters in Maize

The data given in Table 4.4 and graphically depicted in Fig. 4.4 revealed that average weather condition observed at different phenophases of maize.

The data revealed that the rainfall received during each phenophases and the total rainfall received at each phenophases from emergence to maturity was recorded 644.6 mm. The highest rainfall (284.5 mm) was received during silking to milk (P₅) stage, while lowest rainfall (5.4 mm) was received during grandgrowth to tasseling (P₃) stage which may affected the tessel formation.

The total rainy days at each phenophase during the maize crop sown in 27th MW was recorded 38 rainy days. The highest rainy days (13) were recorded during seedling to grandgrowth (P₂) and silking to milk (P₅) stage, while, the lowest rainy days (1) recorded during grandgrowth to tasseling (P₃) stage.

The diurnal temperature variation during the maize sowing in 27th MW showed the average maximum temperature (T_{max}) 31.1 °C, minimum temperature (T_{min}) 21.7 °C and mean temperature (T_{avg.}) 26.4 °C. The highest maximum temperature (33.4 °C) and the lowest minimum temperature (20.3 °C) were recorded respectively at sowing to seedling (p₁) and milk stage to physiological maturity (P₆) stage.

The diurnal relative humidity variation during the maize sowing in 27th MW showed that the mean morning relative humidity (RH-I) 85 %, evening relative humidity (RH-II) 63 % and average relative humidity (RH avg.) 74 %. The highest RH-I (90 %) and RH-II (82 %) recorded at silking to milk (P₅) and teaseling to silking (P₄) stage. While, lowest RH-I (80 %) recorded during sowing to seedling (P₁), grandgrowth to tasseling (P₃) stage and RH-II (54 %) at sowing to seedling (P₁), grandgrowth to tasseling (P₃) stage respectively.

The data on average evaporation recorded at each phenophase showed that mean total evaporation at each phenophase was observed 4.2 mm day⁻¹. The highest evaporation 5.5 mm day⁻¹ was recorded during grandgrowth to tasseling (P₃) stage and the lowest evaporation 2.6 mm day⁻¹ was recorded teaseling to silking (P₄) stage of maize.

The average bright sunshine hours recorded in maize during 27th MW was 4.7 hrs day⁻¹. The highest BSS (7.3 hrs day⁻¹) was recorded during milk stage to physiological maturity (P₆) stage and lowest BSS (1.0 hrs day⁻¹) was recorded during teaselng to silking (p₄) stage.

The average wind velocity observed during 27th MW from sowing to physiological maturity was 5.6 Km hr⁻¹. The highest wind velocity (7.6 Km hr⁻¹) was recorded during sowing to seedling (P₁) stage and lowest wind velocity (2.8 Km hr⁻¹) during milk stage to physiological maturity (P₆) stage of maize.

Table 4.4 Phenophase wise weather parameters in Maize

Weather Parameters	Phenophases of maize						Total	Mean
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆		
Rainfall (mm)	44.8	236.1	5.4	42.5	284.5	31.4	644.6	-
Rainy days	4	13	1	3	13	4	38	-
T max (°C)	33.4	31.2	32.4	27.9	30.4	31.5	-	31.1
T min (°C)	22.9	22.2	21.9	21.7	21.5	20.3	-	21.7
T Mean (°C)	28.2	26.7	27.2	24.8	26.0	25.9	-	26.4
R.H. – I (%)	80	84	80	89	90	88	-	85
R.H. – II (%)	54	63	54	82	68	56	-	63
R.H. Mean (%)	67	73	67	85	79	72	-	74
Evp. (mm day ⁻¹)	5.3	4.5	5.5	2.6	3.2	3.9	-	4.2
B.S.S. (hrs day ⁻¹)	4.4	4.5	6.7	1.0	4.3	7.3	-	4.7
W.V. (km hr ⁻¹)	7.6	5.9	5.9	7.0	4.3	2.8	-	5.6

P₁ – Sowing to seedling

P₃ – Grandgrowth to teaselng

P₅ – Silking to milk stage

P₂ – Seedling to grandgrowth

P₄ – Tasselng to silking

P₆ – Milk stage to physical maturity

4.2.4 Phenophase wise weather parameters in Soybean

The data given in Table 4.5 and graphically depicted in Fig. 4.5 revealed that average weather condition observed at different phenophases of soybean.

The data revealed that the rainfall received during each phenophases and the total rainfall received at each phenophases from emergence to maturity was recorded 634.6 mm. The highest rainfall (230.3 mm) was received during seedling to branching (P_2) stage, while lowest rainfall (24.1 mm) was received during flowering to pod formation stage (P_4) of soybean which may reduced number of flowers formation.

The total rainy days at each phenophase during the soybean crop sown in 27th MW was recorded 35 rainy days. The highest rainy days (11) were recorded during seedling to branching (P_2) stage, while, the lowest rainy days (2) recorded during branching to flowering (P_3) and flowering to pod formation (P_4) stage.

The diurnal temperature variation during the soybean sowing in 27th MW showed the average maximum temperature (T_{max}) 31.1 °C, minimum temperature (T_{min}) 21.7 °C and mean temperature ($T_{avg.}$) 26.4 °C. The highest maximum temperature (33.8 °C) was recorded at sowing to seedling (P_1) stage. The lowest minimum temperature (21.2 °C) was recorded during pod formation to grain formation (P_5) and milk to physiological maturity (P_6) stage.

The diurnal relative humidity variation during the soybean sowing in 27th MW showed that the mean morning relative humidity (RH-I) 86%, evening relative humidity (RH-II) 63 % and average relative humidity (RH avg.) 74 %. The highest RH-I (91 %) recorded at grain formation to physical maturity (P_6) and RH-II (71 %) at flowering to pod formation (P_4), pod formation to grain formation (P_5) stage. While, lowest RH-I (79 %) and RH-II (50 %) recorded at sowing to seedling (P_1) stage, respectively.

The data on average evaporation recorded at each phenophase showed that mean total evaporation at each phenophase was observed 4.1 mm day⁻¹. The highest evaporation 5.8 mm day⁻¹ was recorded during sowing to seedling (P_1) stage

and the lowest evaporation 2.6 mm day⁻¹ was recorded grain formation to physical maturity (P₆) stage of soybean.

The average bright sunshine hours recorded in soybean during 27th MW was 4.7 hrs day⁻¹. The highest BSS (6.5 hrs day⁻¹) was recorded during branching to flowering (P₃) and grain formation to physical maturity (P₆) stage. Lowest BSS (2.1 hrs day⁻¹) was recorded during flowering to pod formation (p₄) stage.

The average wind velocity observed during 27th MW from sowing to physiological maturity was 5.1 Km hr⁻¹. The highest wind velocity (6.8 Km hr⁻¹) was recorded during sowing to seedling (P₁) stage and lowest wind velocity (3.2 Km hr⁻¹) during grain formation to physical maturity (P₆) stage of soybean.

Table 4.5: Phenophase wise weather parameters in Soybean

Weather Parameters	Phenophases of soybean						Total	Mean
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆		
Rainfall (mm)	56.0	230.3	60.2	24.1	112.2	151.8	634.6	-
Rainy days	6	11	2	2	5	9	35	-
T max (°C)	33.8	30.6	31.5	29.8	29.7	31.3	-	31.1
T min (°C)	22.9	21.9	21.8	21.5	21.2	21.2	-	21.7
T Mean (°C)	28.4	26.3	26.7	25.7	25.5	26.3	-	26.4
R.H. – I (%)	79	85	86	85	89	91	-	86
R.H. – II (%)	50	66	58	71	71	61	-	63
R.H. Mean (%)	65	75	72	78	80	76	-	74
Evp. (mm day ⁻¹)	5.8	4.1	5.2	2.6	3.2	3.5	-	4.1
B.S.S.(hrs day ⁻¹)	5.9	3.9	6.5	2.1	3.6	6.5	-	4.7
W.V. (km hr ⁻¹)	6.8	6.0	4.8	4.7	5.3	3.2	-	5.1

P₁ – Sowing to seedling

P₃ – Branching to flowering

P₅ – Pod formation to grain formation

P₂ – Seedling to branching

P₄ – Flowering to pod formation

P₆ – Grain formation to physical maturity

4.2.5 Phenophase wise weather parameters in Sesamum

The data given in Table 4.6 and graphically depicted in Fig. 4.6 revealed that average weather condition observed at different phenophases of sesamum.

The data revealed that the rainfall received during each phenophases and the total rainfall received at each phenophases from emergence to maturity was recorded 590.7 mm. The highest rainfall (318.2 mm) was received during capsules to physical maturity (P₅) stage, while lowest rainfall (1.6 mm) was received during sowing to emergence (P₁) stage of sesamum.

The total rainy days at each phenophase during the sesamum crop sown in 27th MW was recorded 33 rainy days. The highest rainy days (16) were recorded during capsules to physical maturity (P₅), while, the lowest rainy days (0) recorded during sowing to emergence (P₁) stage.

The diurnal temperature variation during the sesamum sowing in 27th MW showed the average maximum temperature (T_{max}) 31.3 °C, minimum temperature (T_{min}) 22.2 °C and mean temperature (T_{avg.}) 26.8 °C. The highest maximum temperature (33.8 °C) and the lowest minimum temperature (21.1 °C) was recorded respectively at sowing to emergence (P₁) stage and capsules to physical maturity (P₅) stage.

The diurnal relative humidity variation during the sesamum sowing in 27th MW showed that the mean morning relative humidity (RH-I) 84 %, evening relative humidity (RH-II) 64 % and average relative humidity (RH avg.) 74 %. The highest RH-I (89 %) recorded at branching to flowering (P₃), flowering to capsules (P₄) and RH-II (80 %) branching to flowering (P₃) stage. While, lowest RH-I (76 %) and RH-II (48 %) recorded at sowing to emergence (P₁) and emergence to branching (P₂) stage, respectively.

The data on average evaporation recorded at each phenophase showed that mean total evaporation at each phenophase was observed 4.2 mm day⁻¹. The highest evaporation 6.1 mm day⁻¹ was recorded during emergence to branching (P₂) and the lowest evaporation 2.8 mm day⁻¹ was recorded during branching to flowering (P₃) stage of sesamum.

The average bright sunshine hours recorded in sesamum during 27th MW was 3.9 hrs day⁻¹. The highest BSS (6.7 hrs day⁻¹) was recorded during emergence to branching (P₂) stage and lowest BSS (1.0 hrs day⁻¹) was recorded during branching to flowering (P₄) stage.

The average wind velocity observed during 27th MW from sowing to physiological maturity was 6.4 Km hr⁻¹. The highest wind velocity (8.4 Km hr⁻¹) was recorded during sowing to emergence (P₁) and lowest wind velocity (4.1 Km hr⁻¹) during capsules to physical maturity (P₅) stage of sesamum.

Table 4.6 Phenophase wise weather parameters in Sesamum

Weather Parameters	Phenophases of sesamum					Total	Mean
	P ₁	P ₂	P ₃	P ₄	P ₅		
Rainfall (mm)	1.6	54.4	112.6	103.9	318.2	590.7	-
Rainy days	0	6	7	4	16	33	-
T max (°C)	33.7	33.8	28.0	30.2	31.0	-	31.3
T min (°C)	23.2	22.9	21.8	22.0	21.1	-	22.2
T Mean (°C)	28.5	28.4	24.9	26.1	26.1	-	26.8
R.H. – I (%)	76	80	89	89	88	-	84
R.H. – II (%)	59	48	80	68	62	-	64
R.H. Mean (%)	67	64	84	79	75	-	74
Evp. (mm day ⁻¹)	4.9	6.1	2.8	3.7	3.7	-	4.2
B.S.S.(hrs day ⁻¹)	3.1	6.7	1.0	3.0	5.5	-	3.9
W.V. (km hr ⁻¹)	8.4	6.4	6.9	6.1	4.1	-	6.4

P₁ – Sowing to emergence
P₃ – Branching to flowering
P₅ – Capsules to physical maturity

P₂ – Emergence to branching
P₄ – Flowering to capsules

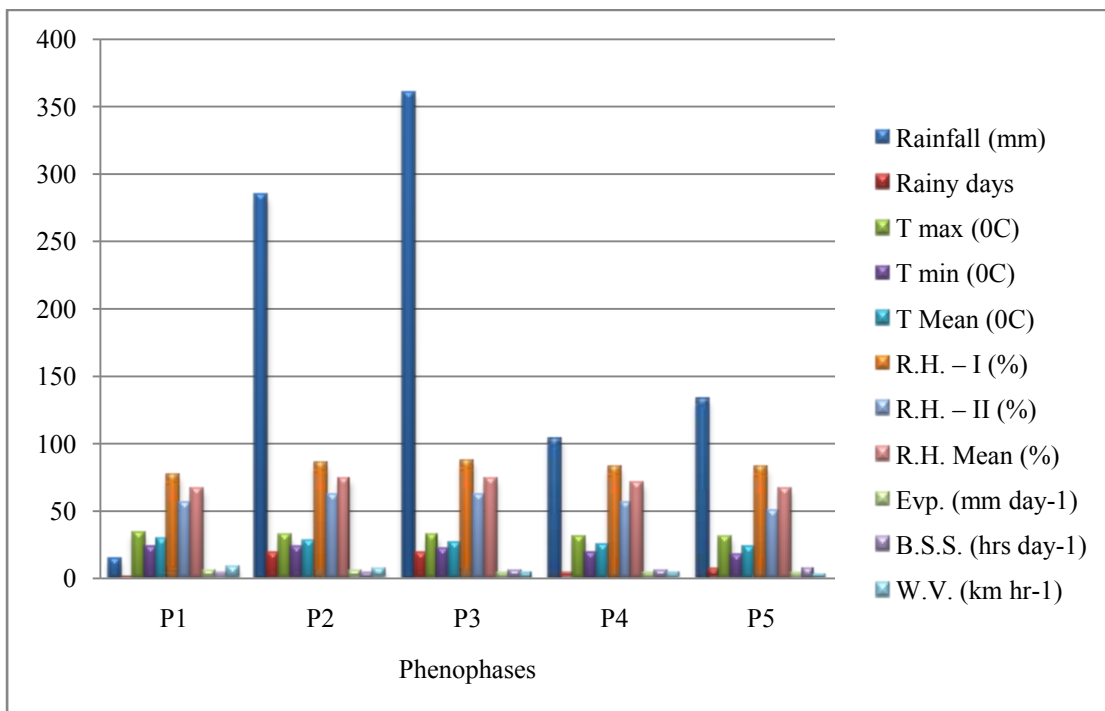


Fig.4.2 Phenophases wise weather parameter in Pigeon pea

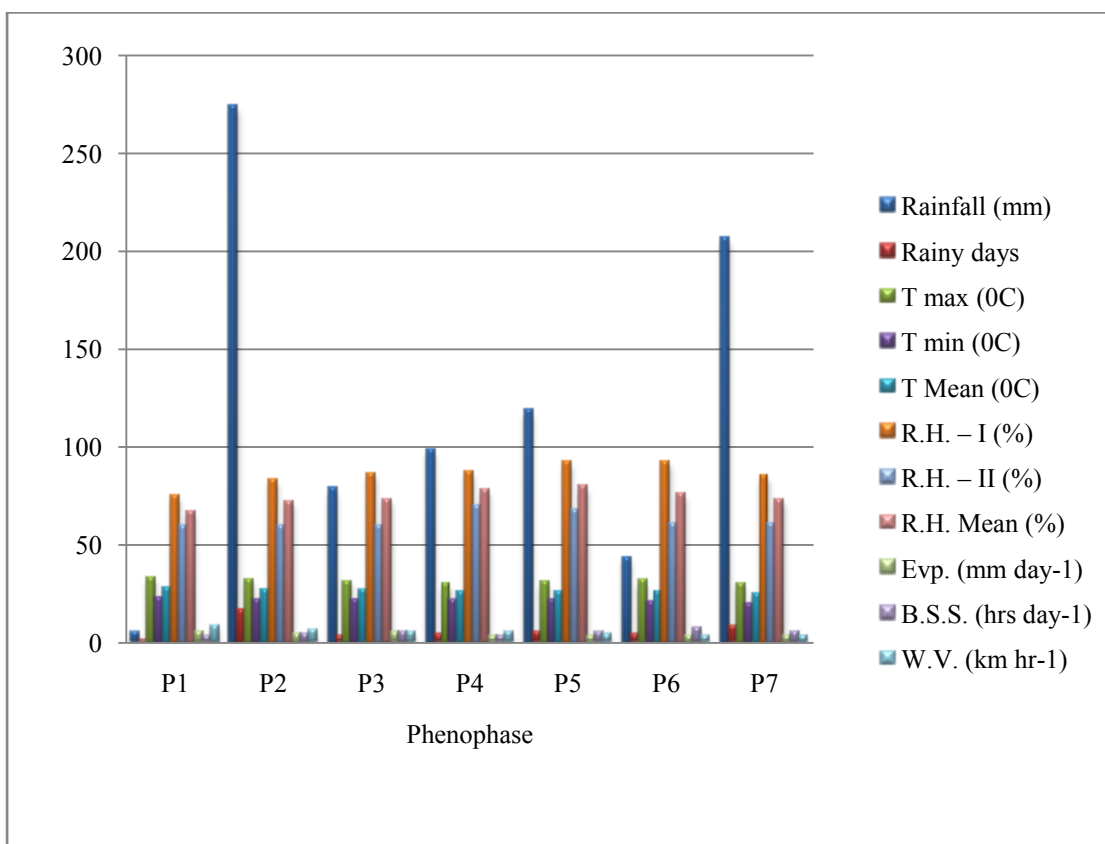


Fig.4.3 Phenophases wise weather parameter in Sorghum

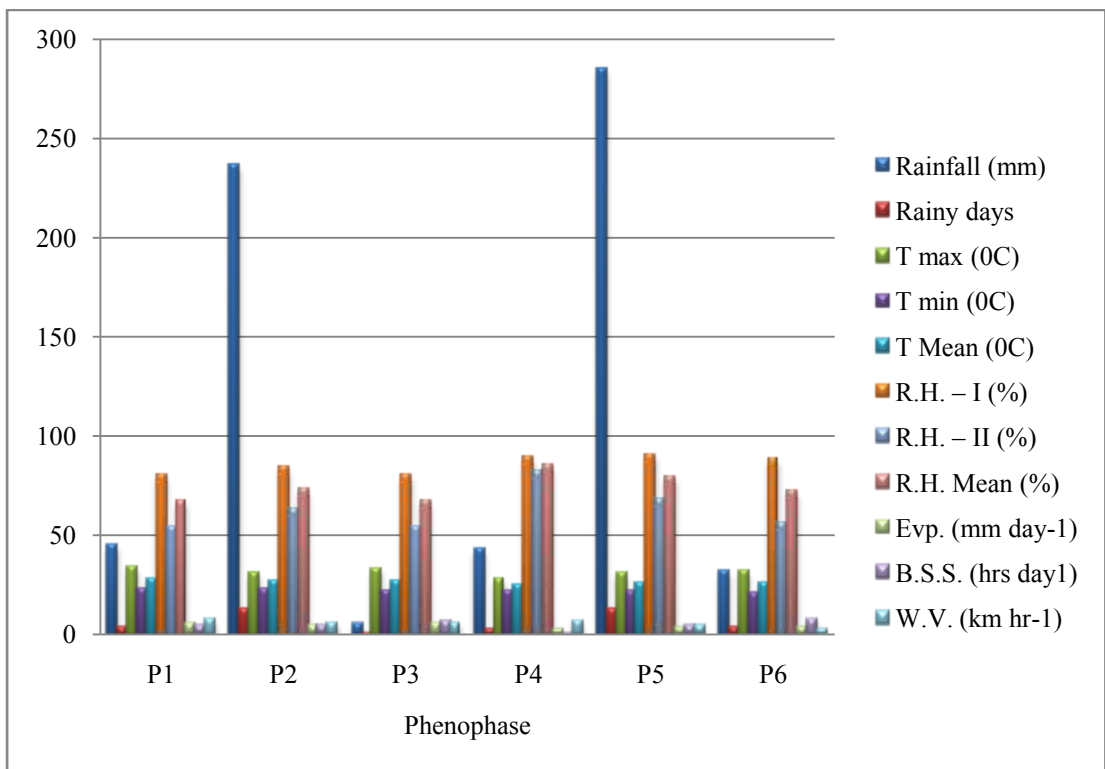


Fig.4.4 Phenophases wise weather parameter in Maize

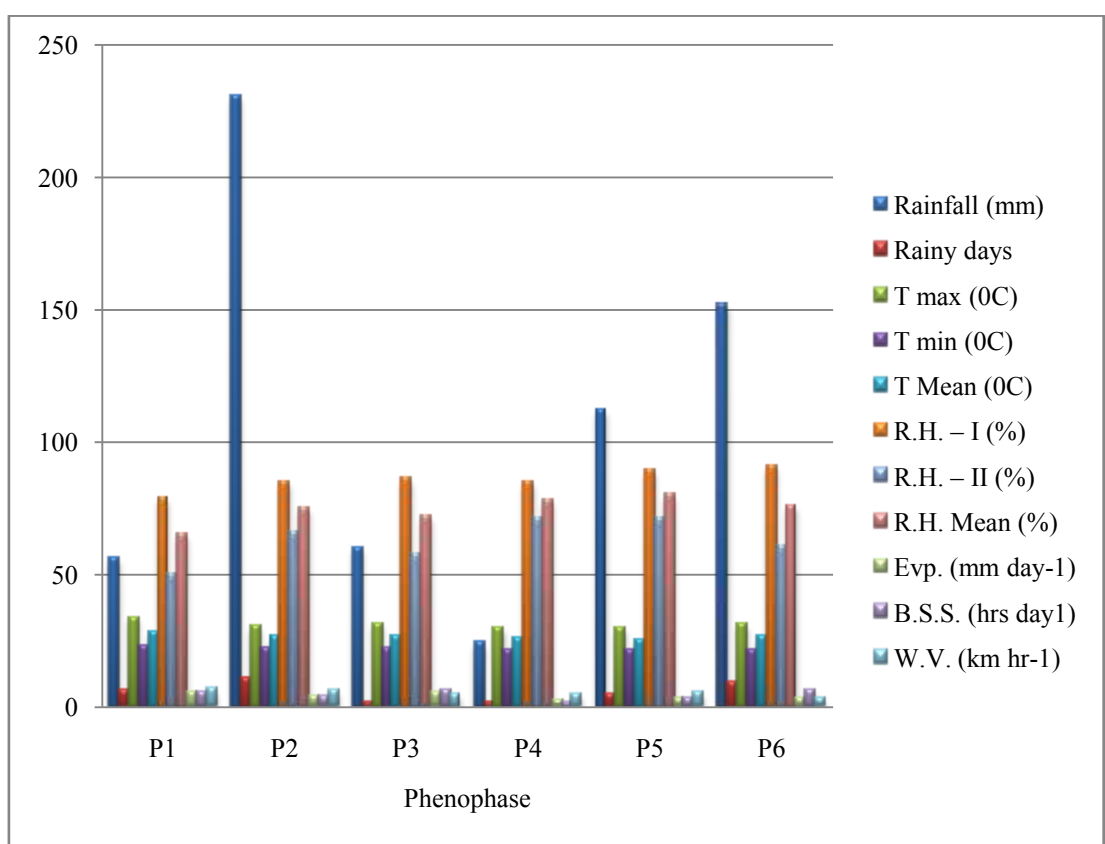


Fig.4.5 Phenophases wise weather parameter in Soybean

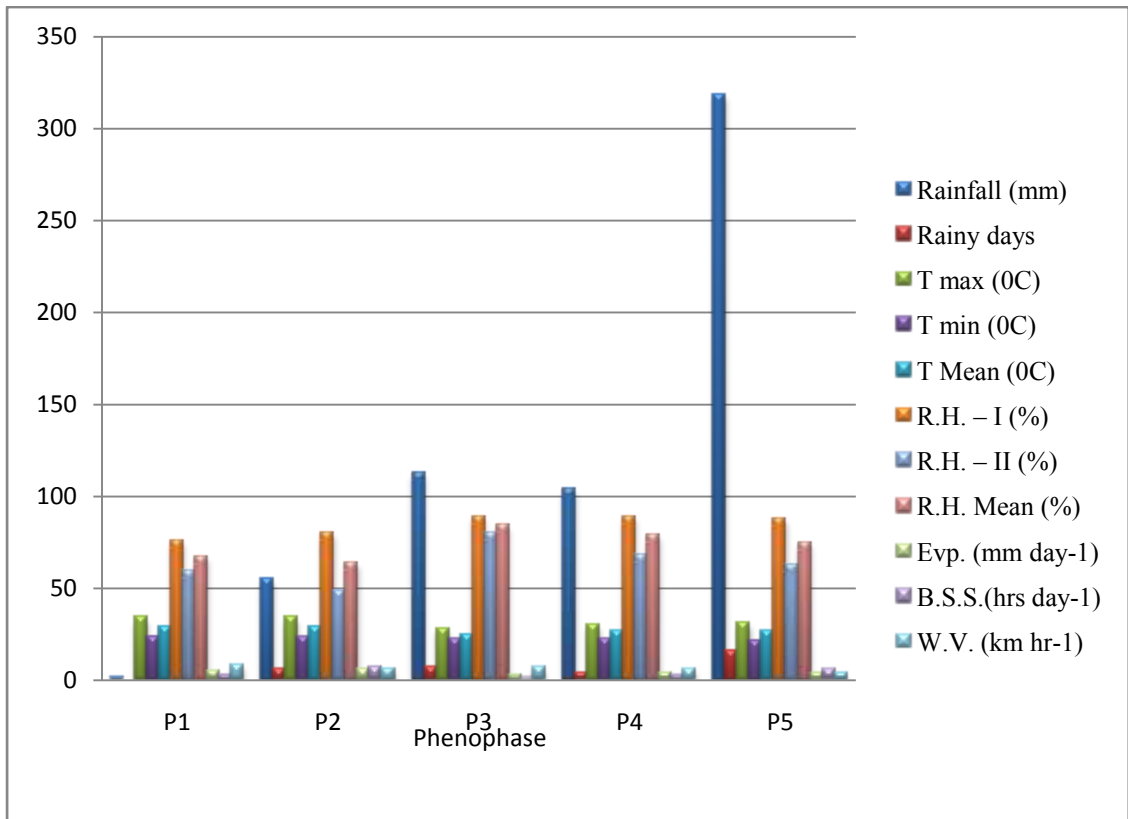


Fig.4.6 Phenophases wise weather parameter in Sesamum

4.3 Microclimatic studies

4.3.1 Soil moisture

4.3.1.1 Soil moisture (%) at 15 cm depth

The data on mean soil moisture (%) present in the soil as influenced by different treatments at different days after sowing is given in Table 4.7 and graphically depicted in Fig. 4.7 (a).

The soil moisture content was influenced by various treatments at all growth stages of crop. Among the different treatment significant difference in soil moisture was found at 15 cm during 30 days interval i.e. 30, 60, 90, 120 and 150 days after sowing. Soil moisture percentage was observed high at 60 and 120 days after sowing and lowest at harvesting time. Moreover, at higher depth recorded higher soil moisture content at all growth stages of crops.

In pigeon pea based intercropping system the treatment i.e. T₁, T₂, T₃ and T₄ having high soil moisture percentage as compared to sole pigeon pea i.e. T₅. Among that intercropping treatment the highest soil moisture percentage was observed in T₃ and lowest in T₂ intercrop treatment. This may be because of in intercropping treatment having high plant population and reduced evaporation rate as compare to sole crop treatment of pigeon pea i.e. T₅. The mean soil moisture data shows that, the mean soil moisture was more than 25% in all treatment during sowing to emergence.

When there is a different crops grown in the intercropping systems could reduce wind speed, improve light interception, provide shade and increase infiltration compared with mono cropping, so lower water evaporation, conserving soil moisture and improving soil structure. Similar result was reported by Kanton and Dennett, (2004) and Ghanbari *et al.*, (2010).

Soil moisture content in the soil was increased dramatically in the legume intercropping due to low evapotranspiration potential for growth period. In intercropping system water uptake from soil surface layers increased due to increased root density in the upper layers, thus decreasing water dissipated by evaporation. Similar result was reported by Naresh *et al.* (2014).

Table 4.7 Effect of Pigeon pea based intercropping on soil moisture (%) at 15 cm depth

Treatment	Days after sowing					
	30	60	90	120	150	Mean
T₁: (Pigeonpea + Sorghum)	29.20	32.23	28.40	33.12	20.18	28.63
T₂: (Pigeonpea + Maize)	29.17	32.14	28.38	33.12	20.18	28.60
T₃: (Pigeonpea + Soybean)	29.40	32.45	28.61	33.13	20.19	28.76
T₄: (Pigeonpea + Sesamum)	29.32	32.32	28.51	33.14	20.20	28.70
T₅: (Sole Pigeon pea)	29.13	32.12	28.36	33.14	20.20	28.59
T₆: (Sole Sorghum)	29.37	32.65	28.61	-	-	30.21
T₇: (Sole Maize)	29.30	32.61	28.57	-	-	30.16
T₈: (Sole Soybean)	30.10	33.12	29.59	-	-	30.94
T₉: (Sole Sesamum)	30.08	33.06	29.50	-	-	30.88

4.3.1.2 Soil moisture (%) at 30 cm depth

The data on mean soil moisture (%) present in the soil as influenced by different treatments at different days after sowing is given in Table 4.8 and graphically depicted in Fig. 4.7 (b).

The soil moisture content was influenced by various treatments at all growth stages of crop. Among the different treatment significant difference in soil moisture was found at 30 cm during 30 days interval i.e. 30, 60, 90, 120 and 150 days after sowing. Soil moisture percentage was observed high at 60 and 120 days after sowing and lowest at harvesting time. Moreover, at higher depth recorded higher soil moisture content at all growth stages of crops.

In pigeon pea based intercropping system the treatment i.e. T₁, T₂, T₃ and T₄ having high soil moisture percentage as compared to sole crop treatment of pigeon pea i.e. T₅. Among that intercropping treatment the highest soil moisture percentage was observed in T₃ and lowest in T₂ intercrop treatment. This may because of in intercropping treatment having high plant population and reduced evaporation rate as compare to sole crop treatment of pigeon pea i.e. T₅. The mean soil moisture data shows that, the mean soil moisture was more than 25% in all treatment during sowing to emergence.

When there is a different crops grown in the intercropping systems could reduce wind speed, improve light interception, provide shade and increase infiltration compared with mono cropping, so lower water evaporation, conserving soil moisture and improving soil structure. Similar result was reported by Kanton and Dennett, (2004) and Ghanbari *et al.*, (2010).

Soil moisture content in the soil was increased dramatically in the legume intercropping due to low evapotranspiration potential for growth period. In intercropping system water uptake from soil surface layers increased due to increased root density in the upper layers, thus decreasing water dissipated by evaporation. Similar result was reported by Naresh *et al.* (2014).

Table 4.8 Effect of Pigeon pea based intercropping on soil moisture (%) at 30 cm depth

Treatment	Days after sowing					
	30	60	90	120	150	Mean
T₁: (Pigeonpea + Sorghum)	30.64	33.22	27.20	34.13	20.19	29.08
T₂: (Pigeonpea + Maize)	30.62	33.15	27.19	34.13	20.19	29.06
T₃: (Pigeonpea + Soybean)	30.73	33.43	27.33	34.14	20.20	29.17
T₄: (Pigeonpea + Sesamum)	30.70	33.30	27.28	34.15	20.20	29.13
T₅: (Sole Pigeon pea)	30.62	33.09	27.18	34.15	20.20	29.05
T₆: (Sole Sorghum)	30.60	32.58	27.62	-	-	30.27
T₇: (Sole Maize)	30.47	32.52	27.58	-	-	30.19
T₈: (Sole Soybean)	31.32	34.60	28.25	-	-	31.39
T₉: (Sole Sesamum)	31.24	34.41	28.21	-	-	31.29

4.3.1.3 Soil moisture (%) at 45 cm depth

The data on mean soil moisture (%) present in the soil as influenced by different treatments at different days after sowing is given in Table 4.9 and graphically depicted in Fig. 4.7 (c).

The soil moisture content was influenced by various treatments at all growth stages of crop. Among the different treatment significant difference in soil moisture was found at 45 cm during 30 days interval i.e. 30, 60, 90, 120 and 150 days after sowing. Soil moisture percentage was observed high at 60 and 120 days after

sowing and lowest at harvesting time. Moreover, at higher depth recorded higher soil moisture content at all growth stages of crops.

In the pigeon pea based intercropping system the treatment i.e. T₁, T₂, T₃ and T₄ having high soil moisture percentage as compared to sole crop treatment of pigeon pea i.e. T₅. Among that intercropping treatment the highest soil moisture percentage was observed in T₃ and lowest in T₂ intercrop treatment. This may because of in intercropping treatment having high plant population and reduced evaporation rate as compare to sole crop treatment of pigeon pea i.e. T₅. The mean soil moisture data shows that, the mean soil moisture was more than 25% in all treatment during sowing to emergence.

When there is a different crops grown in the intercropping systems could reduce wind speed, improve light interception, provide shade and increase infiltration compared with mono cropping, so lower water evaporation, conserving soil moisture and improving soil structure. Similar result was reported by Kanton and Dennett, (2004) and Ghanbari *et al.*, (2010).

Soil moisture content in the soil was increased dramatically in the legume intercropping due to low evapotranspiration potential for growth period. In intercropping system water uptake from soil surface layers increased due to increased root density in the upper layers, thus decreasing water dissipated by evaporation. Similar result was reported by Naresh *et al.* (2014).

Table 4.9 Effect of Pigeon pea based intercropping on soil moisture (%) at 45 cm depth

Treatment	Days after sowing					
	30	60	90	120	150	Mean
T₁: (Pigeonpea + Sorghum)	30.62	33.63	27.35	34.15	20.20	29.19
T₂: (Pigeonpea + Maize)	30.60	33.62	27.32	34.15	20.20	29.18
T₃: (Pigeonpea + Soybean)	30.71	33.70	27.40	34.16	20.21	29.24
T₄: (Pigeonpea + Sesamum)	30.69	33.68	27.38	34.16	20.21	29.22
T₅: (Sole Pigeon pea)	30.60	33.61	27.26	34.16	20.21	29.17
T₆: (Sole Sorghum)	30.64	32.63	27.66	-	-	30.31
T₇: (Sole Maize)	30.61	32.56	27.62	-	-	30.26
T₈: (Sole Soybean)	31.20	34.52	28.49	-	-	31.40
T₉:(Sole Sesamum)	31.16	34.41	28.34	-	-	31.30

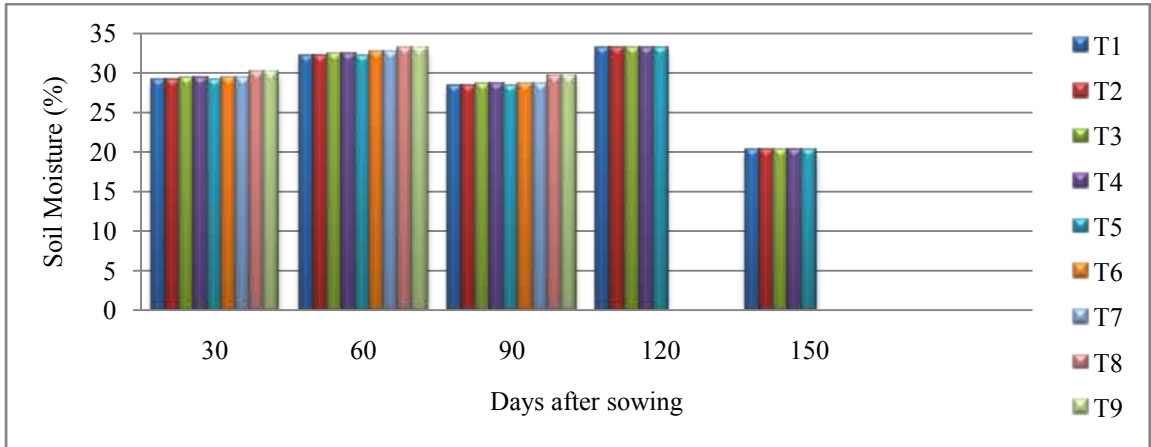


Fig.4.7 (a) Soil moisture (%) at 15 cm depth

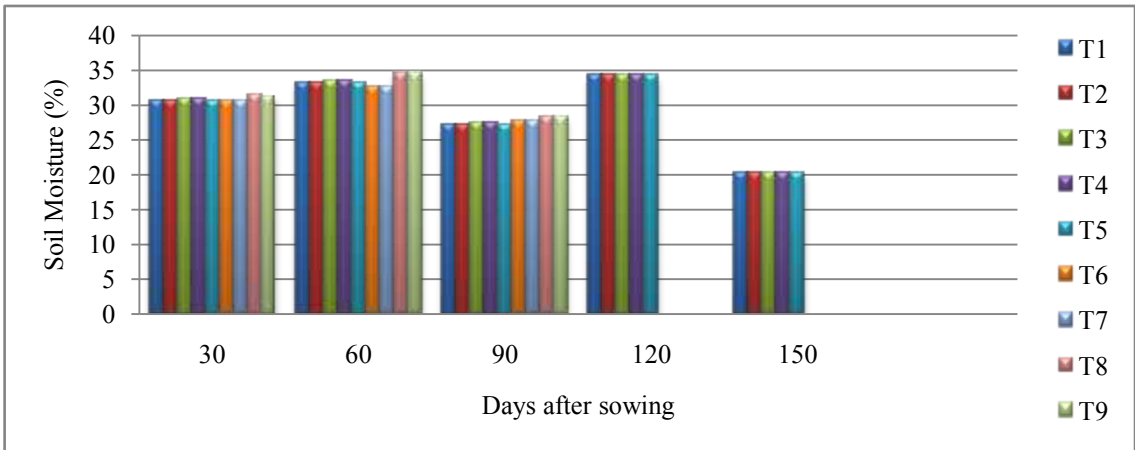


Fig.4.7 (b) Soil moisture (%) at 30 cm depth

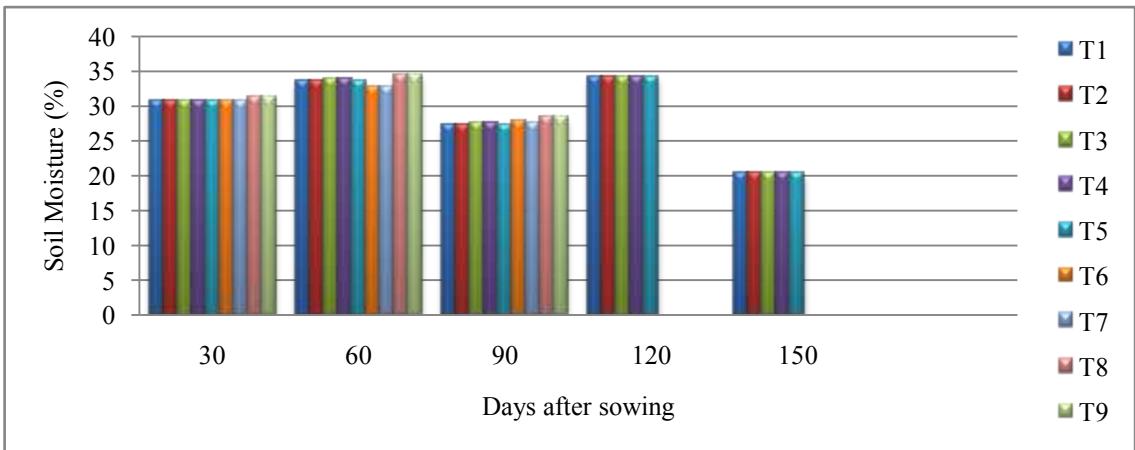


Fig.4.7 (c) Soil moisture (%) at 45 cm depth

4.3.2 Canopy temperature ($^{\circ}\text{C}$)

Canopy temperature was measured by using infrared thermometer. The canopy temperature was recorded at afternoon 2.30 hours shown in Table 4.10 and graphically depicted in Fig. 4.8.

The data revealed that the maximum canopy temperature was showed at 60 and 120 DAS whereas, minimum at the time of harvesting. The canopy temperature inside the intercrop treatments like T₁, T₂, T₃ and T₄ was showed lowest than the sole crop treatment of Pigeon pea i.e. P₅. So, the mean canopy temperature was showed lowest in pigeon pea based intercropping treatments than that of sole pigeon pea treatment.

Plant density, quality of received light, planting direction and wind affect canopy temperature. Intercropping practice could modify the microclimate by reducing light intensity, air temperature, desiccating wind and other climatic components. It was showed that when intercrop and high plant density provides soil cover, a relative low temperature will be maintained within the crop canopy, providing a favourable microclimate for the associated crops. Canopy temperature is reduced in intercropping due to positive effects of two crops including increased land coverage, higher retention of soil moisture, reduced evaporation from soil surface, enhanced water use efficiency and increased relative moisture of canopy. Similar result reported by Lemma, (2002), Wolfswinkel, (2003), Anthony and Rene, (2008), Jaya *et al.*, (2008).

The canopy temperature of intercropping was lower than that of monoculture. Result indicates that average temperature inside the canopy of intercropping was lower than that of sole crop. Based on the present study and previous ones, it can be concluded that microclimate temperature of canopy in intercropping is lower than that of sole. Higher transpiration enhances relative humidity and the energy penetration the canopy is used for photosynthesis and production processes and thus, the amount of energy devoted to air heating is reduced. These factors cause relative coldness of microclimate and since microclimate temperature, to some extent, depends on relative humidity of canopy, humid air retains canopy temperature of intercropping in moderate level and, therefore, canopy

temperature in intercropping is colder than that of monoculture. Similar result was reported by Mohsen and Jafar, (2015).

The increase in canopy temperature due to more competition of resources like soil moisture, nutrient and light by the plants for its growth and development which further effect the assimilation of resources in plants. Similar results were reported by Patel *et al.* (2001).

Table 4.10 Canopy temperature influenced by different treatments

Treatment	Days after sowing					
	30	60	90	120	150	Mean
T₁: (Pigeonpea + Sorghum)	29.33	32.65	29.20	33.64	27.60	30.48
T₂: (Pigeonpea + Maize)	29.21	32.58	29.18	33.62	27.61	30.44
T₃: (Pigeonpea + Soybean)	29.08	31.14	28.60	33.51	27.58	29.98
T₄: (Pigeonpea + Sesamum)	29.10	32.38	29.14	33.49	27.62	30.35
T₅: (Sole Pigeon pea)	29.55	32.83	29.31	33.47	27.67	30.57
T₆: (Sole Sorghum)	28.74	31.43	28.72	-	-	29.63
T₇: (Sole Maize)	28.70	31.36	28.74	-	-	29.60
T₈: (Sole Soybean)	28.67	31.16	28.69	-	-	29.51
T₉: (Sole Sesamum)	28.68	31.24	28.70	-	-	29.54

4.3.3 Relative Humidity (%)

Relative humidity percentage within plant canopy was measured directly with the help of 4-in-1 precision humidity and temperature meter during afternoon 2.30 hours shown in Table 4.11 and graphically depicted in Fig.4.9.

The data revealed that the maximum relative humidity was observed at 60 and 120 DAS whereas, minimum at the time of harvesting. The relative humidity inside the intercrop treatments like T₁, T₂, T₃ and T₄ was showed maximum than the sole crop treatment of Pigeon pea i.e. T₅. So, the mean relative humidity was showed maximum in pigeon pea based intercropping treatments than that of sole pigeon pea treatment.

Relative humidity is nothing but the amount of water vapour present in the air, in relation to the maximum amount of the air can hold at a particular

temperature. While, the main source of water vapour in the lower atmosphere are evaporation and transpiration.

Relative humidity is depending upon the amount of water vapour present in air. It was more in cool air than warm air. Surrounding the crop canopy if there is high moisture content reduce transpiration and increase canopy temperature. Relative humidity changes when temperature changes. Because warm air can hold more water vapor than cool air, relative humidity falls when the temperature rises if no moisture is added to the air similar result was reported by Donald and Upchurch (1997).

Table 4.11 Relative Humidity influenced by different treatments

Treatment	Days after sowing					
	30	60	90	120	150	Mean
T₁: (Pigeonpea + Sorghum)	80	83	72	85	46	73
T₂: (Pigeonpea + Maize)	81	85	73	87	46	74
T₃: (Pigeonpea + Soybean)	83	89	75	90	45	76
T₄: (Pigeonpea + Sesamum)	82	88	74	89	44	75
T₅: (Sole Pigeon pea)	79	81	71	83	41	71
T₆: (Sole Sorghum)	84	90	71	-	-	82
T₇: (Sole Maize)	86	92	70	-	-	83
T₈: (Sole Soybean)	90	97	67	-	-	85
T₉: (Sole Sesamum)	88	95	68	-	-	84

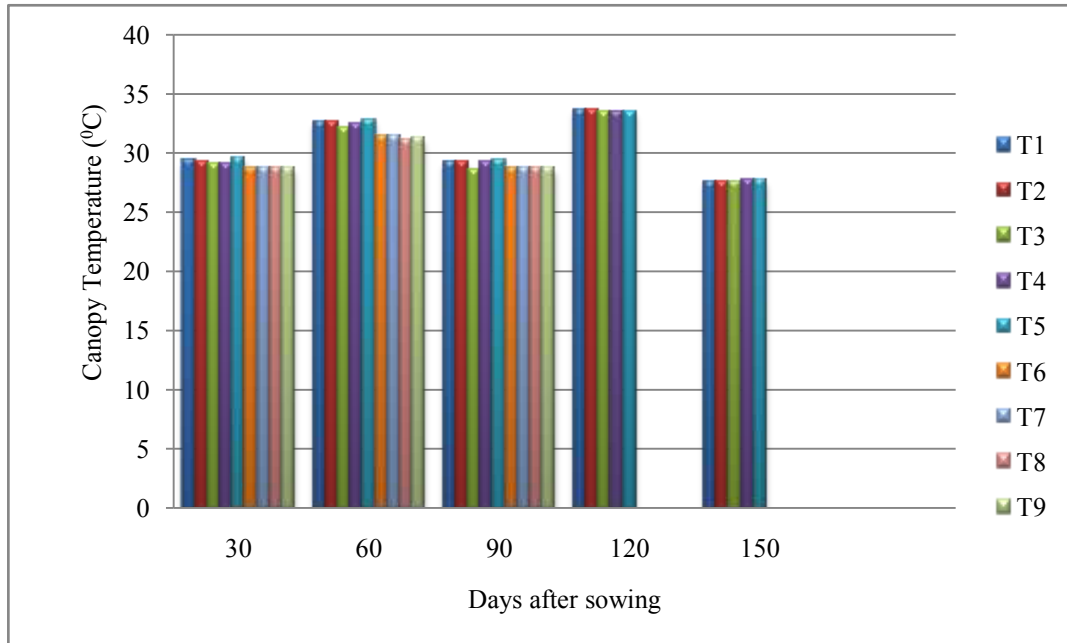


Fig.4.8 Canopy temperature ($^{\circ}\text{C}$) during crop growing period

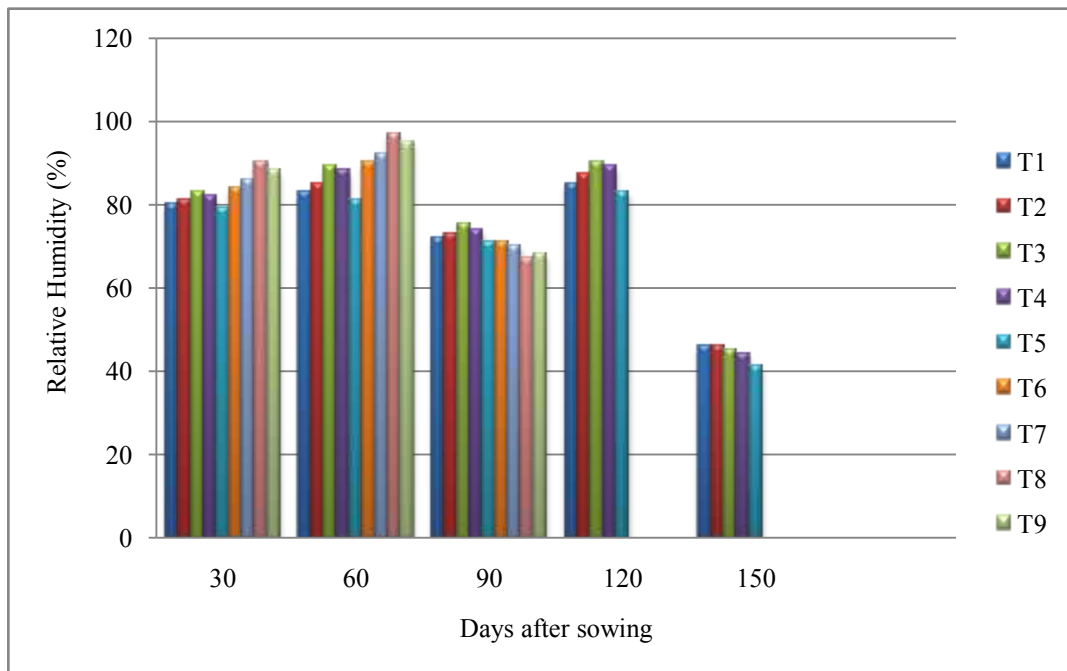


Fig.4.9 Relative humidity (%) during crop growing period

4.4 General growth studies

4.4.1 Mean emergence and final plant stand in percent stand

The data on emergence count was recorded fifteen days after each sowing date, whereas final plant stand was recorded at the time of harvesting. The data recorded on emergence count and final plant stand per net plot, as influenced by different treatments were presented in Table 4.12.

Table.4.12 Mean emergence count and final plant stand (%) of crop as influenced by different treatment (arcsine values)

Treatment	Emergence count (%)	Final plant stand (%)
T ₁ : (Pigeonpea + Sorghum)	(95.63) (77.89)* (96.34) (78.91)	(93.56) (75.35) (94.44) (76.31)
T ₂ : (Pigeonpea + Maize)	(95.24) (77.34) (95.03)(77.08)	(93.44) (75.11) (92.20) (73.78)
T ₃ : (Pigeonpea + Soybean)	(95.43) (77.62) (95.13) (77.21)	(93.48) (75.23) (92.38) (74.00)
T ₄ : (Pigeonpea + Sesamum)	(95.70) (78.03) (96.50) (79.22)	(93.60) (75.35) (94.46) (76.44)
T ₅ : (Sole Pigeon pea)	(95.82) (78.17)	(93.65) (75.46)
T ₆ : (Sole Sorghum)	(96.42) (79.06)	(94.48) (76.44)
T ₇ : (Sole Maize)	(95.20) (77.34)	(92.25) (73.78)
T ₈ : (Sole Soybean)	(95.25) (77.48)	(92.43)(74.00)
T ₉ : (Sole Sesamum)	(96.68) (79.53)	(94.52) (76.44)

*Figures in parenthesis are arcsine value

The emergence count and final plant stand of pigeon pea were 95.82 % and 93.62 %, sorghum 96.42 % and 94.48 %, maize 95.20 % and 92.25 %, soybean 95.25 % and 92.43 %, and of sesamum 96.68 % and 94.52 % respectively. It was evident from the Table 4.11 that the emergence count and final plant stand were satisfactory but not influenced significantly by various treatments and their interaction.

4.4.2 Plant height (cm)

4.4.2.1 Plant height (cm) of pigeon pea as influenced by different treatment

The data on mean plant height of pigeon pea in cm recorded at various stages of crop growth are presented in Table 4.13 and graphically depicted in Fig. 4.10.

The mean height of pigeon pea was recorded 24.3 cm, 78.2 cm, 121.8 cm, 156.1 cm, 165.1 cm and 166 cm at 30, 60, 90, 120, 150 days after sowing and at harvest, respectively.

The data depicted in Table 4.12 revealed that the plant height (cm) was influenced by different treatments at various stages of crop growth. The plant height was increased progressively with succeeding crop growth till the maturity of crop. The rate of increase in plant height was rapid during 30 to 90 days after sowing and slowed down thereafter.

The variation in plant height of pigeon pea in intercropping system was observed because of competition for soil moisture, solar radiation, nutrient uptake and space availability. The decreased in plant height of pigeon pea in pigeon pea + sorghum (159.3 cm), pigeon pea + maize (157.2 cm) and pigeon pea + sesamum (163.0 cm) intercropping treatments as compared to sole pigeon pea (174.8 cm). While, plant height of pigeon pea in intercropping treatment like pigeon pea + soybean (175.6 cm) was increased as compared to sole pigeon pea (174.8 cm).

In general the significantly maximum plant height of pigeonpea was recorded, when grown as sole crop compared to intercropping with cereals i.e. sorghum, maize. While, in case of pigeonpea + soybean intercropping treatment plant height of pigeonpea was higher than sole pigeonpea, similar result was observed by Padhy *et al.* (1992), Chaudhary and Thakur (2005), Egbe and Bar-Anyam (2010), Kumar and Kumar (2018),.

Table.4.13 Plant height (cm) of Pigoen pea as influenced by different treatment

Treatment	Days after sowing					
	30	60	90	120	150	AH
T₁: (Pigeonpea + Sorghum)	22.4	76.2	118.9	154.5	158.4	159.3
T₂: (Pigeonpea + Maize)	22.2	76.1	113.4	152.6	156.3	157.2
T₃: (Pigeonpea + Soybean)	26.6	83.1	125.8	159.6	175.0	175.6
T₄: (Pigeonpea + Sesamum)	24.9	76.7	125.3	156.6	163.0	163.0
T₅: (Sole Pigeonpea)	25.5	78.8	125.6	157.4	172.7	174.8
G mean	24.3	78.2	121.8	156.1	165.1	166.0

4.4.2.2 Plant height (cm) of Sorghum as influenced by different treatment

The data on mean plant height of sorghum in cm recorded at various stages of crop growth are presented in Table 4.14 and graphically depicted in Fig. 4.11.

The mean height of sorghum was recorded 10.1 cm, 24.0 cm, 67.1 cm, 99.0 cm, 139.5 cm, 151.9 cm, 154.8 cm and 155.1 cm at 15, 30, 45, 60, 75, 90, 105 days after sowing and at harvest, respectively.

The data depicted in Table 4.13 revealed that the plant height (cm) was influenced by different treatments at various stages of crop growth. The mean plant height was increased progressively with increasing age of crop. The rate of increase in plant height was faster up to 75 days after sowing after that the height was slowed down.

Plant height of sorghum in intercropping treatment like Pigoenpea + sorghum (149.6 cm) was decreased as compared to sole sorghum (160.6 cm). This is because of competition for soil moisture, solar radiation, nutrient uptake and space availability.

Table.4.14 Plant height (cm) of Sorghum as influenced by different treatment

Treatment	Days after sowing							
	15	30	45	60	75	90	105	AH
T₁: (Pigeonpea + Sorghum)	8.8	23.1	64.7	95.6	130.6	147.1	148.9	149.6
T₆: (Sole sorghum)	11.4	24.8	69.5	102.3	148.3	156.7	160.6	160.6
G mean	10.1	24.0	67.1	99.0	139.5	151.9	154.8	155.1

4.4.2.3 Plant height (cm) of Maize as influenced by different treatment

The data on mean plant height of maize in cm recorded at various stages of crop growth are presented in Table 4.15 and graphically depicted in Fig. 4.12.

The mean height of maize was recorded 14.0 cm, 32.9 cm, 89.2 cm, 186.1 cm, 272.6 cm, 273.3 cm, and 273.4 cm at 15, 30, 45, 60, 75, 90 days after sowing and at harvest, respectively.

The data depicted in Table 4.14 revealed that the plant height (cm) was influenced by different treatments at various stages of crop growth. The mean plant height was increased progressively with increasing age of crop and found maximum at harvest. The rate of increase in plant height during initial stage was faster up to 75 days. Thereafter the rate of increase in the height was slowed down to maturity.

Plant height of maize in intercropping treatment like Pigeonpea + maize (255.3 cm) was decreased as compared to sole maize (291.4 cm). This is because of competition for soil moisture, solar radiation, nutrient uptake and space availability.

Table.4.15 Plant height (cm) of Maize as influenced by different treatment

Treatment	Days after sowing						
	15	30	45	60	75	90	AH
T₂: (Pigeon+Maize)	12.6	30.6	77.7	164.1	254.3	255.1	255.3
T₇: (Sole Maize)	15.3	35.2	100.7	208.0	290.8	291.4	291.4
G mean	14.0	32.9	89.2	186.1	272.6	273.3	273.4

4.4.2.4 Plant height (cm) of Soybean as influenced by different treatment

The data on mean plant height of soybean in cm recorded at various stages of crop growth are presented in Table 4.16 and graphically depicted in Fig. 4.13.

The mean height of soybean was recorded 9.1 cm, 26.6 cm, 31.2 cm, 41.1 cm, 46.2 cm, 48.3 cm, and 48.7 cm at 15, 30, 45, 60, 75, 90 days after sowing and at harvest, respectively.

The data depicted in Table 4.15 revealed that the plant height (cm) was influenced by different treatments at various stages of crop growth. The plant height was increased progressively with succeeding crop growth till the maturity of crop. The rate of increase in plant height was rapid up to 60 days after sowing and slowed down thereafter.

Plant height of soybean in intercropping treatment like pigeonpea + soybean (50.98 cm) was increased as compared to sole soybean (46.40 cm). This is because of competition for soil moisture, solar radiation, nutrient uptake and space availability.

Table.4.16 Plant height (cm) of Soybean as influenced by different treatment

Treatment	Days after sowing						
	15	30	45	60	75	90	AH
T₃: (Pigeonpea + Soybean)	9.2	27.2	32.3	42.7	47.2	50.8	51.0
T₈: (Sole Soybean)	9.1	25.9	30.1	39.5	45.1	45.7	46.4
G mean	9.1	26.6	31.2	41.1	46.2	48.3	48.7

4.4.2.5 Plant height (cm) of Sesamum as influenced by different treatment

The data on mean plant height of sesamum in cm recorded at various stages of crop growth are presented in Table 4.17 and graphically depicted in Fig. 4.14.

The mean height of sesamum was recorded 3.3 cm, 15.7 cm, 72.7 cm, 104.1 cm, 105.5 cm and 106.7 cm at 30, 45, 60, 75 days after sowing and at harvest, respectively.

The data depicted in Table 4.16 revealed that the plant height (cm) was influenced by different treatments at various stages of crop growth. The plant height was increased progressively with succeeding crop growth stages. The rate of increase in plant height was rapid up to 60 days after sowing and slowed down thereafter.

Plant height of sesamum in intercropping treatment like Pigeonpea + sesamum (99.6 cm) was decreased as compared to sole sesamum (113.8 cm). This is because of competition for soil moisture, solar radiation, nutrient uptake and space availability.

Table.4.17 Plant height (cm) of Sesamum as influenced by different treatment

Treatment	Days after sowing					
	15	30	45	60	75	AH
T₄: (Pigeonpea + Sesamum)	3.2	15.3	72.1	97.6	98.7	99.6
T₉ : (Sole Sesamum)	3.5	16.1	73.3	110.3	112.3	113.8
G mean	3.3	15.7	72.7	104.0	105.5	106.7

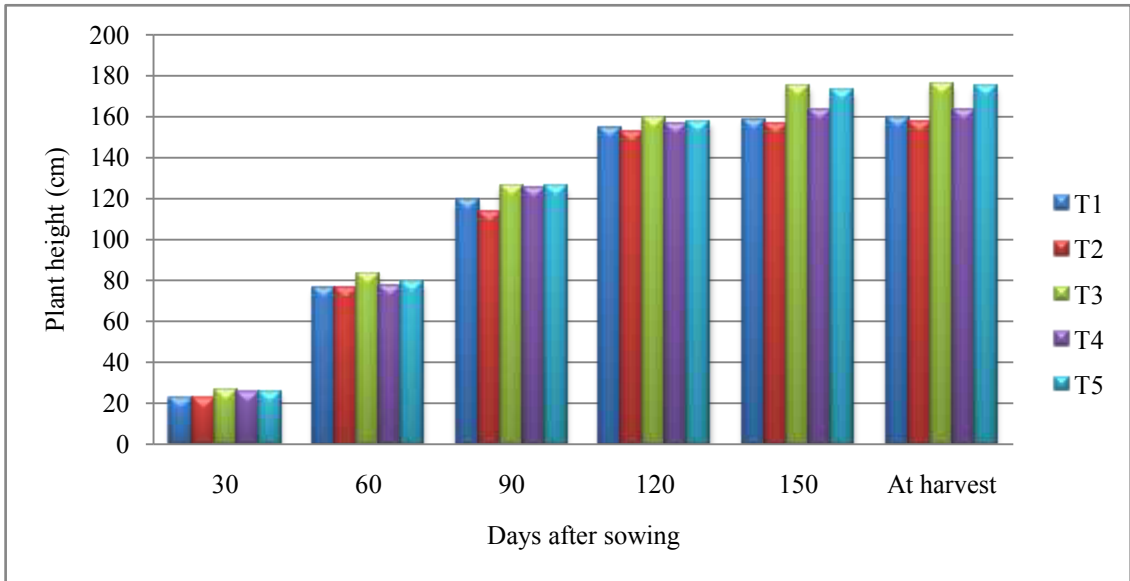


Fig.4.10 Mean plant height of Pigeon pea as influenced by different treatment

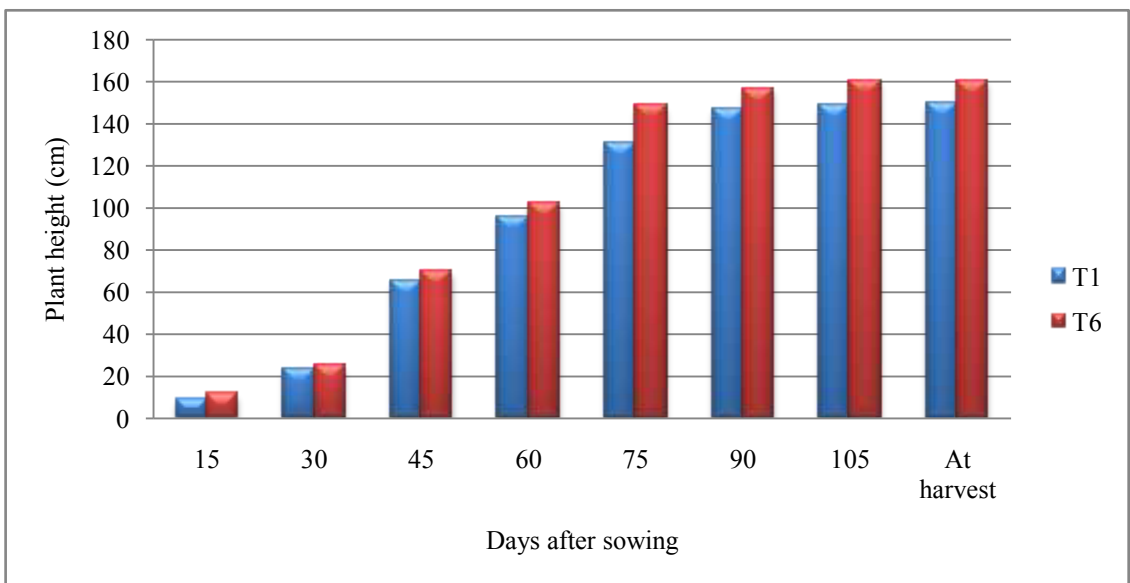


Fig.4.11 Mean plant height of Sorghum as influenced by different treatment

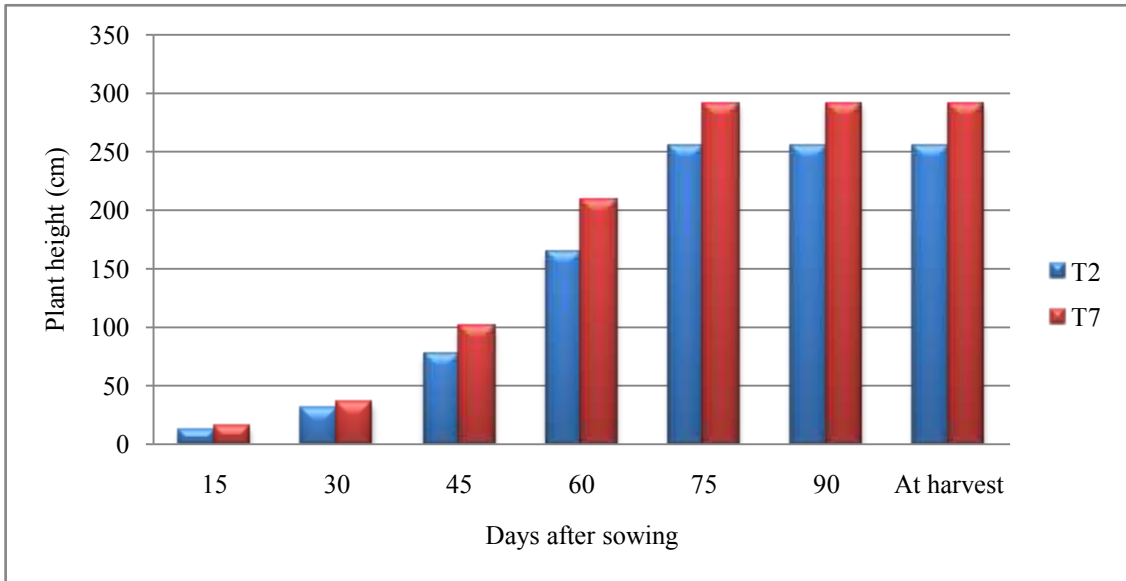


Fig.4.12 Mean plant height of Maize as influenced by different treatment

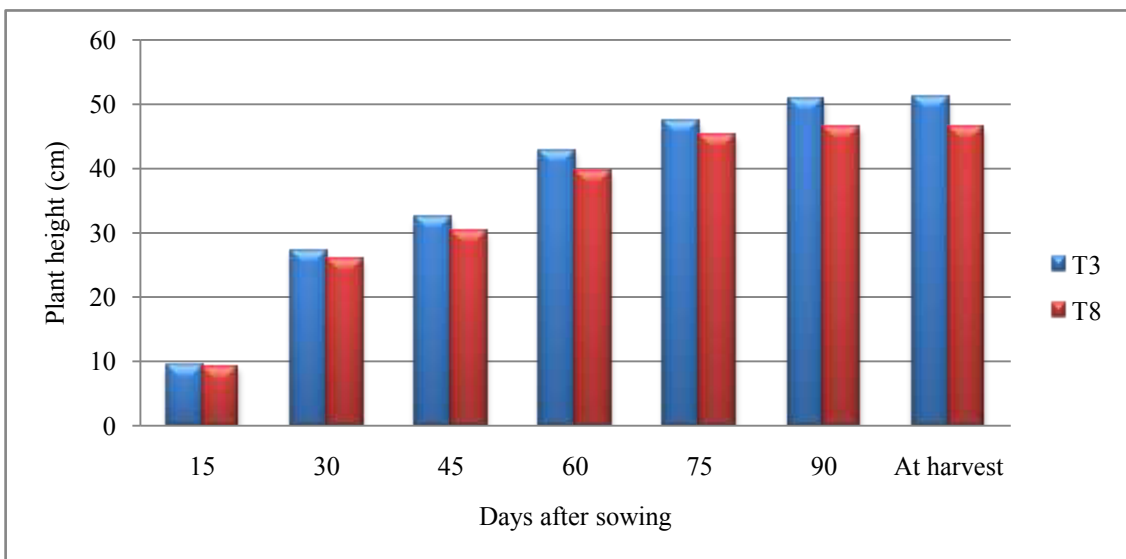


Fig.4.13 Mean plant height of Soybean as influenced by different treatment

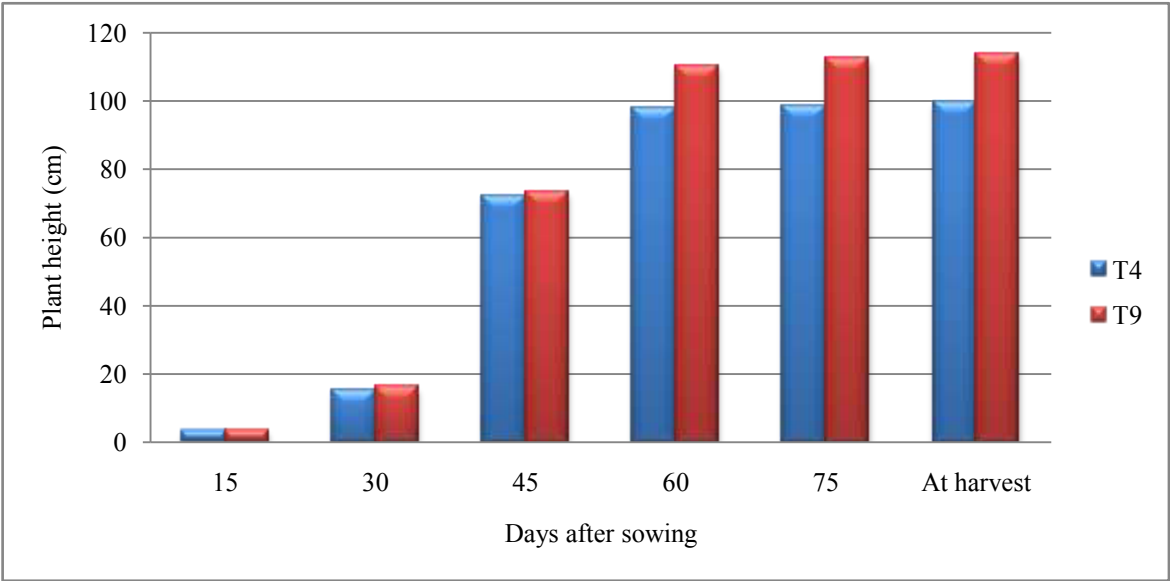


Fig.4.14 Mean plant height of Sesamum as influenced by different treatment

4.4.3 Number of leaves per plant

4.4.3.1 Number of leaves per plant of Pigeon pea as influenced by different treatment

The data on mean number of functional leaves per plant recorded at various stages of crop growth are given in Table 4.18 and graphically depicted in Fig 4.15.

The perusal of data presented in Table 4.17 indicated that the mean number of functional leaves was increased continuously up to 120 DAS of crop growth but later it was decreased due to shedding of leaves up to harvest.

The highest number of leaves to pigeon pea was recorded in sole pigeon pea treatment i.e. (T₅). While, in case of other intercrop treatment i.e. T₁, T₂, T₃ and T₄ observed number of leaves to pigeon pea was lowest than the sole.

Table.4.18 Number of leaves per plant of Pigeon pea as influenced by different treatment

Treatment	Days after sowing					
	30	60	90	120	150	AH
T₁: (Pigeonpea + Sorghum)	7.3	19.8	57.1	133.5	117.8	65.3
T₂: (Pigeonpea + Maize)	6.2	14.4	50.8	117.5	98.5	50.4
T₃: (Pigeonpea + Soybean)	7.6	24.0	76.1	140.2	115.1	53.4
T₄: (Pigeonpea + Sesamum)	7.3	20.9	75.3	138.8	112.4	50.3
T₅: (Sole Pigeonpea)	9.6	26.8	76.5	148.8	116.2	62.7
G mean	7.6	21.2	67.2	135.8	112.0	56.4

4.4.3.2 Number of leaves per plant of Sorghum as influenced by different treatment

The data on mean number of functional leaves per plant recorded at various stages of crop growth are given in Table 4.19 and graphically depicted in Fig 4.16.

Different treatment had no significant effects on number of leaves of sorghum. It was observed that the mean number of leaves was increased up to 75 DAS of crop growth after that the leaves was decreased.

The number of leaves was observed more to sorghum in intercropping treatment (T₁) than in sole sorghum (T₆).

Table.4.19 Number of leaves per plant of Sorghum as influenced by different treatment

Treatment	Days after sowing							
	15	30	45	60	75	90	105	AH
T₁: (Pigeonpea + Sorghum)	3.7	7.2	10.2	12.0	10.1	8.3	5.9	4.1
T₆: (Sole Sorghum)	3.3	7.1	8.6	9.4	7.0	6.5	3.2	2.8
G mean	3.5	7.2	9.4	10.7	8.6	7.4	4.6	3.5

4.4.3.3 Number of leaves per plant of Maize as influenced by different treatment

The data on mean number of functional leaves per plant recorded at various stages of crop growth are given in Table 4.20 and graphically depicted in Fig 4.17.

It was observed that the mean number of leaves was increased up to 60 DAS of crop growth after that the leaves was decreased.

The number of leaves was observed more to maize in intercropping treatment (T₂) than in sole maize (T₇).

Table.4.20 Number of leaves per plant of Maize as influenced by different treatment

Treatment	Days after sowing						
	15	30	45	60	75	90	AH
T₂: (Pigeonpea + Maize)	3.3	6.4	10.2	12.6	11.4	8.7	6.4
T₇: (Sole Maize)	2.2	5.4	7.3	7.4	6.3	4.2	2.1
G mean	2.7	5.9	8.7	10.0	8.9	6.5	4.3

4.4.3.4 Number of leaves per plant of Soybean as influenced by different treatment

The data on mean number of functional leaves per plant recorded at

various stages of crop growth are given in Table 4.21 and graphically depicted in Fig. 4.18.

It was observed that the mean number of leaves was increased rapidly up to 60 DAS of crop growth.

The number of leaves was observed less to soybean in intercropping treatment (T₃) than in sole soybean (T₇).

Table.4.21 Number of leaves per plant of Soybean as influenced by different treatment

Treatment	Days after sowing						
	15	30	45	60	75	90	AH
T₃: (Pigeonpea + Soybean)	2.4	5.5	8.6	12.4	12.8	8.2	1.1
T₈: (Sole Soybean)	3.5	6.6	14.5	18.5	18.4	11.2	1.4
G mean	3.0	6.1	11.6	15.4	15.6	9.5	1.2

4.4.3.5 Number of leaves per plant of Sesamum as influenced by different treatment

The data on mean number of functional leaves per plant recorded at various stages of crop growth are given in Table 4.22 and graphically depicted in Fig. 4.19.

It was observed that the mean number of leaves was increased up to 60 DAS of crop growth after that the leaves was decreased.

The number of leaves was observed more to sesamum in intercropping treatment (T₄) than in sole sesamum (T₉).

Table.4.22 Number of leaves per plant of Sesamum as influenced by different treatment

Treatment	Days after sowing					
	15	30	45	60	75	AH
T₄: (Pigeonpea + Sesamum)	2.8	8.3	18.6	50.6	36.3	25.3
T₉: (Sole Sesamum)	2.0	6.8	18.3	24.6	12.7	6.1
G mean	2.4	7.6	18.4	37.6	24.5	15.7

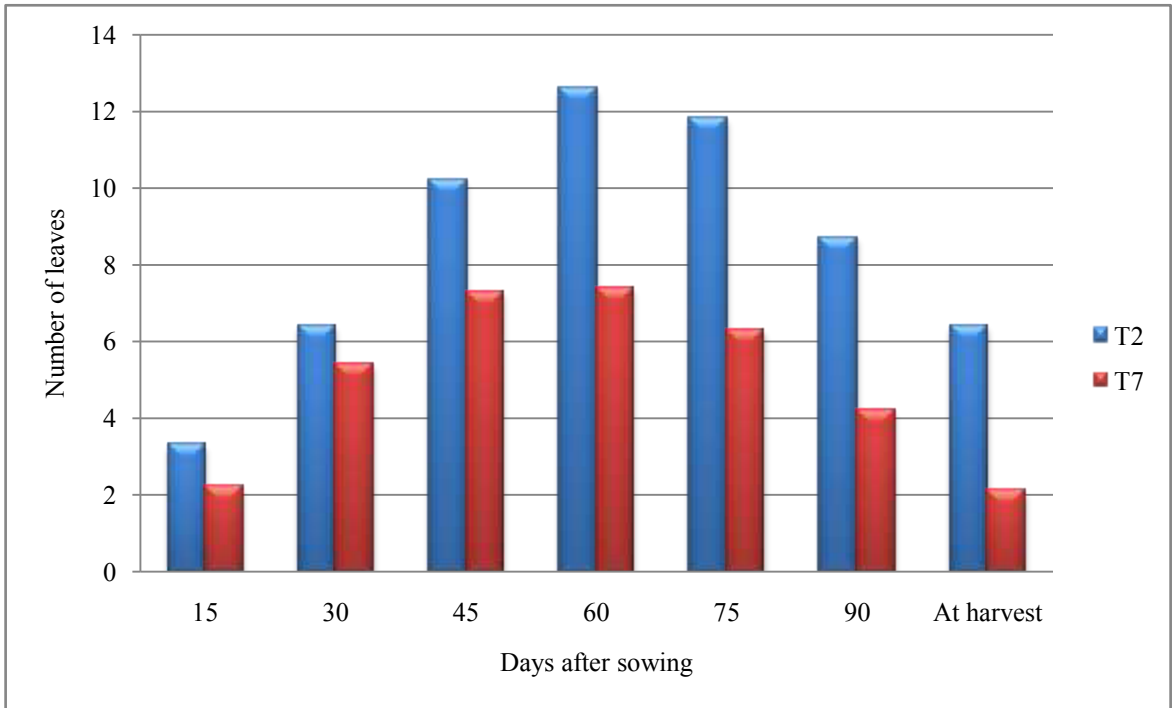


Fig.4.17 Mean number of leaves of Maize as influenced by different treatment

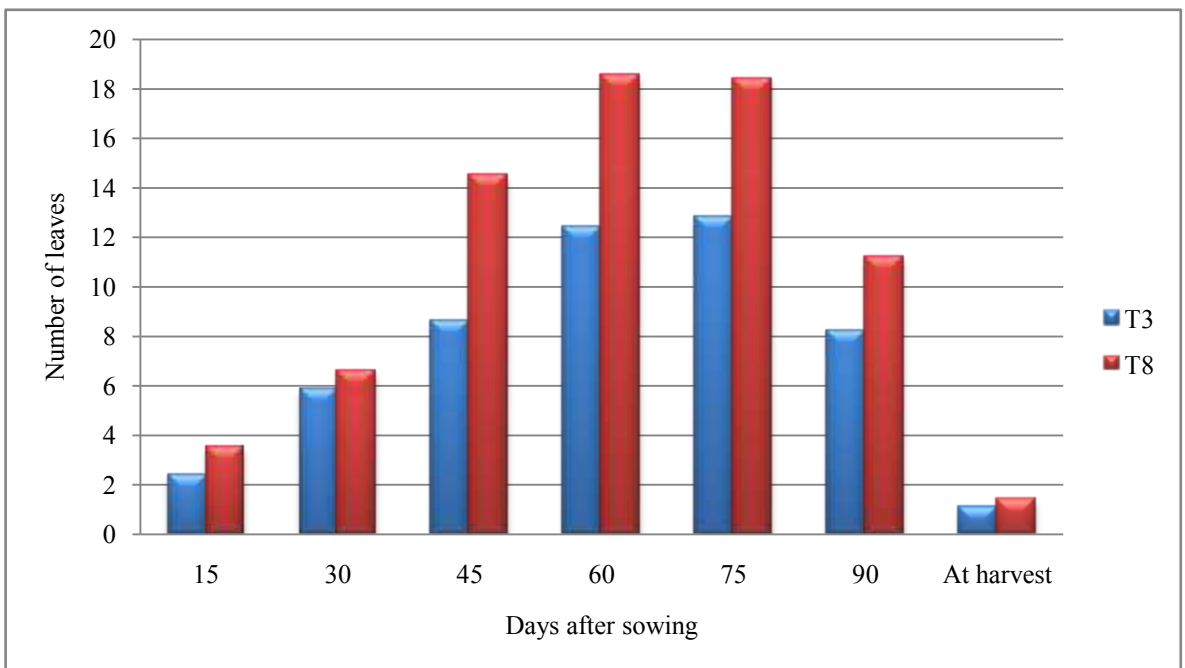


Fig.4.18 Mean number of leaves of Soybean as influenced by different treatment

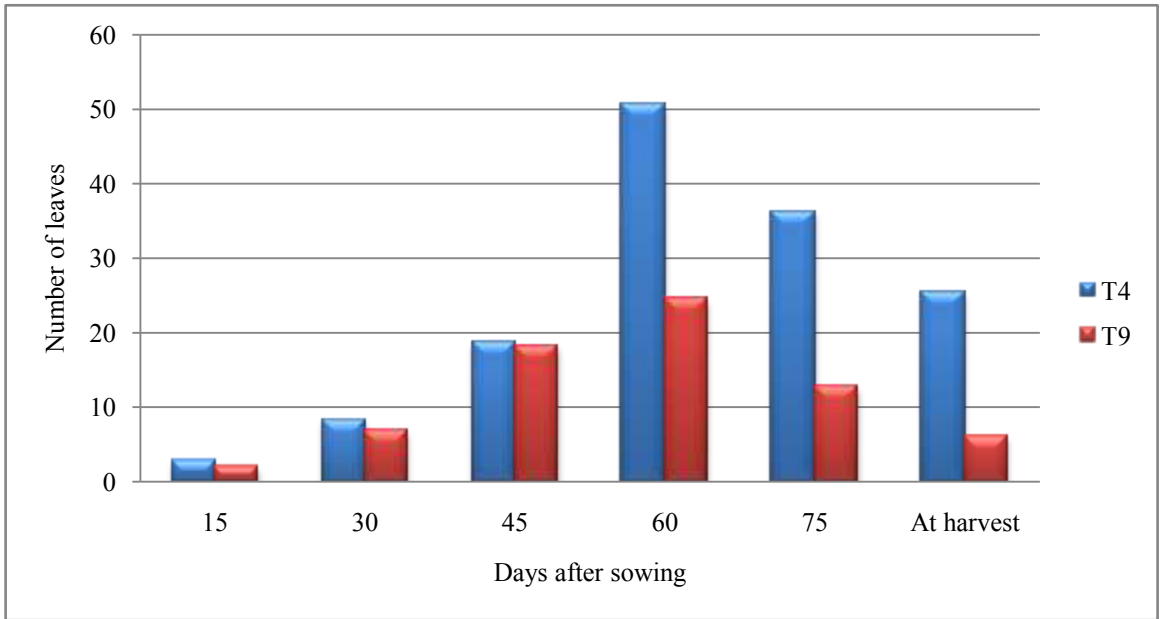


Fig.4.19 Mean number of leaves of Sesamum as influenced by different treatment

4.4.4 Dry matter production (g)

4.4.4.1 Dry matter production (g) of Pigeon pea as influenced by different treatment

The data presented in Table 4.23 and graphically depicted in Fig. 4.20 revealed that the mean dry matter accumulation per plant of pigeon pea crop increased progressively with advancement of crop growth. The rate of dry matter production was slow up to 30 days, fast during 60 to 90 days and very fast during 120 to 150 days and thereafter it was again slowed down. The data on mean dry matter accumulation per plant of pigeon pea indicated significant variation due to intercropping of pigeon pea.

Mean dry matter (g) accumulation per plant was 2.3 g plant⁻¹, 19.3 g plant⁻¹, 37.4 g plant⁻¹, 64.6 g plant⁻¹, 102.4 g plant⁻¹ and 112.5 g plant⁻¹ at 30, 60, 90, 120, 150 days after sowing and at harvest, respectively.

The data revealed that the dry matter production of pigeon pea was lowest in pigeon pea + sorghum (T₁) or Pigeonpea + maize (T₂) intercropping systems as compared to sole pigeon pea. Similar result was observed by Egbe and Bar-Anyam (2010). However, it was observed that the intercropping significantly reduced the dry matter production of pigeon pea and grain yield significantly compared with the sole crop system. Similar result was reported by Kogbe and Adediran (2003).

The erect and taller cereal components grew faster at the early stage and might have avoided the shading effect of the slow growing pigeon pea. The taller sorghum component of the intercropping might have exerted depressive effects through shading the shorter and slow growing pigeon pea component. Hence, the pigeon pea yield under Pigeon Pea + sorghum was low compared to pigeon pea yields with other intercrops i.e. soybean. Similar result was observed by Kathmale *et al.* (2014). Whereas, the similar result was observed in pigeon pea + maize intercropping and attributed to negative effects of the intercropped cereal crop on the pigeon pea component. Similar result was reported by Dasbak and Asiegbu (2009).

Table.4.23 Dry matter production (g) of Pigeon pea as influenced by different treatment

Treatment	Days after sowing					
	30	60	90	120	150	AH
T₁: (Pigeonpea + Sorghum)	2.1	18.3	35.4	57.6	96.5	100.5
T₂: (Pigeonpea + Maize)	2.0	18.0	35.4	59.1	99.8	106.2
T₃: (Pigeonpea + Soybean)	2.4	20.0	38.2	68.0	104.2	118.1
T₄: (Pigeonpea + Sesamum)	2.3	18.8	37.7	67.5	101.1	115.0
T₅: (Sole Pigeonpea)	2.4	21.1	40.3	71.1	110.5	122.7
G mean	2.3	19.3	37.4	64.6	102.4	112.5

4.4.4.2 Dry matter production (g) of Sorghum as influenced by different treatment

The data presented in Table 4.24 and graphically depicted in Fig. 4.21 revealed that the mean dry matter accumulation per plant of sorghum crop increased progressively at various stages of crop growth. However, initially it was increased lower rate up to 45 DAS and there after increased very high rate up to harvest.

Mean dry matter (g) accumulation per plant was 2.2 g plant⁻¹, 6.4 g plant⁻¹, 41.3 g plant⁻¹, 67.0 g plant⁻¹, 80.5 g plant⁻¹, 86.4 g plant⁻¹, 101.4 g plant⁻¹, and 106.0 g plant⁻¹ at 15, 30, 45, 60, 75, 90, 105 days after sowing and at harvest, respectively.

Dry matter production of sorghum was more in Pigeon pea + sorghum (T₁) intercropping than in sole sorghum (T₆). So, it was pointed out that intercrops produced more dry matter than sole.

Table.4.24 Dry matter production (g) of Sorghum as influenced by different treatment

Treatment	Days after sowing							
	15	30	45	60	75	90	105	AH
T₁:(Pigeonpea+Sorghum)	2.2	7.5	42.4	68.1	82.2	88.2	103.4	108.7
T₆:(Sole Sorghum)	2.1	5.3	40.2	66.6	78.7	84.6	99.3	103.3
G mean	2.2	6.4	41.3	67.4	80.5	86.4	101.3	106.0

4.4.4.3 Dry matter production (g) of Maize as influenced by different treatment

The data presented in Table 4.25 and graphically depicted in Fig. 4.22 revealed that the mean dry matter accumulation per plant of maize crop increased progressively at various stages of crop growth. However, initially it was increased lower rate up to 30 DAS and there after increased very high rate up to harvest.

Mean dry matter (g) accumulation per plant was 6.5 g plant⁻¹, 13.1 g plant⁻¹, 53.1 g plant⁻¹, 113.6 g plant⁻¹, 222.1 g plant⁻¹, 230.1 g plant⁻¹ and 234.6 g plant⁻¹, at 15, 30, 45, 60, 75, 90 days after sowing and at harvest, respectively.

Dry matter production of maize was more in Pigeonpea + maize (T₂) intercropping than in sole maize (T₇). So, it was pointed out that intercrops produced more dry matter than sole. Similar result was observed by Rachie and Silvestre, (1977).

Table.4.25 Dry matter production (g) of Maize as influenced by different treatment

Treatment	Days after sowing						
	15	30	45	60	75	90	AH
T ₂ : (Pigeonpea + Maize)	7.0	13.7	54.5	117.9	225.2	232.0	237.7
T ₇ : (Sole Maize)	6.1	12.5	51.8	109.3	218.9	228.1	231.4
Gmean	6.5	13.1	53.1	113.6	222.1	230.1	234.6

4.4.4.4 Dry matter production (g) of Soybean as influenced by different treatment

The data presented in Table 4.26 and graphically depicted in Fig. 4.23 revealed that the mean dry matter accumulation per plant of soybean crop increased progressively with advancement of crop growth. The rate of dry matter production was slow up to 45 DAS and thereafter it was fast up to harvest.

Mean dry matter (gm) accumulation per plant was 0.9 g plant⁻¹, 1.5 g plant⁻¹, 5.9 g plant⁻¹, 10.1 g plant⁻¹, 14.0 g plant⁻¹, 15.0 g plant⁻¹ and 16.2 g plant⁻¹, at 15, 30, 45, 60, 75, 90 days after sowing and at harvest, respectively.

The dry matter production of soybean was lower in pigeon pea + soybean intercropping than in sole. Similar result was shown in pigeon + greengram intercropping system by Dhandayuthapani *et al.* (2015).

Table.4.26 Dry matter production (g) of Soybean as influenced by different treatments

Treatment	Days after sowing						
	15	30	45	60	75	90	AH
T₂: (Pigeonpea + Soybean)	0.7	1.4	5.0	8.4	12.4	13.9	14.6
T₇: (Sole Soybean)	1.0	1.5	6.7	11.5	15.7	16.0	17.8
Gmean	0.9	1.5	5.9	10.0	14.0	15.0	16.2

4.4.4.5 Dry matter production (gm) of Sesamum as influenced by different treatment

The data on mean dry matter accumulation per plant of sesamum recorded at various stages of crop growth are presented in Table 4.27 and graphically depicted in Fig. 4.24.

Mean dry matter production was increased progressively at every stage of crop growth. The rate of dry matter production was slow up to 30 days and thereafter somewhat increases in dry matter accumulation at 45 days, very fast during 45 to 60 days and slowed down at harvest stage.

Mean dry matter production per plant was recorded at different growth stages 1.5 g plant⁻¹, 4.0 g plant⁻¹, 8.2 g plant⁻¹, 10.4 g plant⁻¹ and 13.5 g plant⁻¹ at 30, 45, 60, 75 days after sowing and at harvest, respectively.

The dry matter production of sesamum was more in pigeonpea + sesamum (T₄) intercropping than in sole sesamum (T₉). So, it was pointed out that intercrops produced more dry matter than sole.

Table.4.27 Dry matter production (g) of Sesamum as influenced by different treatment

Treatment	Days after sowing					
	15	30	45	60	75	AH
T₄: (Pigeonpea + Sesamum)	0.2	1.5	4.2	9.1	11.3	14.6
T₉: (Sole Sesamum)	0.1	1.5	3.6	7.2	9.5	12.3
Gmean	0.1	1.5	3.9	8.2	10.4	13.5

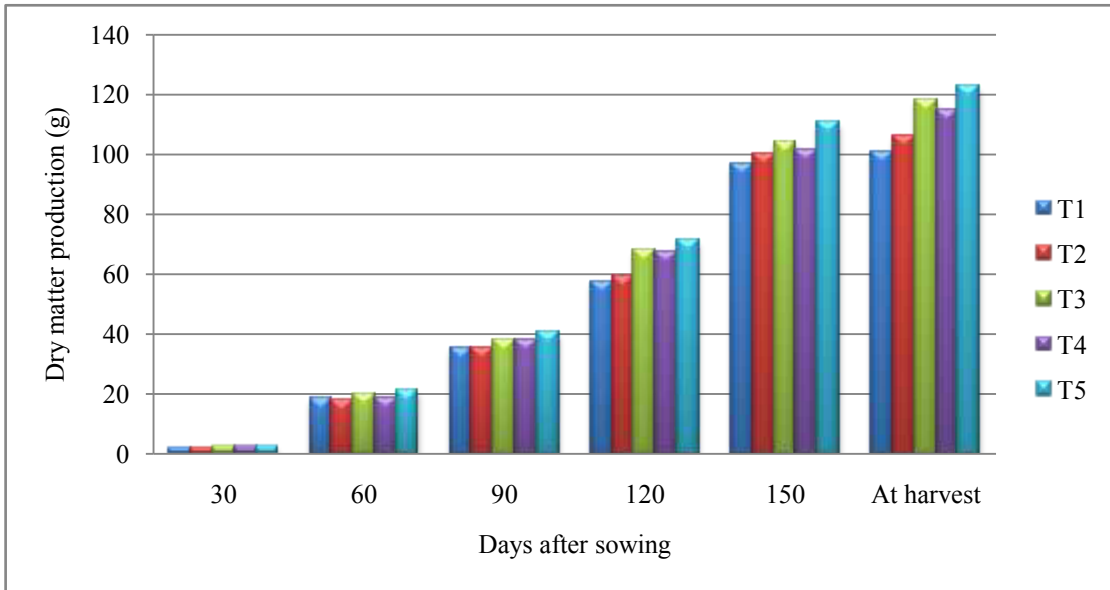


Fig.4.20 Mean dry matter production of Pigeon pea as influenced by different treatment

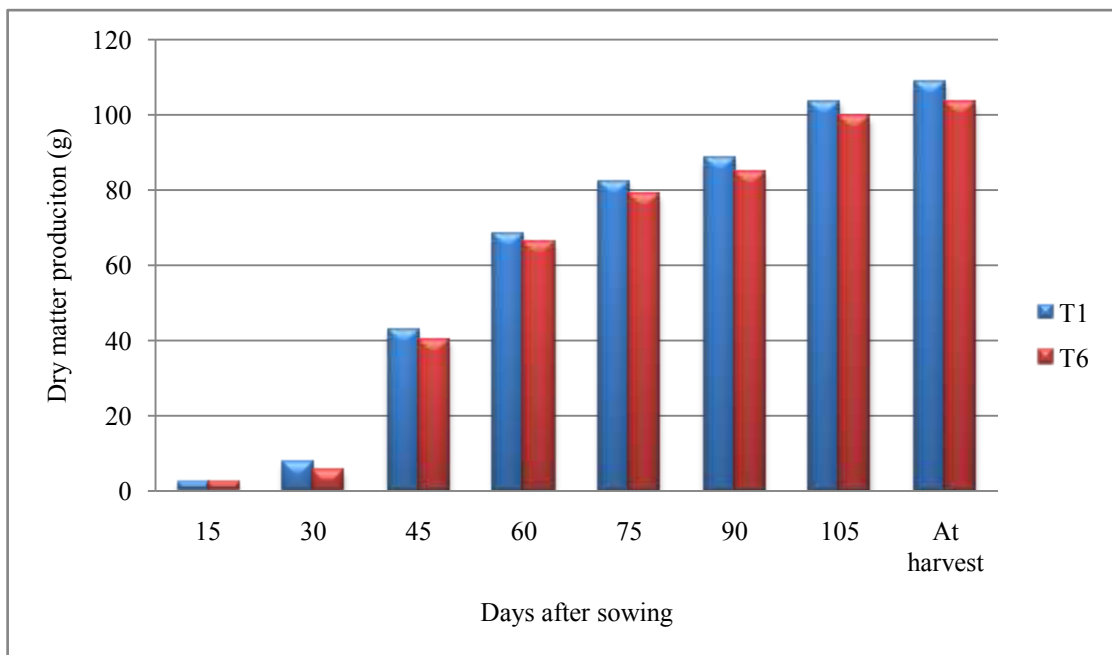


Fig.4.21 Mean dry matter production of Sorghum as influenced by different treatment

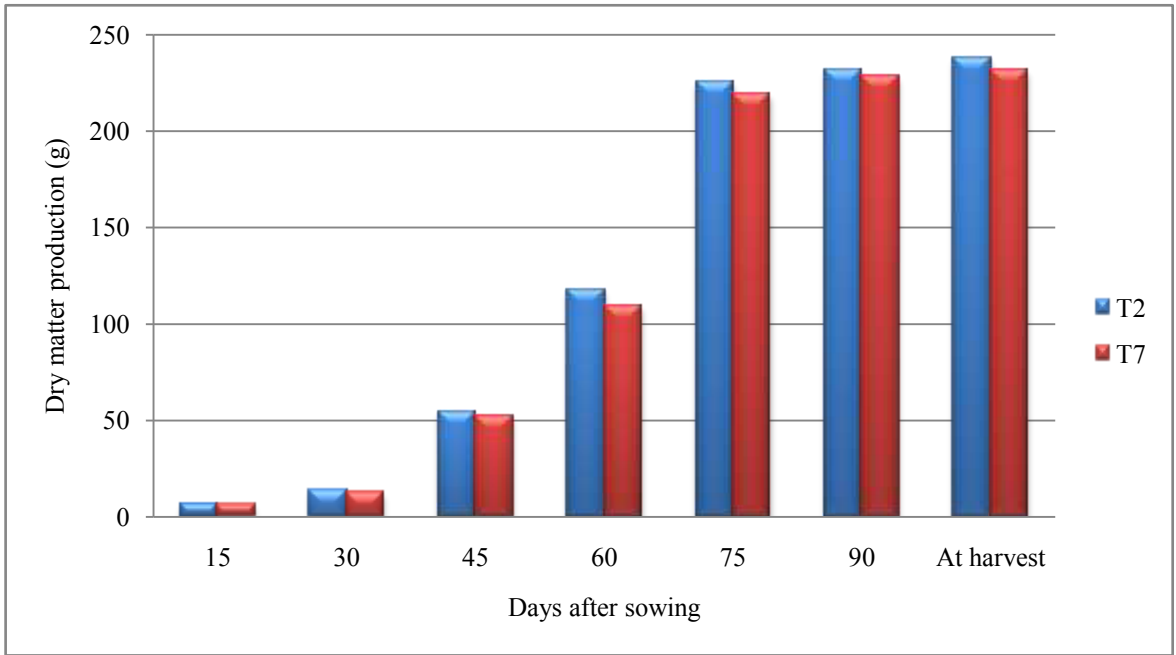


Fig.4.22 Mean dry matter production of Maize as influenced by different treatment

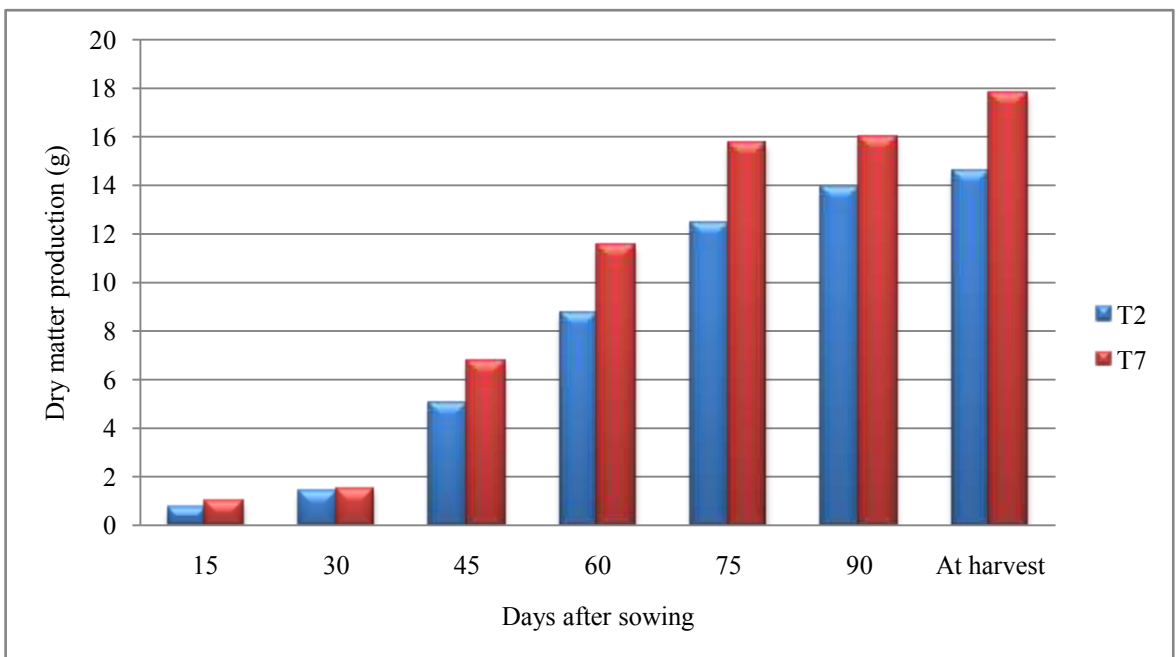


Fig.4.23 Mean dry matter production of Soybean as influenced by different treatment

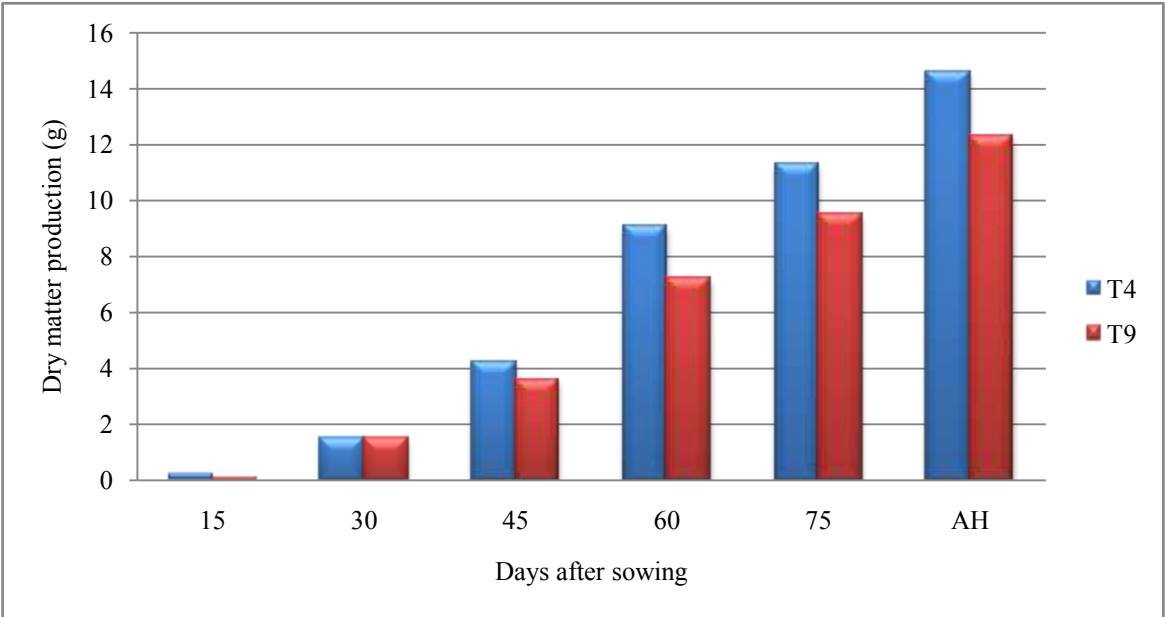


Fig.4.24 Mean dry matter production of Sesamum as influenced by different treatment

4.5 Yield Parameter

4.5.1 Seed / Grain yield (Kg ha⁻¹)

The data from Table 4.28 and graphically depicted in Fig. 4.25 shows that mean pigeon pea equivalent yield (Kg ha⁻¹) was significantly influenced by different treatment. The pigeon pea yield was significantly affected by the intercropping pattern.

There was a significant difference between pigeon pea equivalent yields with various pigeon pea based intercropping systems. The PEY was obtained highest from the pigeon pea + soybean (T₃) intercropping system (1503 Kg ha⁻¹), followed by the pigeon pea + sesamum (T₄) intercropping system (1402 Kg ha⁻¹), pigeon pea + maize (T₂) intercropping system (1277) than the sole pigeon pea (T₅) (1249 Kg ha⁻¹). Whereas, the PEY was obtained lowest from pigeon pea + sorghum (T₁) intercropping system (861 Kg ha⁻¹) as compared to sole pigeon pea. However, in the pigeon pea equivalent yield it was observed that the treatment T₃ was significantly superior than other treatment, which was at par with the treatment T₄.

The legume and legume as main crop and intercrop might have symbiotic effect with each other and reduced the competition for moisture and nutrients between the component crops and significantly increased yield of both component crops. Hence, the PEY from pigeon pea + soybean intercropping treatment was highest. Similar result was reported by Waghmare *et al.* (1982) and Kathmale *et al.* (2014).

Sole pigeon pea seemed to have been more remunerative than pigeon pea + sorghum intercropping probably because of intense inter-specific competition from the sorghum component and subsequently reduced profits. On the other hand, maize crop adversely affected the yield of pigeon pea however the PEY was more than sole pigeon pea because of good yield of maize but it could not compensate the losses occurred due to reduced pigeon pea yield. Similar result was observed by Egbe and Idoko, (2012) and Tiwari *et al.* (2012).

So it was observed that sole pigeon pea gave significantly higher grain yield than the intercropped. However, intercropping systems gave higher PEY over

sole pigeon pea except from pigeonpea + sorghum intercropping treatment. Similar results were observed by Ito *et al.*, (1993), Singh and Singh, (1994), Tomar *et al.* (2004), Rekha and Dhurua, (2009), and Reddy *et al.* (2015).

Table 4.28 Seed yield of crops

Treatments	Seed yield(Kg ha ⁻¹)		
	Main	Inter	Pig.Equi. Yield
T₁ (Pigeonpea + Sorghum)	597	602	861
T₂ (Pigeonpea + Maize)	837	1453	1277
T₃ (Pigeonpea + Soybean)	1283	345	1503
T₄ (Pigeonpea + Sesamum)	1292	99	1402
T₅ (Sole Pigeon pea)	1349	-	1349
T₆ (Sole Sorghum)	3280	-	3280
T₇ (Sole Maize)	4108	-	4108
T₈ (Sole Soybean)	1410	-	1410
T₉ (Sole Sesamum)	285	-	285
S.E±	-	-	54.62
CD at 5%	-	-	165.16
G Mean	1604.6	624.8	1260.8

4.5.2 Stalk / Stover yield (Kg ha⁻¹)

The data from Table 4.29 and graphically depicted in Fig. 4.26 shows that mean pigeonpea equivalent stalk/stover yield (Kg ha⁻¹) was significantly influenced by different treatments. The stalk yield was significantly affected by the intercropping patten. Stalk/stover yield was significantly superior in treatment (T₂) 3088 Kg ha⁻¹ i.e. pigeonpea + maize as compared to all treatment and lowest stalk/stover yield was in treatment (1418 Kg ha⁻¹) i.e. sole soybean.

Among pigeon pea based intercropping systems, higher stalk yield of sorghum as an intercrop was recorded in pigeon pea + sorghum system. Hence, the pigeon pea equivalent stalk yield under Pigeon Pea + sorghum was highest as compared to pigeon pea yields with other intercrops. Similar result was reported by Kathmale *et al.* (2014).

Table 4.29 Stalk /Stover yield of crops

Treatments	Stalk/Stover yield(Kg ha ⁻¹)		
	Main	Inter	Total
T₁ (Pigeonpea + Sorghum)	1970	589	2559
T₂ (Pigeonpea + Maize)	1960	1128	3088
T₃ (Pigeonpea + Soybean)	2080	640	2720
T₄ (Pigeonpea + Sesamum)	2096	162	2258
T₅ (Sole Pigeon pea)	2120	-	2120
T₆ (Sole Sorghum)	2284	-	2284
T₇ (Sole Maize)	2884	-	2884
T₈ (Sole Soybean)	1418	-	1418
T₉ (Sole Sesamum)	1734	-	1734
G Mean	2060.7	629.8	2340.6

4.5.3 Biological yield (Kg ha⁻¹)

The data from Table 4.30 and graphically depicted in Fig. 4.27 shows that mean biological yield (Kg ha⁻¹) was significantly influenced by different treatments. The biological yield was significantly affected by the intercropping system. The Biological yield was significantly superior in intercropped treatment (T₂) 5378 Kg ha⁻¹ i.e. pigeon pea + maize as compared to sole pigeon pea (T₅) 3469 Kg ha⁻¹ whereas highest biological yield was obtained from treatment (T₇) 6992 i.e. sole maize and lowest biological yield was obtained from the treatment (T₉) 2019 Kg ha⁻¹ i.e. sole sesamum.

Pigeon pea based intercropping systems have proved sustainable in respect of yield and income with short duration intercrops of cereals, pulses and oilseed crops across diverse rainfed agroecologies. Similar result was reported by Rao *et al.*, (2003) and Vittal *et al.*, (2005).

Intercropping can significantly increase total productivity as compared to sole cropping thanks to better utilization of water, nutrients and solar energy. Similar result was noticed by Yildirim and Guvenc, (2005).

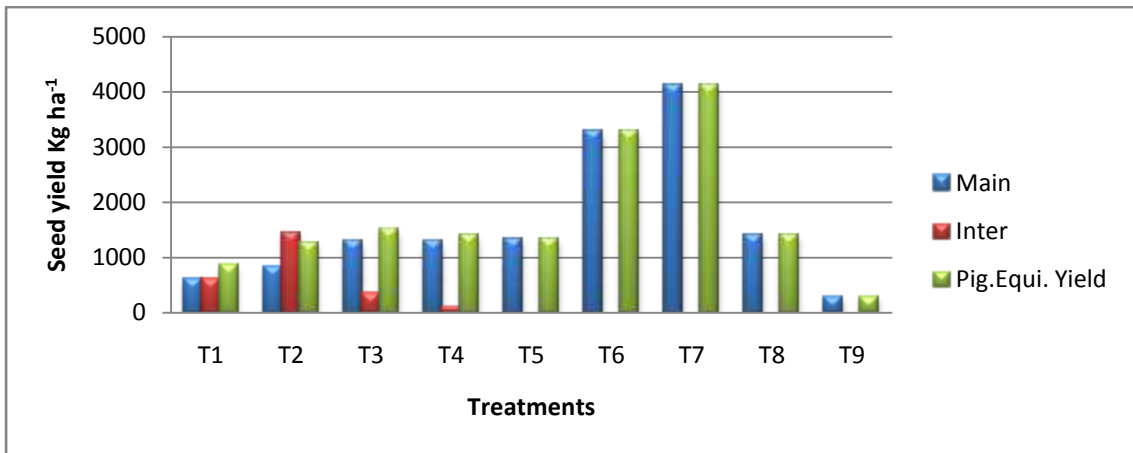


Fig.4.25 Seed yield of crops

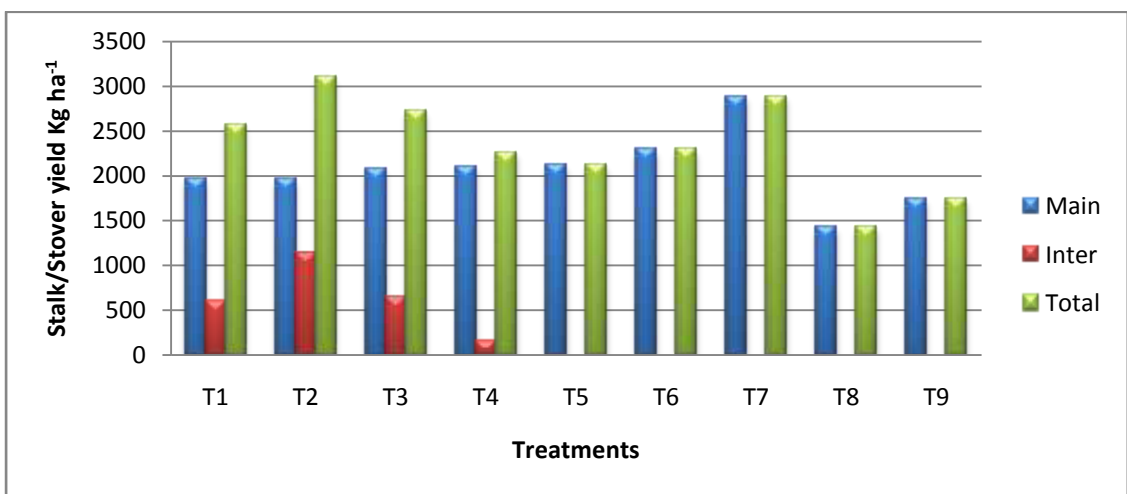


Fig.4.26 Stalk/Stover yield of crops

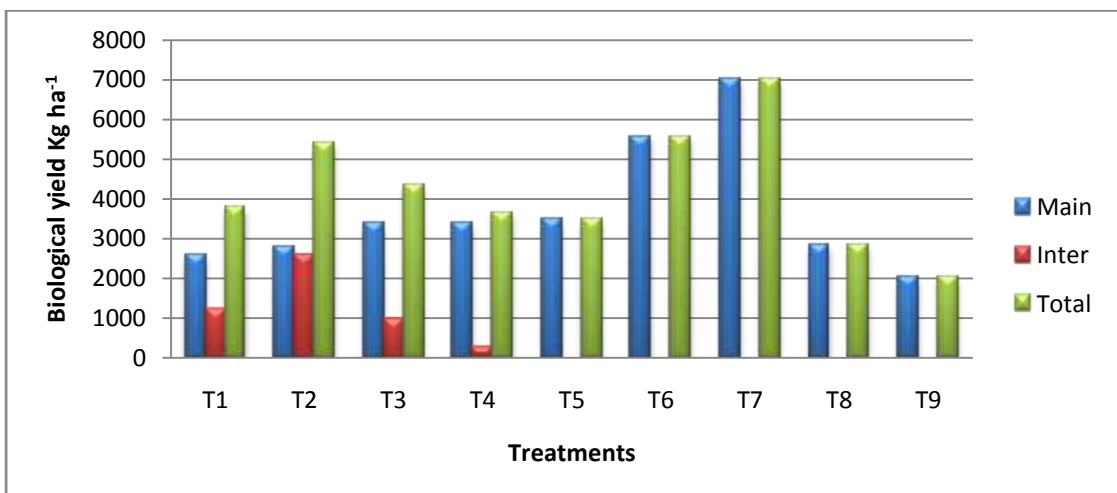


Fig.4.27 Biological yield of crops

Table 4.30 Biological yield of crops

Treatments	Biological yield (Kg ha ⁻¹)		
	Main	Inter	Total
T₁ (Pigeonpea + Sorghum)	2567	1191	3758
T₂ (Pigeonpea + Maize)	2797	2581	5378
T₃ (Pigeonpea + Soybean)	3363	985	4348
T₄ (Pigeonpea + Sesamum)	3388	261	3649
T₅ (Sole Pigeon pea)	3469	-	3469
T₆ (Sole Sorghum)	5564	-	5564
T₇ (Sole Maize)	6992	-	6992
T₈ (Sole Soybean)	2828	-	2828
T₉ (Sole Sesamum)	2019	-	2019
G Mean	3665.2	1254.5	4222.8

4.6.1 Land Equivalent Ratio (LER)

The ratio of the area under sole cropping to the area under intercropping needed to give equal amounts of yield at the same management level. It is the sum of fractions of the intercropped yields divided by the sole crop yield. The LER indicates the clear picture of merits and demerit of intercropping system. It describes the relative land area required under sole cropping to produce the same yield as under intercropping. Intercropping of pigeon pea with soybean and sesamum crops resulted in LER more than one, indicating its advantage. It was range from 0.62 to 1.29. In present study, intercropping of pigeon pea with soybean and sesamum recorded significantly higher LER (1.19 and 1.29) compare to sole and other intercropping system, which indicate 19% and 29% more area would be required by sole crop to equal the yield attained under this intercropping system. Similar result was obtained by Kathmale *et al.*, (2014).

Table 4.31 Effect of intercropping on Land Equivalent Ratio

Treatments	Equivalent area (ha)		LER
	Main crop	Inter crop	
T₁ (Pigeonpea + Sorghum)	0.44	0.18	0.62
T₂ (Pigeonpea + Maize)	0.62	0.35	0.97
T₃ (Pigeonpea + Soybean)	0.95	0.24	1.19
T₄ (Pigeonpea + Sesamum)	0.95	0.34	1.29
T₅ (Sole Pigeon pea)	1.00	-	1.00
T₆ (Sole Sorghum)	1.00	-	1.00
T₇ (Sole Maize)	1.00	-	1.00
T₈ (Sole Soybean)	1.00	-	1.00
T₉ (Sole Sesamum)	1.00	-	1.00

4.7 Agro meteorological indices

The data recorded on these aspects were not subjected 'F' of variance and results are interpreted on the basis of values.

4.7.1 Growing Degree Days (GDD)

4.7.1.1 Growing Degree Days (GDD) of Pigeon pea

Thermal time is widely used for describing the temperature responses to growth and development of crops. Thermal time or GDD required for completion of different phenophases of pigeon pea were worked out and given in Table 4.31 and graphically depicted in Fig. 4.28.

The data revealed that there was marked influence on GDD at sowing to emergence, emergence to branching, branching to flowering, flowering to pod formation and pod formation to physiological maturity was observed 247.3, 1196.5, 2736.0, 2946.8 and 4167.0 °C day, respectively.

Among the different treatment, the highest total GDD (4315.7 °C day) was accumulated by treatment (T₁) i.e. pigeon pea intercropped with sorghum and lowest total GDD (3988.3 °C day) found in treatment (T₅) i.e. sole pigeon pea than other treatments.

The result indicated that the total GDD accumulated from sowing to physiological maturity ranged between 3988.3 to 4315.7 °C day among the treatments.

Table.4.32 Accumulated Growing Degree Day (GDD °C day) to attain various phenophases in Pigeon pea under different treatment

Treatment	Phenophases					
	P ₁	P ₂	P ₃	P ₄	P ₅	Total
T₁: (Pigeonpea + Sorghum)	247.3	1228.5	2816.4	3055.4	4315.7	4315.7
T₂: (Pigeonpea + Maize)	247.3	1228.5	2791.8	3030.8	4274.6	4274.6
T₃: (Pigeonpea + Soybean)	247.3	1201.9	2742.0	2957.0	4184.7	4184.7
T₄: (Pigeonpea + Sesamum)	247.3	1174.9	2690.7	2882.7	4071.9	4071.9
T₅: (Sole Pigeon pea)	247.3	1148.5	2639.1	2808.1	3988.3	3988.3
Gmean	247.3	1196.5	2736.0	2946.8	4167.0	-

P₁ – Sowing to emergence

P₃ – Branching to flowering

P₅ – Pod formation to physiological maturity

P₂ – Emergence to branching

P₄ – Flowering to pod formation

4.7.1.2 Growing Degree Days (GDD) of Sorghum

Thermal time is widely used for describing the temperature responses to growth and development of crops. Thermal time or GDD required for completion of different phenophases of sorghum were worked out and given in Table 4.32 and graphically depicted in Fig. 4.29.

The data revealed that there was marked influence on GDD at sowing to emergence, emergence to penical initiation, penical initiation to flag leaf stage, flag leaf stage to boot stage, boot stage to flowering, flowering to dough stage and dough stage to physiological maturity was observed 160.5, 1393.6, 1690.3, 1964.4, 2179.6, 2421.6 and 3058.2 °C day, respectively.

Among the different treatment, the highest total GDD (3109.8 °C day) was accumulated by treatment (T₁) i.e. pigeon pea intercropped with sorghum and lowest total GDD (3006.5 °C day) found in treatment (T₆) i.e. sole sorghum.

The result indicated that the total GDD accumulated from sowing to physiological maturity ranged between 3006.5 to 3109.8 °C day among the treatment.

Table.4.33 Accumulated Growing Degree Day (GDD °C day) to attain various phenophases in Sorghum under different treatment

Treatment	Phenophases							Total
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	
T1:(Pigoenpea+Sorghum)	160.5	1395.2	1703.7	1978.3	2208.4	2462.0	3109.8	3109.8
T6:(Sole Sorghum)	160.5	1392.0	1676.9	1950.5	2150.7	2381.2	3006.5	3006.5
G mean	160.5	1393.6	1690.3	1964.4	2179.6	2421.6	3058.2	-

P₁ – Sowing to emergence

P₂ Emergence to penical initiation

P₃ – Penical initiation to flag leaf stage

P₄ – Flag leaf stage to boot stage

P₅ – Boot stage to flowering

P₆ – Flowering to dough stage

P₇ – Dough stage to physical maturity

4.7.1.3 Growing Degree Days (GDD) of Maize

Thermal time is widely used for describing the temperature responses to growth and development of crops. Thermal time or GDD required for completion of different phenophases of maize were worked out and given in Table 4.33 and graphically depicted in Fig. 4.30.

The data revealed that there was marked influence on GDD at sowing to seedling, seedling to grandgrowth, grandgrowth to tasseling, teaseling to silking,

silking to milk stage and milk stage to physical maturity was observed 385.7, 1298.8, 1494.0, 1605.9, 2325.1 and 2692.5 °C day, respectively.

Among the different treatment, the highest total GDD (2743.6 °C day) was accumulated by treatment (T₂) i.e. pigeon pea intercropped with maize and lowest total GDD (2641.3 °C day) found in treatment (T₇) i.e. sole maize.

The result indicated that the total GDD accumulated from sowing to physiological maturity ranged between 2641.3 to 2743.6 °C day among the treatment.

Table.4.34 Accumulated Growing Degree Day (GDD °C day) to attain various phenophases in Maize under different treatment

Treatment	Phenophases						Total
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	
T ₂ :(Pigeonpea+Maize)	385.7	1314.5	1522.8	1644.7	2365.0	2743.6	2743.6
T ₇ :(Sole Maize)	385.7	1283.0	1465.2	1567.0	2285.2	2641.3	2641.3
G mean	385.7	1298.8	1494.0	1605.9	2325.1	2692.5	-

P₁ – Sowing to seedling

P₂ – Seedling to grandgrowth

P₃ – Grandgrowth to tasseling

P₄ – Tasseling to silking

P₅ – Silking to milk stage

P₆ – Milk stage to physical maturity

4.7.1.4 Growing Degree Days (GDD) of Soybean

Thermal time is widely used for describing the temperature responses to growth and development of crops. Thermal time or GDD required for completion of different phenophases of soybean were worked out and given in Table 4.34 and graphically depicted in Fig. 4.31.

The data revealed that there was marked influence on GDD at sowing to seedling, seedling to branching, branching to flowering, flowering to pod formation, pod formation to grain formation and grain formation to physiological maturity was observed 644.1, 1475.2, 1666.9, 1825.9, 2021.7 and 2629.3 °C day, respectively.

Among the different treatment, the highest total GDD (2721.3 °C day) was accumulated by treatment (T₈) i.e. sole soybean and lowest total GDD (2537.3 °C day) found in treatment (T₃) i.e. pigeon pea intercropped with soybean.

The result indicated that the total GDD accumulated from sowing to physiological maturity ranged between 2537.3 to 2721.3 °C day among the treatment.

Table.4.35 Accumulated Growing Degree Day (GDD °C day) to attain various phenophases in Soybean under different treatment

Treatment	Phenophases						Total
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	
T₃:(Pigeonpea+Soybean)	644.1	1446.7	1628.2	1773.2	1942.6	2537.3	2537.3
T₈:(Sole Soybean)	644.1	1503.6	1705.6	1878.6	2100.7	2721.3	2721.3
G mean	644.1	1475.2	1666.9	1825.9	2021.7	2629.3	-

P₁ – Sowing to seedling

P₂ – Seedling to branching

P₃ – Branching to flowering

P₄ – Flowering to pod formation

P₅ – Pod formation to grain formation

P₆ – Grain formation to physical maturity

4.7.1.5 Growing Degree Days (GDD) of Sesamum

Thermal time is widely used for describing the temperature responses to growth and development of crops. Thermal time or GDD required for completion of different phenophases of sesamum were worked out and given in Table 4.35 and graphically depicted in Fig. 4.32.

The data revealed that there was marked influence on GDD at sowing to emergence, emergence to branching, branching to flowering, flowering to capsules and capsules to physiological maturity was observed 134.3, 650.5, 856.9, 1122.7 and 2393.2 °C day, respectively.

Among the different treatment, the highest total GDD (2447.3 °C day) was accumulated by treatment (T₄) i.e. pigeon pea intercropped with sesamum and lowest total GDD (2339.1 °C day) found in treatment (T₉) i.e. sole sesamum.

The result indicated that the total GDD accumulated from sowing to physiological maturity ranged between 2339.1 to 2447.3 °C day among the treatment.

Table.4.36 Accumulated Growing Degree Day (GDD °C day) to attain various phenophases in Sesamum under different treatment

Treatment	Phenophases					Total
	P ₁	P ₂	P ₃	P ₄	P ₅	
T₄:(Pigeonpea+Sesamum)	134.3	664.7	883.0	1163.3	2447.3	2447.3
T₉:(Sole Sesamum)	134.3	636.2	830.7	1082.0	2339.1	2339.1
G mean	134.3	650.5	856.9	1122.7	2393.2	-

P₁ – Sowing to emergence

P₂ – Emergence to branching

P₃ – Branching to flowering

P₄ – Flowering to capsules

P₅ – Capsules to physical maturity

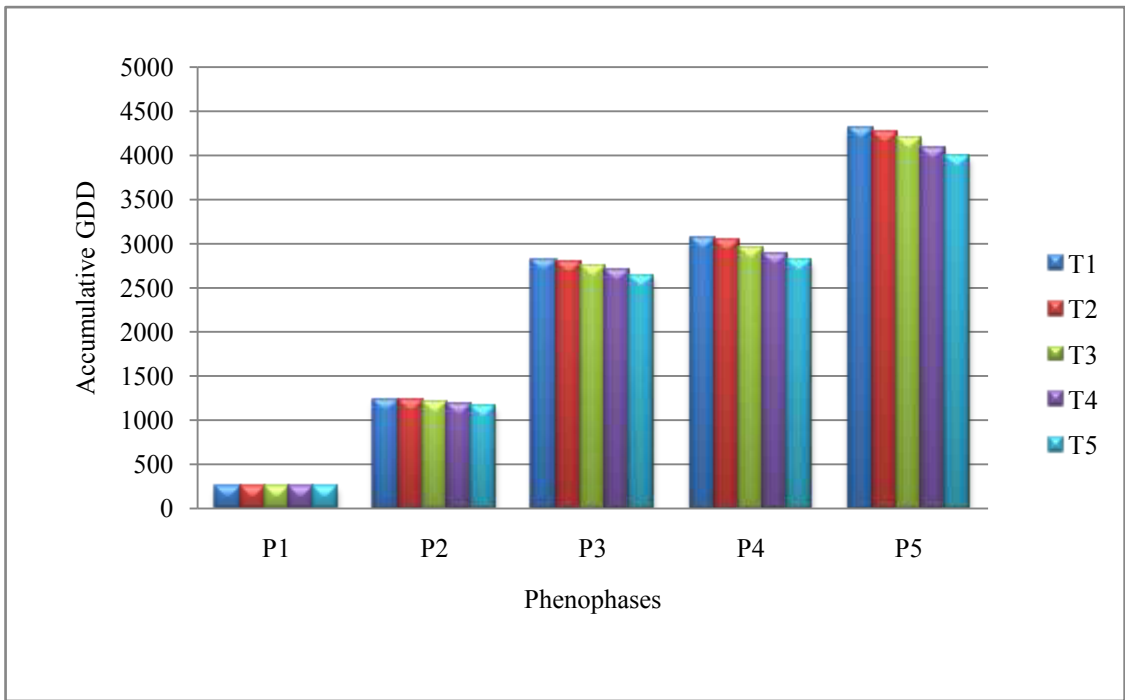


Fig.4.28 Accumulated Growing Degree Days (GDD) to attain various phenophases in Pigeon pea

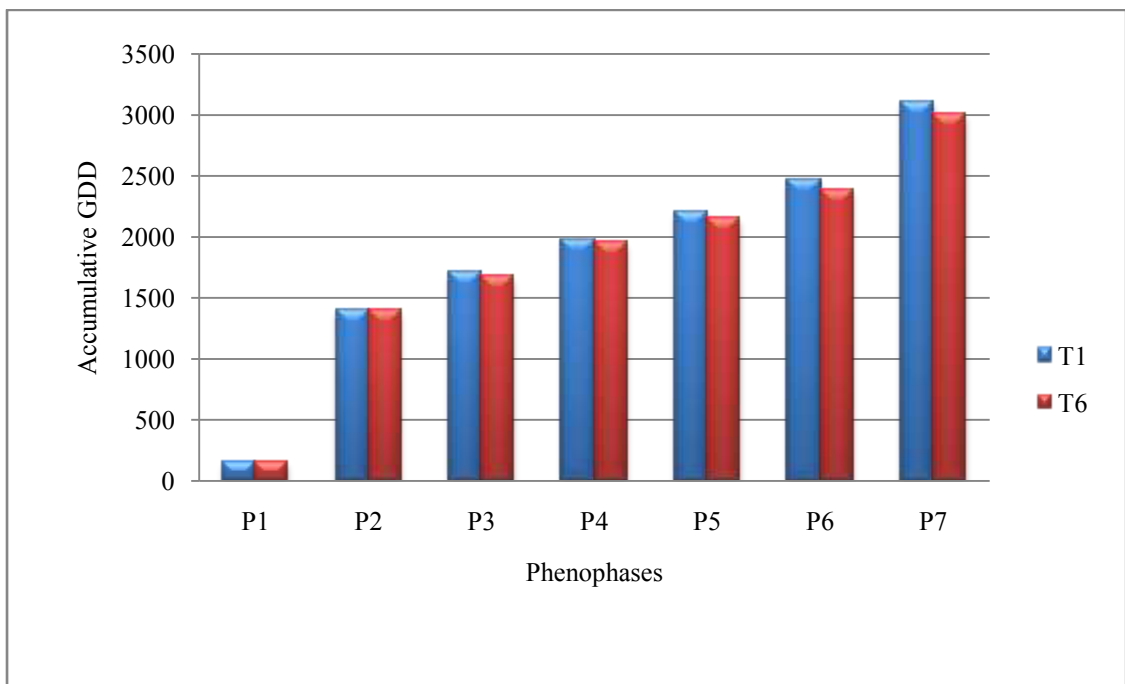


Fig.4.29 Accumulated Growing Degree Days (GDD) to attain various phenophases in Sorghum

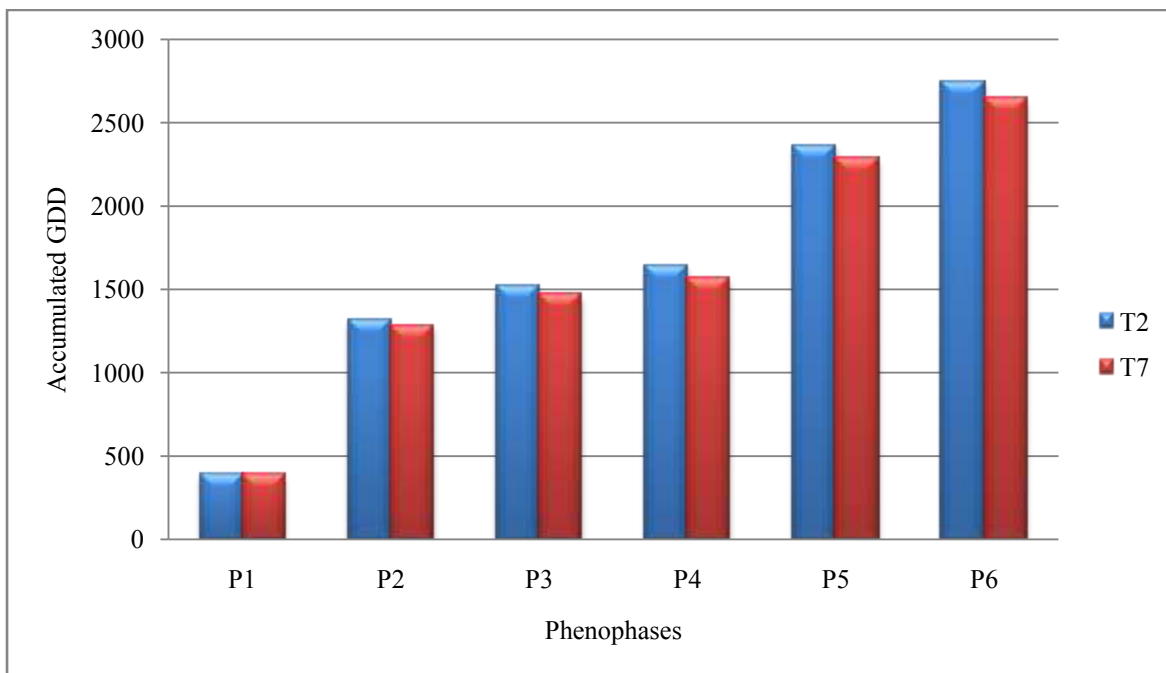


Fig.4.30 Accumulated Growing Degree Days (GDD) to attain various phenophases in Maize

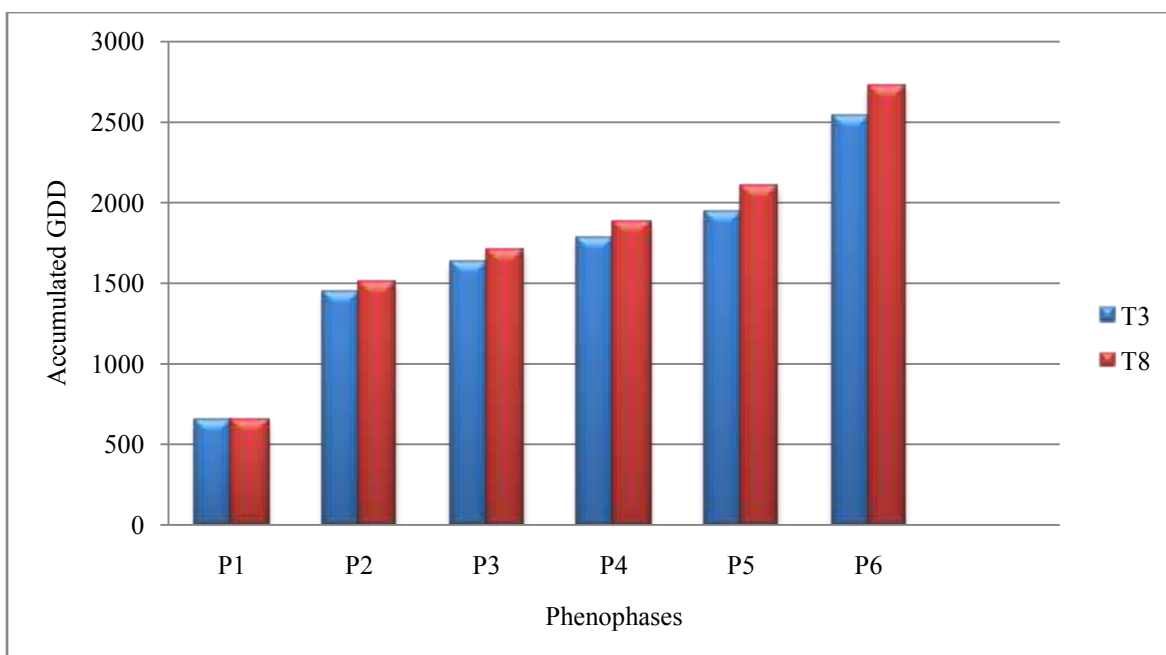


Fig.4.31 Accumulated Growing Degree Days (GDD) to attain various phenophases in Soybean

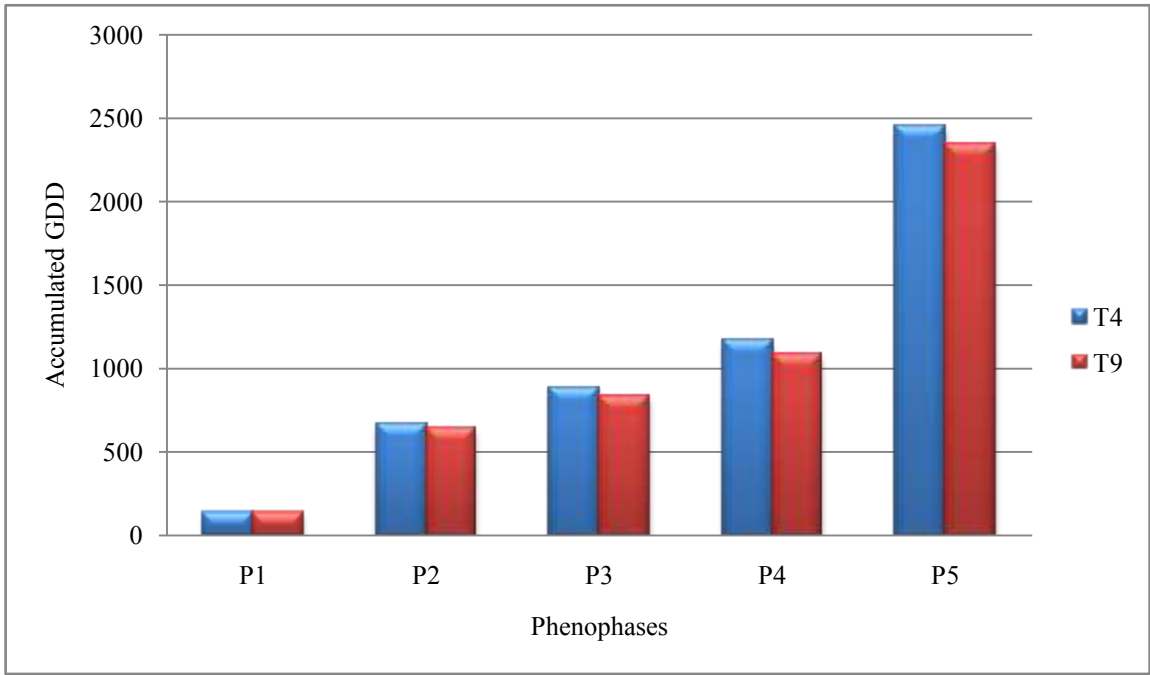


Fig.4.32 Accumulated Growing Degree Days (GDD) to attain various phenophases in Sesamum

4.7.2 Helio Thermal Units (HTU)

4.7.2.1 Helio Thermal Units (HTU) of Pigeon pea

The data presented in Table 4.36 and graphically depicted in Fig. 4.33 and represented helio thermal unit requirement for each phenophases were different required by different treatment.

The data revealed that there was marked influence on HTU at sowing to emergence, emergence to branching, branching to flowering, flowering to pod formation and pod formation to physiological maturity was observed 840.8, 5016.1, 13824.5, 14997.0 and 24080.4 °C day hour, respectively.

Among the different treatment, the highest total HTU (25021.4 °C day) was accumulated by treatment (T₁) i.e. pigeon pea intercropped with sorghum as compared to sole pigeon pea and lowest total (22907.1 °C day) found in treatment (T₅) i.e. sole pigeon pea than other treatments.

The mean helio thermal units observed in treatments (T₁, T₂, T₃, T₄ and T₅) were ranged from 22907.1 to 25021.4 °C day hour.

Table.4.37 Accumulated Helio Thermal Unit (HTU °C day hrs) to attain various phenophases in Pigeon pea under different treatment

Treatment	Phenophases					
	P ₁	P ₂	P ₃	P ₄	P ₅	Total
T₁:(Pigeonpea+Sorghum)	840.8	5158.1	14367.6	15443.1	25021.4	25021.4
T₂:(Pigeonpea+Maize)	840.8	5158.1	14225.5	15372.7	24825.2	24825.2
T₃:(Pigeonpea+Soybean)	840.8	4945.7	13724.0	14949.5	24156.9	24156.9
T₄:(Pigeonpea+Sesamum)	840.8	4922.2	13562.0	14810.0	23491.2	23491.2
T₅:(Sole Pigeon pea)	840.8	4896.2	13243.6	14409.7	22907.1	22907.1
G mean	840.8	5016.1	13824.5	14997.0	24080.4	-

P₁ – Sowing to emergence

P₂ – Emergence to branching

P₃ – Branching to flowering

P₄ – Flowering to pod formation

P₅ – Pod formation to physiological maturity

4.7.2.2 Helio Thermal Units (HTU) of Sorghum

The data presented in Table 4.37 and graphically depicted in Fig. 4.34 and represented helio thermal unit requirement for each phenophases were different required by different treatment.

The data revealed that there was marked influence on HTU at sowing to emergence, emergence to penical initiation, penical initiation to flag leaf stage, flag leaf stage to boot stage, boot stage to flowering, flowering to dough stage and dough stage to physiological maturity was observed 497.6, 6416.6, 8132.7, 8941.4, 10171.3, 11904.8 and 15721.9 °C day hour, respectively.

Among the different treatment, the highest total HTU (16143.9 °C day hrs) was accumulated by treatment (T₁) i.e. pigeon pea intercropped with sorghum as compared to sole sorghum and lowest HTU (15299.8 °C day hrs) found in treatment (T₆) i.e. sole sorghum.

The mean helio thermal units observed in treatments (T₁ and T₆) were ranged from 15299.8 to 16143.9 °C day hrs.

Table.4.38 Accumulated Helio Thermal Unit (HTU °C day hrs) to attain various phenophases in Sorghum under different treatment

Treatment	Phenophases							
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	Total
T1:(Pigoenpea+Sorghum)	497.6	6547.4	8213.3	9064.6	10510.1	12386.7	16143.9	16143.9
T6:(Sole Sorghum)	497.6	6285.7	8052.1	8818.2	9832.4	11422.9	15299.8	15299.8
G mean	497.6	6416.6	8132.7	8941.4	10171.3	11904.8	15721.9	-

- P₁ – Sowing to emergence
- P₂ – Emergence to penical initiation
- P₃ – Penical initiation to flag leaf stage
- P₄ – Flag leaf stage to boot stage
- P₅ – Boot stage to flowering
- P₆ – Flowering to dough stage
- P₇ – Dough stage to physical maturity

4.7.2.3 Helio Thermal Units (HTU) of Maize

The data presented in Table 4.38 and graphically depicted in Fig. 4.35 and represented helio thermal unit requirement for each phenophases were different required by different treatment.

The data revealed that there was marked influence on HTU at sowing to seedling, seedling to grandgrowth, grandgrowth to tasseling, tasseling to silking, silking to milk stage and milk stage to physical maturity was observed 1812.8, 5878.3, 7182.5, 7848.9, 10977.7 and 13657.2 °C day hrs, respectively.

Among the different treatment, the highest total HTU (14029.6 °C day hrs) was accumulated by treatment (T₂) i.e. pigeon pea intercropped with maize as compared to sole maize and lowest HTU (13284.8 °C day hrs) found in treatment (T₇) i.e. sole maize.

The mean helio thermal units observed in treatments (T₂ and T₇) were ranged from 13284.8 to 14029.6 °C day hrs.

Table.4.39 Accumulated Helio Thermal Unit (HTU °C day hrs) to attain various phenophases in Maize under different treatment

Treatment	Phenophases						
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Total
T₂:(Pigeonpea+Maize)	1812.8	6085.3	7418.4	8027.9	11341.3	14029.6	14029.6
T₇:(Sole Maize)	1812.8	5671.2	6946.6	7669.8	10614.0	13284.8	13284.8
G mean	1812.8	5878.3	7182.5	7848.9	10977.7	13657.2	-

P₁ – Sowing to seedling

P₂ – Seedling to grandgrowth

P₃ – Grandgrowth to tasseling

P₄ – Tasseling to silking

P₅ – Silking to milk stage

P₆ – Milk stage to physical maturity

4.7.2.4 Helio Thermal Units (HTU) of Soybean

The data presented in Table 4.39 and graphically depicted in Fig. 4.36 and represented helio thermal unit requirement for each phenophases were different required by different treatment.

The data revealed that there was marked influence on HTU at sowing to seedling, seedling to branching, branching to flowering, flowering to pod formation, pod formation to grain formation and grain formation to physiological maturity was observed 3864.6, 7108.6, 8316.5, 8641.7, 9356.3 and 13339.7 °C day hrs, respectively.

Among the different treatment, the highest total HTU (13914.5 °C day hrs) was accumulated by treatment (T₈) i.e. sole soybean as compared to intercropped and lowest HTU (12764.8 °C day hrs) found in treatment (T₃) i.e. pigeon pea intercropped with soybean.

The mean helio thermal units observed in treatments (T₃ and T₈) were ranged from 12764.8 to 13914.5 °C day hrs.

Table.4.40 Accumulated Helio Thermal Unit (HTU °C day hrs) to attain various phenophases in Soybean under different treatment

Treatment	Phenophases						
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Total
T₃:(Pigeonpea+Soybean)	3864.6	6914.5	8239.5	8543.9	9018.2	12764.8	12764.8
T₈:(Sole Soybean)	3864.6	7302.6	8393.4	8739.4	9694.4	13914.5	13914.5
G mean	3864.6	7108.6	8316.5	8641.7	9356.3	13339.7	-

P₁ – Sowing to seedling

P₂ – Seedling to branching

P₃ – Branching to flowering

P₄ – Flowering to pod formation

P₅ – Pod formation to grain formation

P₆ – Grain formation to physical maturity

4.7.2.5 Helio Thermal Units (HTU) of Sesamum

The data presented in Table 4.40 and graphically depicted in Fig. 4.37 and represented helio thermal unit requirement for each phenophases were different required by different treatment.

The data revealed that there was marked influence on HTU at sowing to emergence, emergence to branching, branching to flowering, flowering to capsules and capsules to physiological maturity was observed 456.6, 3941.3, 4270.4, 5053.8 and 11660.4 °C day hrs, respectively.

Among the different treatment, the highest total HTU (12131.6 °C day hrs) was accumulated by treatment (T₄) i.e. pigeon pea intercropped with sesamum as compared to sole sesamum and lowest HTU (11189.2 °C day hrs) found in treatment (T₉) i.e. sole sesamum.

The mean helio thermal units observed in treatments (T₄ and T₉) were ranged from 11189.2 to 12131.6 °C day hrs.

Table.4.41 Accumulated Helio Thermal Unit (HTU °C dar hrs) to attain various phenophases in Sesamum under different treatment

Treatment	Phenophases					
	P ₁	P ₂	P ₃	P ₄	P ₅	Total
T₄:(Pigeonpea+Sesamum)	456.6	4063.3	4390.8	5203.7	12131.6	12131.6
T₉:(Sole Sesamum)	456.6	3819.3	4150.0	4903.9	11189.2	11189.2
G mean	456.6	3941.3	4270.4	5053.8	11660.4	-

P₁ – Sowing to emergence

P₂ – Emergence to branching

P₃ – Branching to flowering

P₄ – Flowering to capsules

P₅ – Capsules to physical maturity

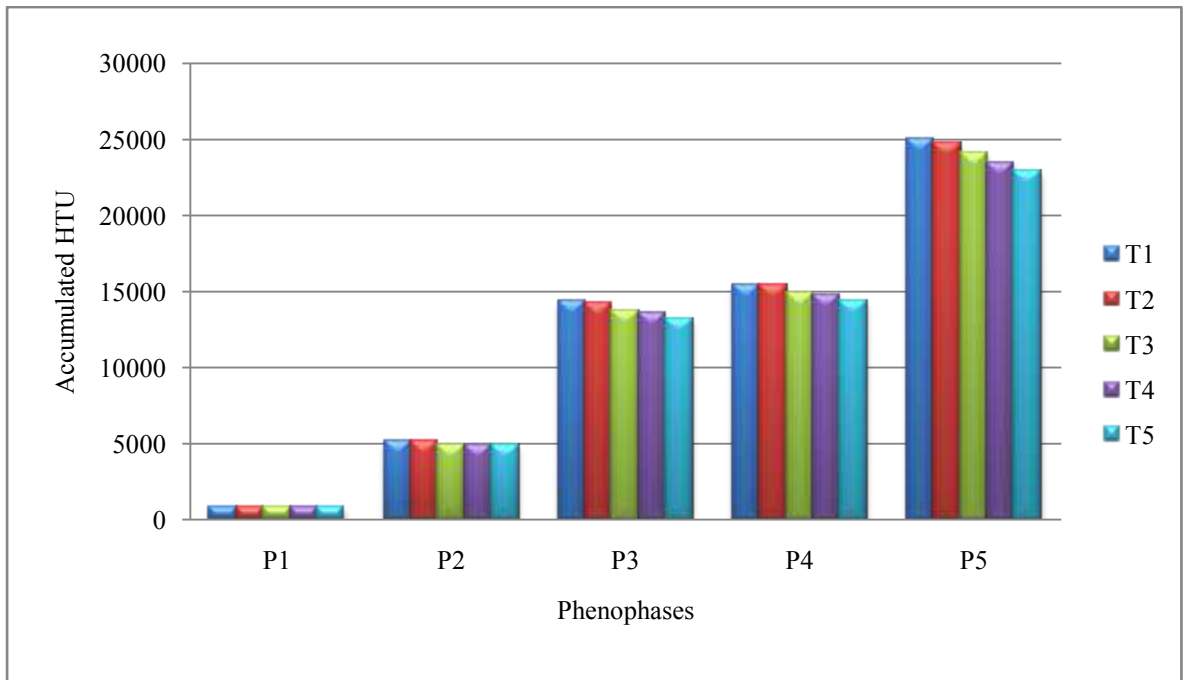


Fig.4.33 Accumulated Helio Thermal Unit (HTU) to attain various phenophases in Pigeon pea under different treatment

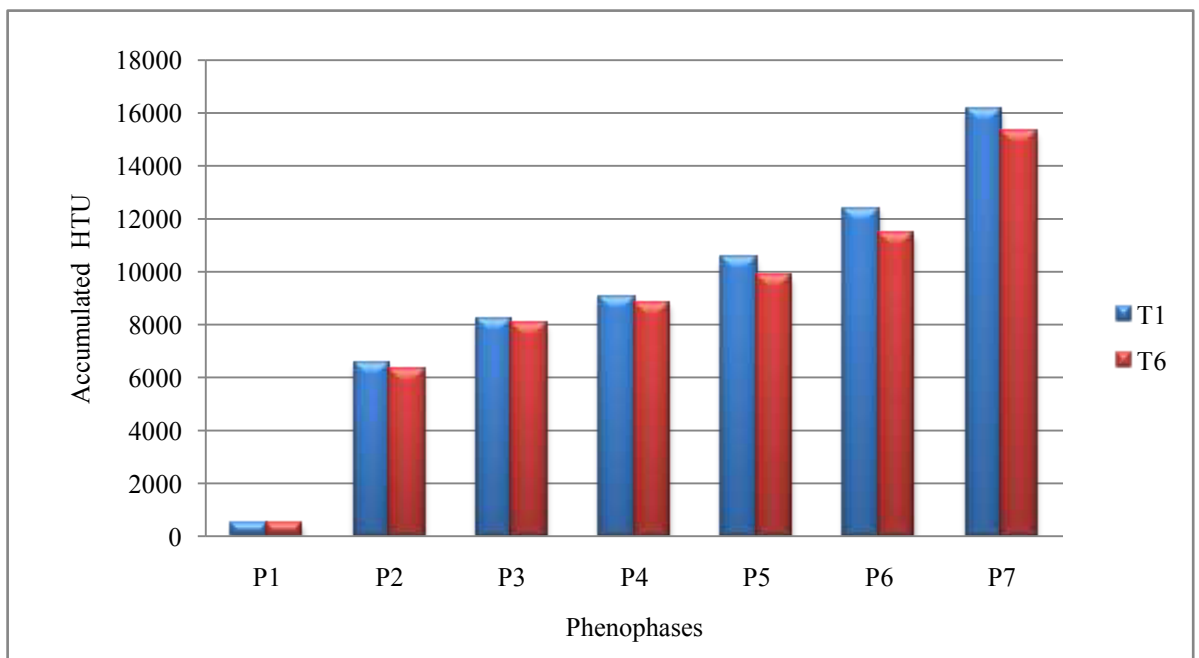


Fig. 4.34 Accumulated Helio Thermal Unit (HTU) to attain various phenophases in Sorghum under different treatments

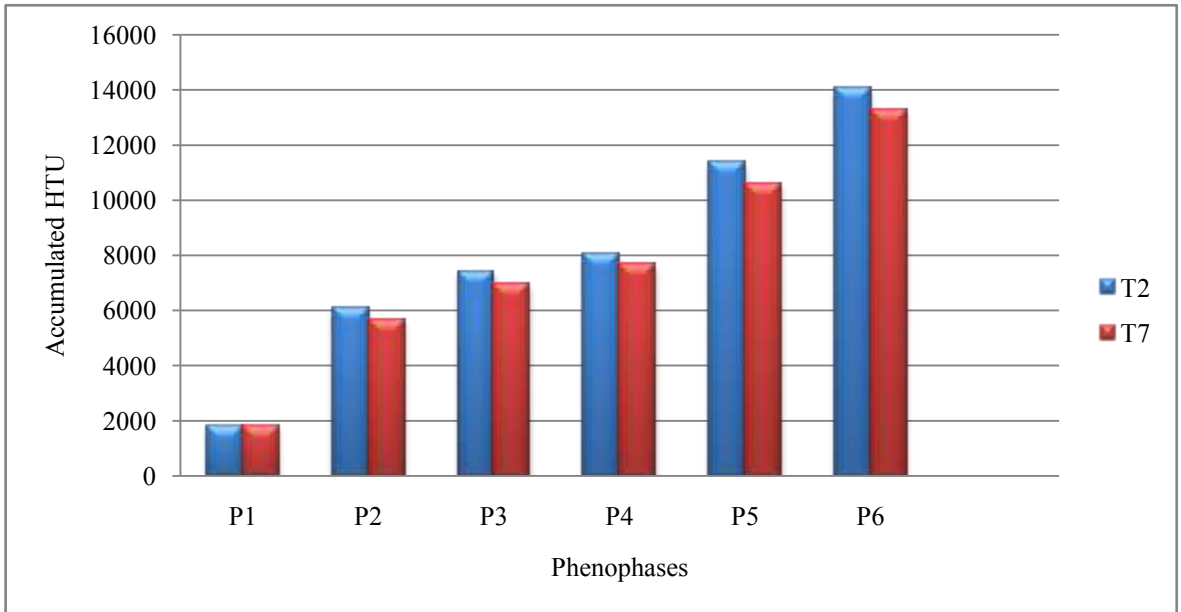


Fig. 4.35 Accumulated Helio Thermal Unit (HTU) to attain various phenophases in Maize under different treatment

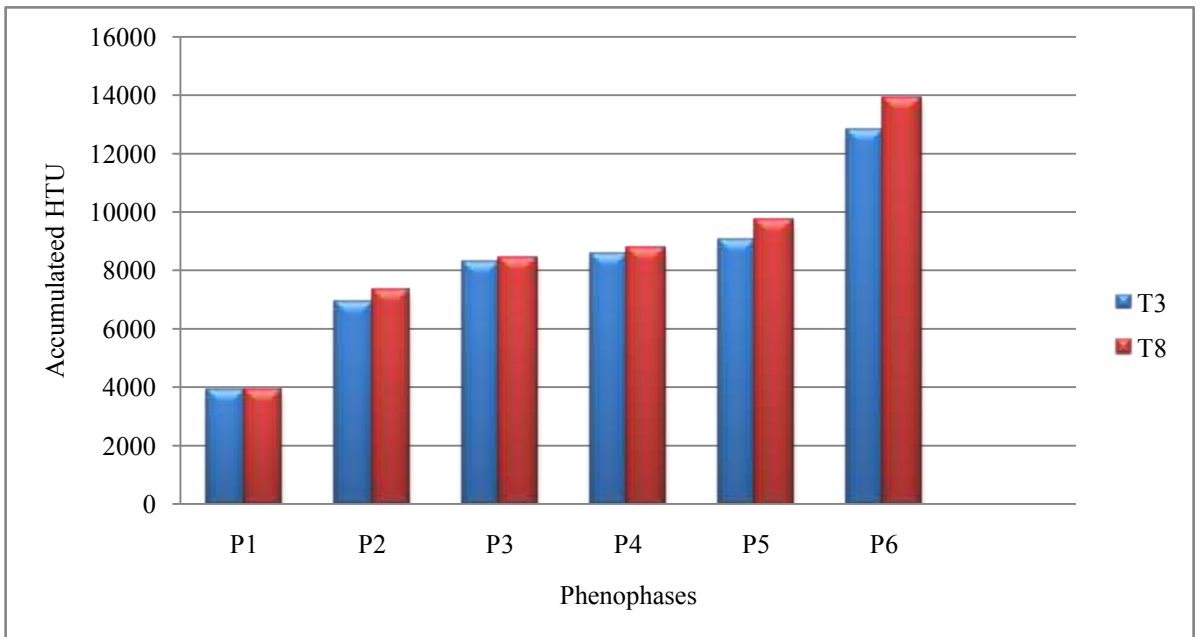


Fig.4.36 Accumulated Helio Thermal Unit (HTU) to attain various phenophases in Soybean under different treatment

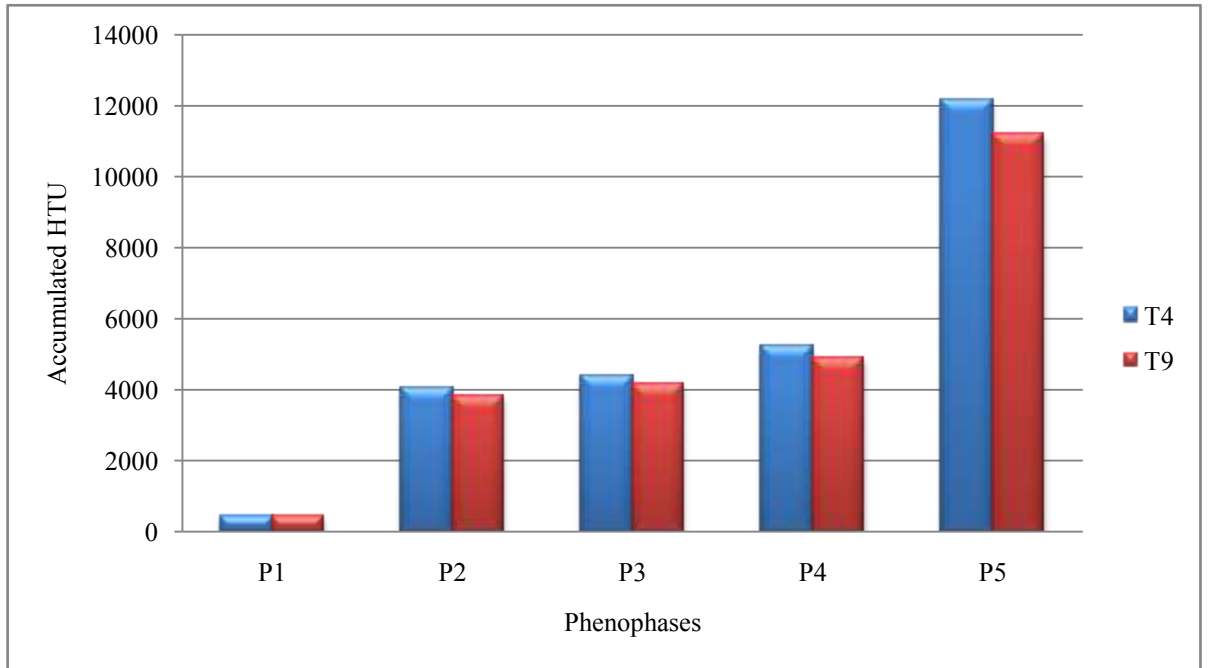


Fig.4.37 Accumulated Helio Thermal Unit (HTU) to attain various phenophases in Sesamum under different treatment

4.7.3 Photo Thermal Unit (PTU)

4.7.3.1 Photo Thermal Unit (PTU) of Pigeon pea

The data presented in Table 4.41 and graphically depicted in Fig. 4.38 respectively. The data indicated that photo-thermal unit requirement for each phenophases required by different treatment.

The data revealed that the different treatments have marked influence on PTU at sowing to emergence, emergence to branching, branching to flowering, flowering to pod formation and pod formation to physiological maturity was observed 2473.0, 11964.6, 27359.8, 29467.8 and 41670.0 °C day hrs, respectively.

Among the different treatment, the highest total PTU (43156.5 °C day hrs) was accumulated by treatment (T₁) i.e. pigeonpea intercropped with sorghum as compared to sole pigeon pea and lowest total (39883.0 °C day hrs) found in treatment (T₅) i.e. sole pigeonpea.

Table.4.42 Accumulated Photo Thermal Unit (PTU °C day hrs) to attain various phenophases in Pigeon pea under different treatment

Treatment	Phenophases					
	P ₁	P ₂	P ₃	P ₄	P ₅	Total
T₁:(Pigeonpea+Sorghum)	2473.0	12285.0	28163.5	30553.5	43156.5	43156.5
T₂:(Pigeonpea+Maize)	2473.0	12285.0	27918.4	30308.4	42745.9	42745.9
T₃:(Pigeonpea+Soybean)	2473.0	12019.0	27419.5	29569.5	41846.0	41846.0
T₄:(Pigeonpea+Sesamum)	2473.0	11749.0	26906.5	28826.5	40718.5	40718.5
T₅:(Sole Pigeon pea)	2473.0	11485.0	26391.0	28081.0	39883.0	39883.0
G mean	2473.0	11964.6	27359.8	29467.8	41670.0	-

P₁ – Sowing to emergence

P₃ – Branching to flowering

P₅ – Pod formation to physiological maturity

P₂ – Emergence to branching

P₄ – Flowering to pod formation

4.7.3.2 Photo Thermal Unit (PTU) of Sorghum

The data presented in Table 4.40 and graphically depicted in Fig. 4.39 respectively. The data indicated that photo-thermal unit requirement for each phenophases required by different treatment.

The data revealed that the different treatment have marked influence on PTU at sowing to emergence, emergence to penical initiation, penical initiation to flag leaf stage, flag leaf stage to boot stage, boot stage to flowering, flowering to dough stage and dough stage to physiological maturity was observed 1605.0, 13935.8, 16902.8, 19643.8, 21795.3, 24215.8 and 30581.3 °C day hrs, respectively.

Among the different treatment the highest total PTU (31097.5 °C day hrs) was accumulated by treatment (T₁) i.e. pigeonpea intercropped with sorghum and lowest total PTU (30065.0 °C day hrs) found in treatment (T₆) i.e. sole sorghum.

Table.4.43 Accumulated photo thermal unit (PTU °C day hrs) to attain various phenophases in Sorghum under different treatment

Treatment	Phenophases							Total
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	
T1:(Pigeonpea+Sorghum)	1605.0	13951.5	17036.5	19782.5	22083.5	24619.5	31097.5	31097.5
T6:(Sole Pigeonpea)	1605.0	13920.0	16769.0	19505.0	21507.0	23812.0	30065.0	30065.0
G mean	1605.0	13935.8	16902.8	19643.8	21795.3	24125.8	30581.3	-

P₁ – Sowing to emergence
P₂ – Emergence to penical initiation
P₃ – Penical initiation to flag leaf stage
P₄ – Flag leaf stage to boot stage
P₅ – Boot stage to flowering
P₆ – Flowering to dough stage
P₇ – Dough stage to physical maturity

4.7.3.3 Photo Thermal Unit (PTU) of Maize

The data presented in Table 4.43 and graphically depicted in Fig. 4.40 respectively. The data indicated that photo-thermal unit requirement for each phenophases required by different treatment.

The data revealed that the different treatment have marked influence on PTU at sowing to seedling, seedling to grandgrowth, grandgrowth to tasseling, tasseling to silking, silking to milk stage and milk stage to physical maturity was observed 4628.4, 15585.0, 17928.0, 19270.2 and 32309.4 °C day hrs, respectively.

Among the different treatment the highest total PTU (32923.2 °C day hrs) was accumulated by treatment (T₂) i.e. pigeonpea intercropped with maize and lowest total PTU (31695.6 °C day hrs) found in treatment (T₇) i.e. sole maize.

Table.4.44 Accumulated Photo Thermal Unit (PTU °C day hrs) to attain various phenophases in Maize under different treatment

Treatment	Phenophases						Total
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	
T2:(Pigeonpea+Maize)	4628.4	15774.0	18273.6	19736.4	28380.0	32923.2	32923.2
T7:(Sole Maize)	4628.4	15396.0	17582.4	18804.0	27422.4	31695.6	31695.6
G mean	4628.4	15585.0	17928.0	19270.2	27901.2	32309.4	-

P₁ – Sowing to seedling
P₂ – Seedling to grandgrowth
P₃ – Grandgrowth to tasseling
P₄ – Tasseling to silking
P₅ – Silking to milk stage
P₆ – Milk stage to physical maturity

4.7.3.4 Photo Thermal Unit (PTU) of Soybean

The data presented in Table 4.44 and graphically depicted in Fig. 4.41 respectively. The data indicated that photo-thermal unit requirement for each phenophases required by different treatment.

The data revealed that the different sowing dates have marked influence on PTU at sowing to seedling, seedling to branching, branching to flowering, flowering to pod formation, pod formation to grain formation and grain formation to physiological maturity was observed 6441.0, 14751.5, 16668.9, 18258.9, 20216.5 and 26293.1 °C day hrs, respectively.

Among the different treatment the highest total PTU (21416.1 °C day hrs) was accumulated by treatment (T₈) i.e. sole soybean and lowest total PTU (19575.6 °C day hrs) found in treatment (T₃) i.e. pigeon pea intercropped with soybean.

Table.4.45 Accumulated Photo Thermal Unit (PTU °C day hrs) to attain various phenophases in Soybean under different treatment

Treatment	Phenophases						Total
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	
T₃:(Pigeonpea+Soybean)	6441.0	14467.0	16282.0	17732.1	19425.9	25373.2	25373.2
T₈:(Sole Soybean)	6441.0	15035.9	17055.8	18785.7	21007.0	27213.0	27213.0
G mean	6441.0	14751.5	16668.9	18258.9	20216.5	26293.1	-

P₁ – Sowing to seedling

P₂ – Seedling to branching

P₃ – Branching to flowering

P₄ – Flowering to pod formation

P₅ – Pod formation to grain formation

P₆ – Grain formation to physical maturity

4.7.3.5 Photo Thermal Unit (PTU) of Sesamum.

The data presented in Table 4.45 and graphically depicted in Fig. 4.42 respectively. The data indicated that photo-thermal unit requirement for each phenophases required by different treatment.

The data revealed that the different treatment have marked influence on PTU at sowing to emergence, emergence to branching, branching to flowering, flowering to capsules and capsules to physiological maturity was observed 134.3, 5295.8, 7359.8, 10017.8 and 22722.6 °C day hrs, respectively.

Among the different treatment the highest total PTU (23263.4 °C day hrs) was accumulated by treatment (T₄) i.e. pigeon pea intercropped with sesamum and lowest total PTU (22181.8 °C day hrs) found in treatment (T₉) i.e. sole sesamum.

Table.4.46 Accumulated Photo Thermal Unit (PTU °C day hrs) to attain various phenophases in Sesamum under different treatment

Treatment	Phenophases					
	P ₁	P ₂	P ₃	P ₄	P ₅	Total
T₄:(Pigeonpea+Sesamum)	1343.1	6647.2	8830.0	11633.2	24472.7	24472.7
T₉:(Sole Sesamum)	1343.1	6361.6	8306.9	10820.1	23391.0	23391.0
G mean	1343.1	6504.4	8568.5	11226.7	23931.9	-

P₁ – Sowing to emergence

P₂ – Emergence to branching

P₃ – Branching to flowering

P₄ – Flowering to capsules

P₅ – Capsules to physical maturity

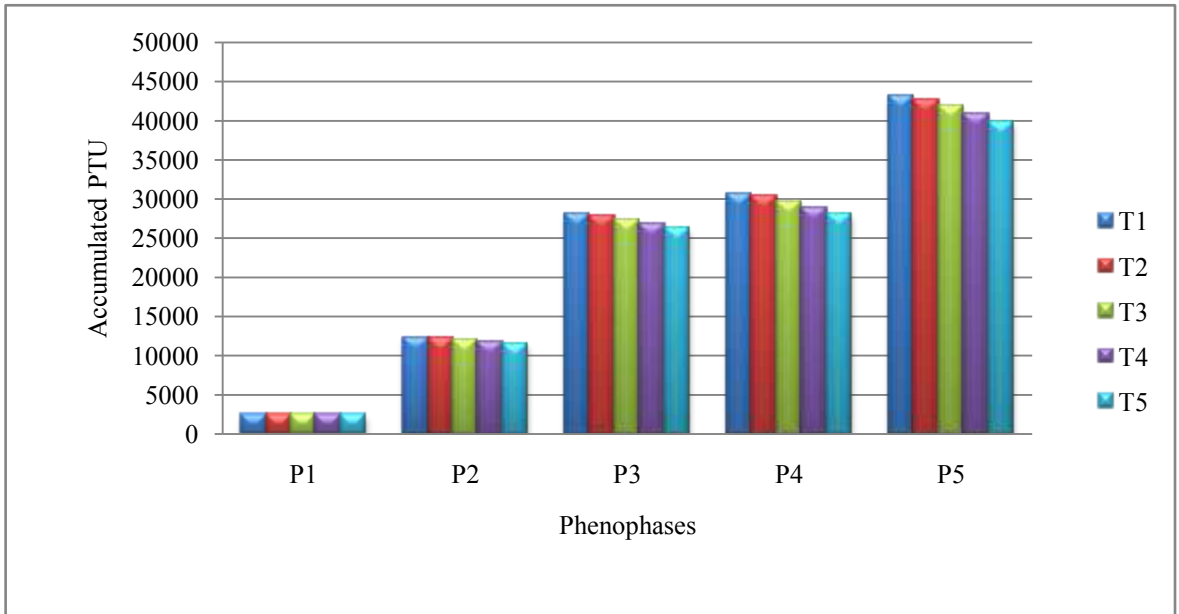


Fig.4.38 Accumulated Photo Thermal Unit (PTU) to attain various phenophases in Pigeon pea

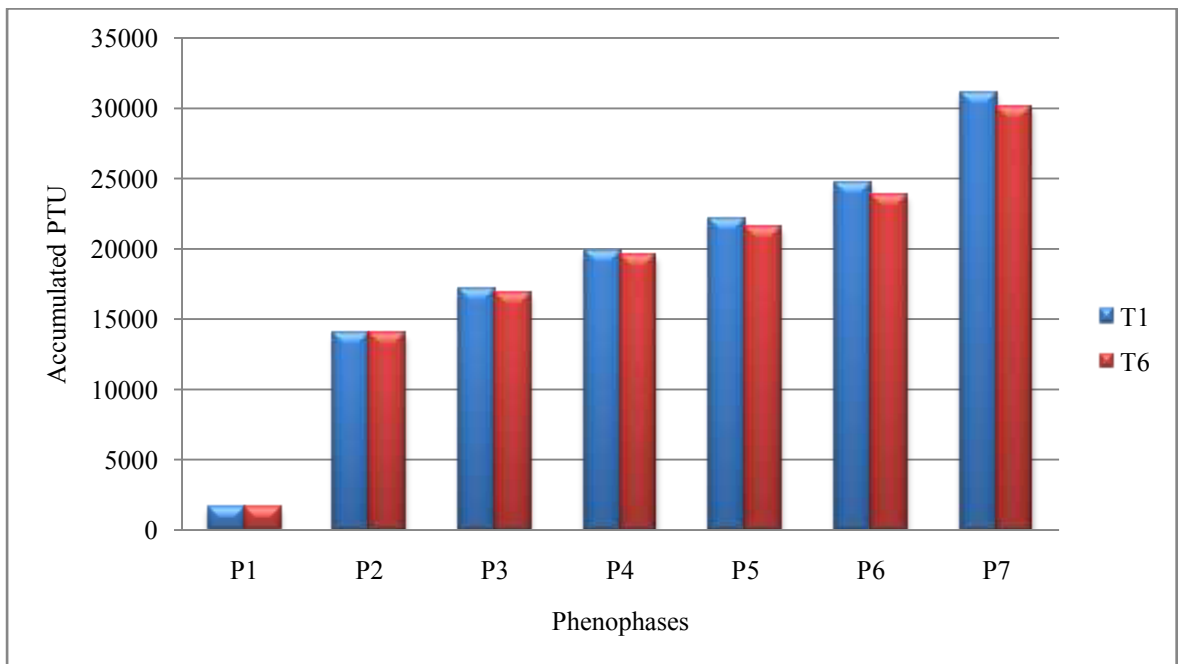


Fig.4.39 Accumulated Photo Thermal Unit (PTU) to attain various phenophases in Sorghum

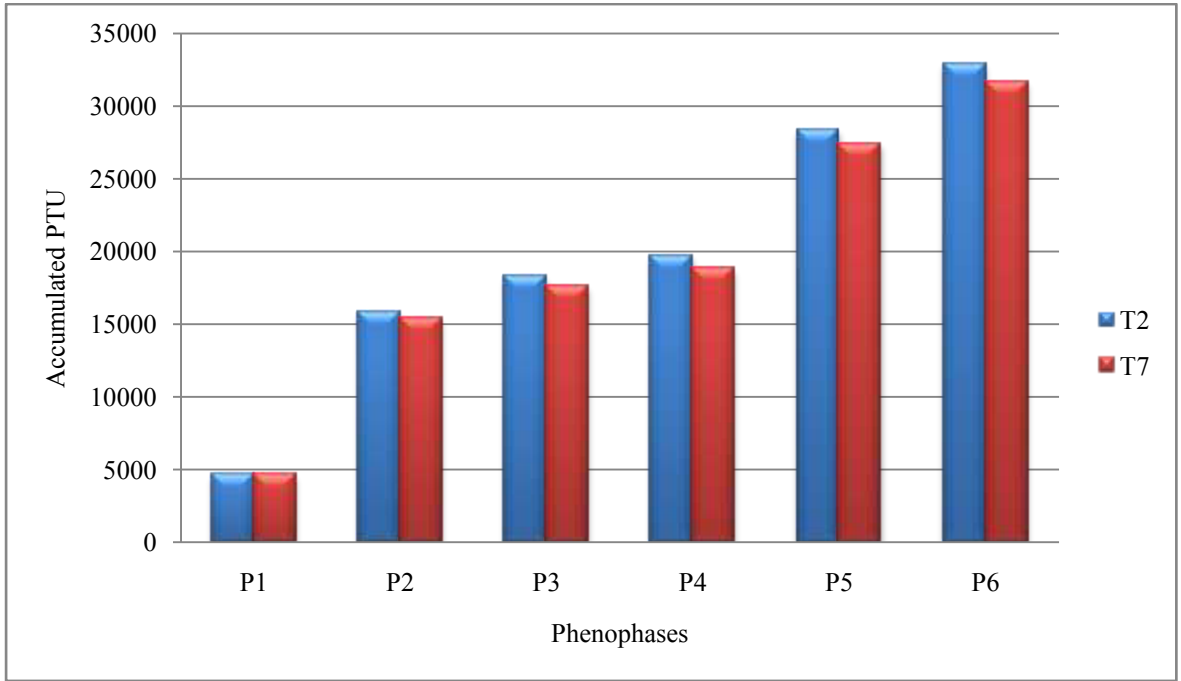


Fig.4.40 Accumulated Photo Thermal Unit (PTU) to attain various phenophases in Maize

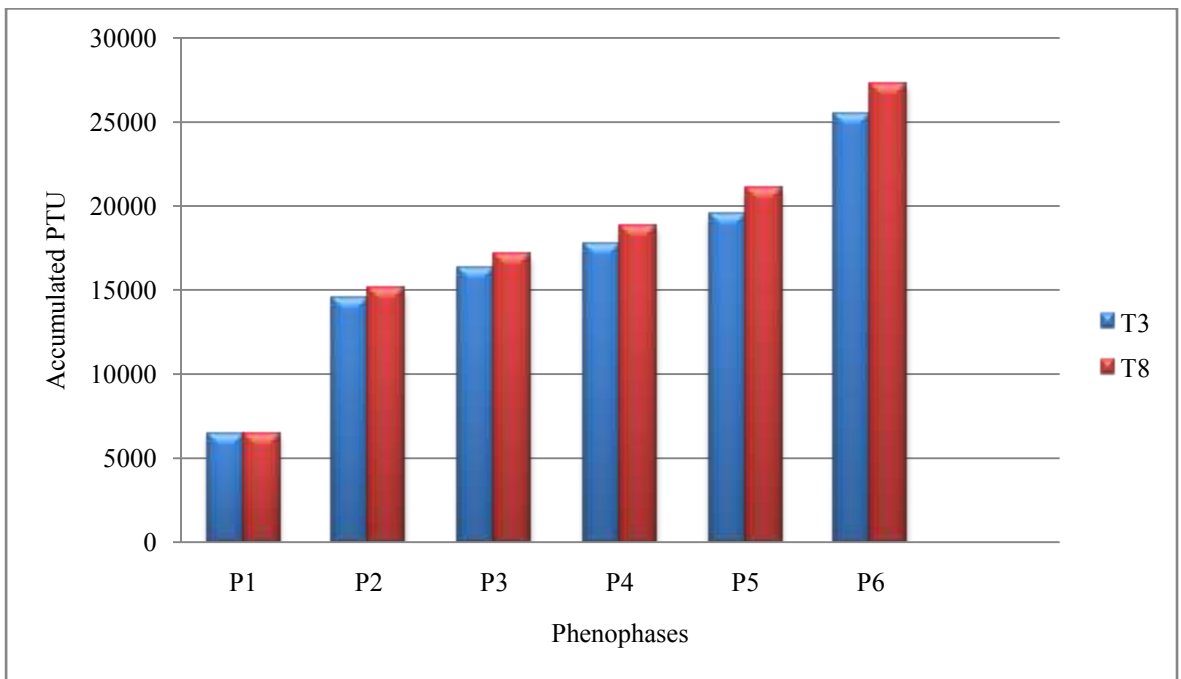


Fig.4.41 Accumulated Photo Thermal Unit (PTU) to attain various phenophases in Soybean

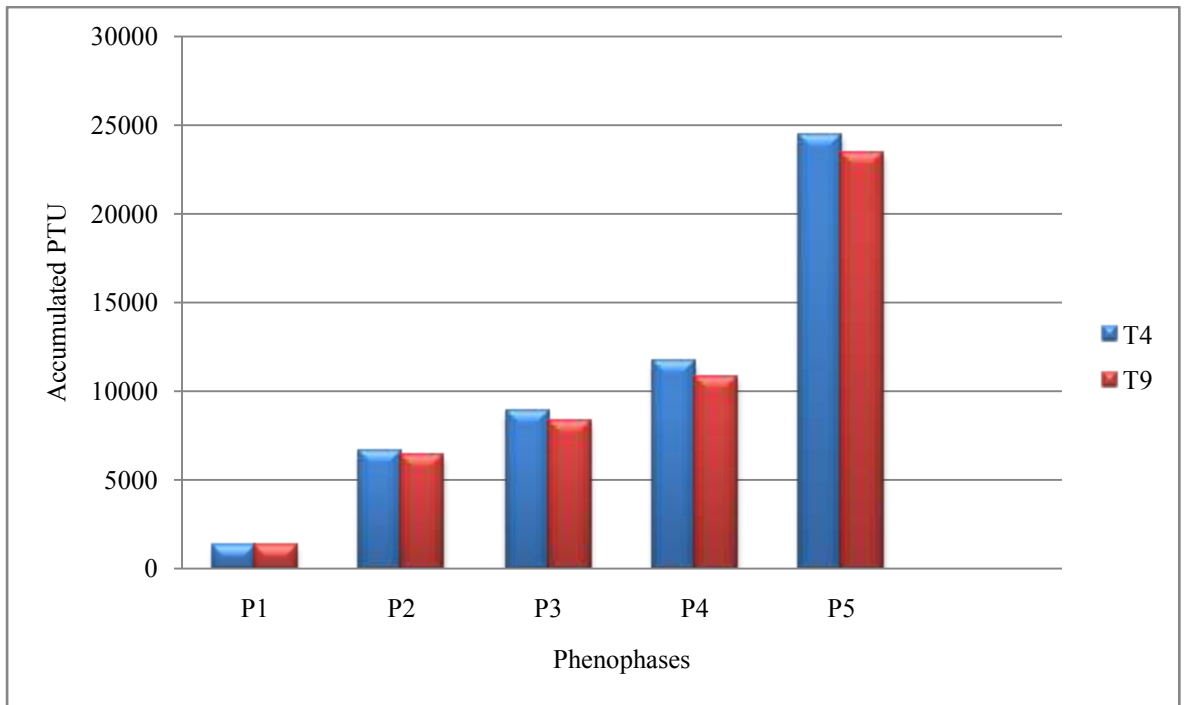


Fig.4.42 Accumulated Photo Thermal Unit (PTU) to attain various phenophases in Sesamum

4.8 Correlation coefficient between weather parameters and seed yield at different phenophases

4.8.1 Correlation coefficient between weather parameters and seed yield at different phenophases of Pigeon pea

The correlation studies were undertaken to assess the impact of different weather parameters prevailed during the various phenological stages of pigeon pea which were important in utilizing the weather resources for synthesis of yield. The correlation coefficient between weather parameters and seed yield prevailed at different phenophases of pigeon pea are presented in Table.4.46.

The rainfall was positively correlated with seed yield at P₂ and P₅ stages however; it was negatively correlated at P₄ stage. The rainy days was positively correlated at P₂ and P₅ stages however, it was negatively correlated at P₁ and P₄ stages.

The temperature maximum was positively correlated with seed yield at P₄ stage. The temperature minimum was positively correlated with seed yield at P₂, P₃ and P₅ stages however, it was negatively correlated at P₄ stage.

The relative humidity II was positively correlated with seed yield at P₃ and P₅ stages however, it was negatively correlated with seed yield at P₄ stage.

The evaporation was positively correlated with seed yield at P₁ and P₅ stages. The BSS was positively correlated with P₄ stage however; it was negatively correlated with seed yield at P₃ and P₅ stages. The wind velocity was positively correlated with seed yield at P₃ stage.

Table 4.47 Correlation coefficient between weather parameters with seed yield at different phenophases of Pigeon pea

Weather parameters	Phenophases of Pigeon pea				
	P1	P2	P3	P4	P5
Rainfall (mm)	-0.917	0.662*	0.084	-0.884**	0.880**
Rainy days	-0.927**	0.665*	-0.367	-0.959**	0.925**
T max (⁰ C)	-0.447	0.631	-0.367	0.916**	0.462
T min (⁰ C)	-0.415	0.826**	0.955**	-0.844**	0.874**
T Mean (⁰ C)	-0.582	0.740*	0.811**	-0.011	0.857**
R.H. – I (%)	0.103	-0.468	-0.367	-0.241	-0.253
R.H. – II (%)	0.496	-0.116	0.965**	-0.938**	0.908**
R.H. Mean (%)	0.498	-0.220	0.922**	-0.839**	0.808**
Evp. (mm day ⁻¹)	0.949**	0.441	-0.367	0.603	0.965**
B.S.S. (hrs day ⁻¹)	-0.351	0.146	-0.878**	0.903**	-0.813**
W.V. (km hr ⁻¹)	-0.268	0.842**	0.792**	-0.542	0.481

* - 5 % Significant

** - 1 % Significant

P₁ – Sowing to emergence

P₂ – Emergence to branching

P₃ – Branching to flowering

P₄ – Flowering to pod formation

P₅ – Pod formation to physiological maturity

4.8.2 Correlation coefficient between weather parameters and seed yield at different phenophases of Sorghum.

The correlation studies were undertaken to assess the impact of different weather parameters prevailed during the various phenological stages of sorghum which were important in utilizing the weather resources for synthesis of yield. The correlation coefficient between weather parameters and seed yield prevailed at different phenophases of sorghum are presented in Table.4.47.

The rainfall was negatively correlated with seed yield at P₇ stage however, the rainy days was negatively correlated at P₅ stage.

The temperature maximum was positively correlated with seed yield at P₆ and P₇ stages and negatively correlated at P₄ and P₅ stages however, the temperature minimum was positively correlated with seed yield at P₆ stage and negatively correlated at P₅ stage.

The relative humidity I was positively correlated with seed yield at P₆ stage however, the relative humidity II was positively correlated with seed yield at P₄ and P₆ stages and negatively correlated with seed yield at P₇ stage.

The evaporation was positively correlated with seed yield at P₃ and P₇ stages and negatively correlated at P₆ stage. The BSS was positively correlated with P₇ stage however, it was negatively correlated with seed yield at P₅ and P₆ stages. The wind velocity was positively correlated with seed yield at P₅ stage however, the negatively at P₇ stage.

Table 4.48 Correlation coefficient between weather parameters with grain yield at different phenophases of Sorghum

Weather parameters	Phenophases of Sorghum						
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇
Rainfall (mm)	-0.006	-0.065	-0.512	-0.573	-0.623	0.068	-0.941**
Rainy days	0.034	-0.001	-0.446	0.446	-0.894**	0.577	-0.217
T max (°C)	0.015	-0.289	0.682	-0.766*	-0.836*	0.813*	0.857*
T min (°C)	-0.029	0.403	0.090	0.461	-0.868*	0.912**	0.341
T Mean (°C)	0.012	-0.175	0.635	-0.695	-0.854*	0.919**	0.847*
R.H. – I (%)	0.037	0.390	-0.387	-0.439	-0.666	0.898**	0.642
R.H. – II (%)	0.016	0.346	-0.724	0.788*	0.332	0.886*	-0.919**
R.H. Mean (%)	0.051	0.520	-0.647	0.707	-0.328	0.915**	0.203
Evp. (mm day ⁻¹)	-0.219	-0.244	0.759*	-0.649	-0.691	-0.777*	0.979**
B.S.S. (hrs day ⁻¹)	-0.117	-0.140	0.675	-0.609	-0.829*	-0.917**	0.821*
W.V.(km hr ⁻¹)	-0.071	-0.025	0.574	-0.685	0.871*	-0.574	-0.934**

* - 5 % Significant

** - 1 % Significant

P₁ – Sowing to emergence

P₂ – Emergence to penical initiation

P₃ – Penical initiation to flag leaf stage

P₄ – Flag leaf stage to boot stage

P₅ – Boot stage to flowering

P₆ – Flowering to dough stage

P₇ – Dough stage to physical maturity

4.8.3 Correlation coefficient between weather parameters and seed yield at different phenophases of Maize.

The correlation studies were undertaken to assess the impact of different weather parameters prevailed during the various phenological stages of maize which were important in utilizing the weather resources for synthesis of yield. The correlation coefficient between weather parameters and seed yield prevailed at different phenophases of maize are presented in Table.4.48.

The rainfall was positively correlated with seed yield at P₅ stage and negatively correlated at P₂ and P₄ stage however, the rainy days was negatively correlated at P₂, P₃ and P₄ stages.

The temperature maximum was positively correlated with seed yield at P₄ stage and negatively correlated at P₂ and P₅ stages however, the temperature minimum was positively correlated with seed yield at P₅ and P₆ stages and negatively correlated at P₂ stage.

The relative humidity I was positively correlated with seed yield at P₂ and P₆ stages and negatively correlated at P₄ stage however, the relative humidity II was positively correlated with seed yield at P₂, P₅ and P₆ stages and negatively correlated at P₄ stage.

The evaporation was positively correlated with seed yield at P₄ stage however, it was negatively correlated at P₂ and P₆ stages. The BSS was positively correlated with P₄ stage, it was negatively correlated at P₂ and P₅ stages. The wind velocity was positively correlated with seed yield at P₅ stage however, the negatively at P₂ stage.

Table 4.49 Correlation coefficient between weather parameters with grain yield at different phenophases of Maize

Weather parameters	Phenophases of Maize					
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆
Rainfall (mm)	0.227	-0.995**	-0.482	-0.996**	0.991**	0.575
Rainy days	0.447	-0.981**	-0.970**	-0.970**	0.727	0.448
T max (°C)	-0.743	-0.993**	-0.242	0.916**	-0.855*	-0.016
T min (°C)	0.745	-0.925**	0.713	0.524	0.928**	0.798*
T Mean (°C)	-0.740	-0.925**	0.358	0.891**	-0.636	0.824*
R.H. – I (%)	0.733	0.926**	-0.697	-0.958**	0.679	0.814*
R.H. – II (%)	0.745	0.989**	0.532	-0.922**	0.858*	0.857*
R.H. Mean (%)	0.745	0.996**	0.208	-0.948**	0.828*	0.848*
Evp. (mm day ⁻¹)	-0.694	-0.984**	-0.718	0.877**	0.239	-0.801*
B.S.S. (hrs day ⁻¹)	-0.724	-0.979**	0.574	0.763*	-0.787*	0.651
W.V.(km hr ⁻¹)	-0.609	-0.894*	0.336	0.694	0.946**	0.465

* - 5 % Significant

** - 1 % Significant

P₁ – Sowing to seedling

P₂ – Seedling to grandgrowth

P₃ – Grandgrowth to tasseling

P₄ – Tasseling to silking

P₅ – Silking to milk stage

P₆ – Milk stage to physical maturity

4.8.4 Correlation coefficient between weather parameters and seed yield at different phenophases of Soybean.

The correlation studies were undertaken to assess the impact of different weather parameters prevailed during the various phonological stages of soybean which were important in utilizing the weather resources for synthesis of yield .The

correlation coefficient between weather parameters and seed yield prevailed at different phenophases of soybean are presented in Table.4.49.

The rainfall was positively correlated with seed yield at P₅ stage, it was negatively correlated at P₆ stage however, the rainy days was positively correlated at P₃ stage.

The temperature maximum was positively correlated with seed yield at P₄ and P₆ stages and negatively at P₃ stage however, the temperature minimum was positively correlated with seed yield at P₅ stage and negatively correlated at P₃ and P₆ stages.

The relative humidity I was positively correlated with seed yield at P₃ stage and negatively correlated at P₆ stage however, the relative humidity II was negatively correlated with seed yield at P₆ stage.

The evaporation was positively correlated with seed yield at P₆ stage and negatively correlated with seed yield at P₃ stage. The BSS was positively correlated with seed yield at P₅ and P₆ stages however, it was negatively correlated at P₄ stage. The wind velocity was negatively correlated with seed yield at P₃, P₅ and P₆ stages.

Table 4.50 Correlation coefficient between weather parameters with grain yield at different phenophases of Soybean

Weather parameters	Phenophases of Soybean					
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆
Rainfall (mm)	0.406	0.709	0.674	-0.603	0.837*	-0.844*
Rainy days	-0.445	0.445	0.819*	-0.578	0.727	-0.578
T max (⁰ C)	0.711	-0.228	-0.795*	0.796*	0.484	0.946**
T min (⁰ C)	0.677	-0.749	-0.791*	0.636	0.898**	-0.966**
T Mean (⁰ C)	0.745	-0.641	-0.812*	0.814*	0.920**	-0.928**
R.H. – I (%)	-0.655	0.474	0.854*	-0.704	0.623	-0.776*
R.H. – II (%)	-0.746	-0.064	0.752	-0.686	-0.575	-0.932**
R.H. Mean (%)	-0.732	0.151	0.798*	-0.719	0.335	-0.929**
Evp. (mm day ⁻¹)	0.700	0.427	-0.820*	0.652	-0.235	0.925**
B.S.S. (hrs day ⁻¹)	0.727	-0.170	-0.706	-0.788*	0.902**	0.931**
W.V.(km hr ⁻¹)	-0.690	0.610	-0.862*	0.581	-0.857*	-0.963**

* - 5 % Significant

** - 1 % Significant

P₁ – Sowing to seedling

P₂ – Seedling to branching

P₃ – Branching to flowering

P₄ – Flowering to pod formation

P₅ – Pod formation to grain formation

P₆ – Grain formation to physical maturity

4.8.5 Correlation coefficient between weather parameters and seed yield at different phenophases of Sesamum.

The correlation studies were undertaken to assess the impact of different weather parameters prevailed during the various phenological stages of sesamum which were important in utilizing the weather resources for synthesis of yield. The correlation coefficient between weather parameters and seed yield prevailed at different phenophases of sesamum are presented in Table.4.50.

The rainfall was negatively correlated with seed yield at P₅ stage. The temperature maximum was negatively correlated with seed yield at P₅ stage however, the temperature minimum was negatively correlated with seed yield at P₅ stage.

The relative humidity II was positively correlated with seed yield at P₅ stage. The evaporation was positively correlated with seed yield at P₂ stage. The BSS was negatively correlated with seed yield at P₅ stage and the wind velocity was positively correlated with seed yield at P₅ stage. The wind velocity was positively correlated with seed yield at P₅ stages.

Table 4.51 Correlation coefficient between weather parameters with grain yield at different phenophases of Sesamum

Weather parameters	Phenophases of Sesamum				
	P ₁	P ₂	P ₃	P ₄	P ₅
Rainfall (mm)	-0.580	-0.459	-0.374	0.313	-0.845*
Rainy days	-0.446	-0.408	-0.460	0.252	0.262
T max (°C)	-0.425	0.486	0.463	-0.586	-0.905**
T min (°C)	-0.567	0.274	0.461	0.740	0.818*
T Mean (°C)	-0.474	0.531	0.464	-0.542	0.695
R.H. – I (%)	0.293	-0.018	-0.454	0.569	-0.609
R.H. – II (%)	0.623	-0.476	-0.503	0.600	0.822*
R.H. Mean (%)	0.589	-0.447	-0.491	0.598	0.250
Evp. (mm day ⁻¹)	-0.709	0.754*	0.519	-0.666	0.542
B.S.S. (hrs day ⁻¹)	-0.626	0.033	0.480	-0.371	-0.859*
W.V.(km hr ⁻¹)	-0.697	0.681	0.127	0.682	0.889**

* - 5 % Significant

** - 1 % Significant

P₁ – Sowing to emergence
P₃ – Branching to flowering
P₅ – Capsules to physical maturity

P₂ – Emergence to branching
P₄ – Flowering to capsules



*Summary
and
Conclusion*

CHAPTER – V

SUMMARY AND CONCLUSION

A field investigation entitled “Effect of microclimate on Pigeon pea (*cajanus cajan* L.) based intercropping system” Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *kharif* season of 2019.

The experiment was laid out in a randomized block design (RBD) with tree replication, where in major crops more taken in intercropping and sole cropping. The plot size of the experiment was 5.4 m × 4.5 m. Sowing was done by adapting dibbling method on 2nd July 2019, with row proportion 4:2 and at various spacing and varieties. The recommended dose of fertilizer (RDF), were applied at the time of sowing and cultural practices, plant protection measures were under taken as per requirement of crop.

To evaluate the treatment effect, the various growth observations were recorded in the experiment from 15 DAS (Sorghum, Maize, Soybean and Sesamum) and 30 DAS (Pigeon pea) up to the harvest at an interval of 15 days (Sorghum, Maize, Soybean and Sesamum) and 30 days (Pigeon pea) respectively, while the observations on yield attributing characters and post-harvest studies were recorded at respective stages. The crop was harvested at the maturity stage. The important findings emerged from the present investigations are summarized below, with conclusion.

The different crop growth stages and whole life cycle affected differentially by variable weather. Effect of weather variables on different phenophases of different crops was important for deciding the critical growth stages with following objectives.

- 1) To study the effect of different intercrops on microclimate.
- 2) To study the effect of weather parameters on growth and yield of pigeon pea based intercropping system.

5.1 To study the effect of different Pigeon pea based intercrops on microclimate

Effect of different intercrops on microclimate was observed with the help of soil moisture, canopy temperature and relative humidity.

Intercropping systems could reduce wind speed, improve light interception, provide shade and increase infiltration compared with mono cropping, so lower water evaporation, conserving soil moisture and improving soil structure

whereas, in intercropping system water uptake from soil surface layers increased due to increased root density in the upper layers, thus decreasing water dissipated by evaporation. Soil moisture content in the soil was increased dramatically in the pigeon pea based intercropping system than the sole due to low evapotranspiration potential for growth period. So, the microclimate within the plant canopy was affected significantly.

It was showed that plant density, quality of received light, planting direction and wind affect canopy temperature. When intercrop and high plant density provides soil cover, a relative low temperature will be maintained within the crop canopy, providing a favourable microclimate for the associated crops. Canopy temperature is reduced in intercropping due to positive effects of two crops including increased land coverage, higher retention of soil moisture, reduced evaporation from soil surface, enhanced water use efficiency and increased relative moisture of canopy. So, the canopy temperature of intercropped pigeon pea was lower than that of sole cropping.

Based on the present study and previous ones, it can be observed that microclimate temperature of canopy in intercropping is lower than that of sole. Higher transpiration enhances relative humidity and the energy penetration the canopy is used for photosynthesis and production processes and thus, the amount of energy devoted to air heating is reduced. Relative humidity changes when temperature changes. Because warm air can hold more water vapor than cool air, relative humidity falls when the temperature rises if no moisture is added to the air. High moisture content in the air surrounding crop canopies can reduce transpiration and increase canopy temperature. These factors cause relative coldness of microclimate and since microclimate temperature, to some extent, depends on relative humidity of canopy, humid air retains canopy temperature of intercropping in moderate level and, therefore, canopy temperature in intercropping is colder than that of monoculture.

From the above result it was showed that the microclimate within (T_3) pigeon pea + soybean intercropping treatment better than the other intercropping treatments i.e. (T_1), (T_2) and (T_4). Whereas, the microclimate within the other intercropping was also better than the sole pigeon (T_5).

Hence, the intercropping practice could modify the microclimate by reducing light intensity, air temperature, desiccating wind and other climatic components

5.2 To study the effect of weather parameters on growth and yield of Pigeon pea based intercropping system.

Plant height

The variation in plant height of pigeon pea in intercropping system was observed because of competition for soil moisture, solar radiation. Plant height of pigeon pea in the treatment T₃ i.e. pigeon pea intercropped with soybean recorded significantly highest at harvest on the mean basis. Whereas, the plant height of pigeon pea recorded lowest when intercropped with sorghum (T₁), maize (T₂) and sesamum (T₄) as compared to sole pigeon pea i.e. (T₅).

Throughout growing period, in intercropping system due to difference in height of both crops the competition for light was observed less by intercrops i.e. sorghum (T₁), maize (T₂) and sesamum (T₄) than sole i.e. (T₆), (T₇) and (T₉). So, the plant height of intercropped sorghum, maize and sesamum was observed lowest on the mean basis as compared to sole sorghum, maize and sesamum whereas, the plant height of intercropped soybean i.e. (T₃) was observed highest on the mean basis than the sole (T₈) which may be due to shading effect of pigeon pea, the light availability to inter soybean was restricted.

Number of leaves

Number of leaves of pigeon pea in the treatment T₅ i.e. sole pigeon pea recorded highest on the mean basis as compared to intercropped with sorghum (T₁), maize (T₂), soybean (T₃) and sesamum (T₄).

Number of leaves of sorghum (T₁), maize (T₂) and sesamum (T₄) was recorded highest in intercropping treatment on the mean basis than in sole sorghum (T₆), maize (T₇) and sesamum (T₉) whereas, the number of leaves of soybean was observed lowest on the mean basis in the intercropping treatment (T₃) than sole (T₈).

Dry matter production (gm)

Dry matter production of pigeon pea in the treatment T₅ i.e. sole pigeon pea recorded highest at harvest on the mean basis as compared to intercropped with sorghum (T₁), maize (T₂), soybean (T₃) and sesamum (T₄). The dry matter production of intercropped pigeon pea was decreased due to competition for solar radiation, soil moisture was more as compared to sole.

Throughout growing period the harvesting of solar radiation by inter sorghum (T₁), maize (T₂) and sesamum (T₄) was observed more than sole sorghum (T₆), maize (T₇) and sesamum (T₉) due to which the dry matter production of

sorghum, maize and sesamum in intercropped treatments on the mean basis observed more as compared to sole whereas, the dry matter production of inter soybean (T₃) was less on the mean basis as compared to sole (T₈).

Yield

Significantly higher Pigeon pea equivalent yield 1503 Kg ha⁻¹ was attained with T₃ i.e. pigeon pea intercropped with soybean followed by 1402 Kg ha⁻¹ with pigeon pea + sesamum (T₄). The increase in pigeon pea equivalent yield in pigeon pea + soybean intercropping system might be due to no competition between main crop and intercrop for growth, development and for above ground and below ground resources as crop was of shorter duration. The lowest pigeon pea equivalent yield of 861 kg ha⁻¹ was recorded in (T₁) i.e. pigeon pea + sorghum intercropping system and might be due to intense inter-specific competition.

In the pigeon pea based intercropping system, highest stalk / stover yield 3088 Kg ha⁻¹ was attained with T₂ i.e. pigeon pea intercropped with maize as compared to sole. The lowest stalk / stover yield of 1418 Kg ha⁻¹ was recorded in T₈ i.e. sole soybean.

In the pigeon pea based intercropped system, highest biological yield 5378 Kg ha⁻¹ was attained with T₂ i.e. pigeon pea intercropped with maize as compared to sole. The lowest biological yield of 3530 Kg ha⁻¹ was recorded in T₄ i.e. pigeon pea intercropped with sesamum.

Land Equivalent Ratio (LER)

In present study, intercropping of pigeon pea with soybean and sesamum recorded significantly higher LER (1.19 and 1.29) compare to sole and other intercropping system.

Growing Degree Days (GDD)

In pigeon pea the highest total GDD was accumulated by treatment (T₁) i.e. pigeon pea intercropped with sorghum as compared to sole pigeon pea and lowest total GDD found in treatment T₅ i.e. sole pigeon pea.

The accumulated GDD by sorghum, maize and sesamum was highest in intercropped treatment i.e. (T₁), (T₂) and (T₄) than in sole i.e. (T₆), (T₇) and (T₉) whereas, the accumulated GDD by soybean was highest in sole treatment i.e. (T₈) than intercropped (T₃).

Helio Thermal Unit (HTU)

In pigeon pea the highest total HTU was accumulated by treatment (T₁) i.e. pigeon pea intercropped with sorghum as compared to sole pigeon pea and lowest total HTU found in treatment T₅ i.e. sole pigeon pea.

The accumulated HTU by sorghum, maize and sesamum was highest in intercropped treatment i.e. (T₁), (T₂) and (T₄) than in sole i.e. (T₆), (T₇) and (T₉) whereas, the accumulated HTU by soybean was highest in sole treatment i.e. (T₈) than intercropped (T₃).

Photo Thermal Unit (PTU)

In pigeon pea the highest total PTU) was accumulated by treatment (T₁) i.e. pigeon pea intercropped with sorghum as compared to sole pigeon pea and lowest total PTU found in treatment T₅ i.e. sole pigeon pea.

The accumulated PTU by sorghum, maize and sesamum was highest in intercropped treatment i.e. (T₁), (T₂) and (T₄) than in sole i.e. (T₆), (T₇) and (T₉) whereas, the accumulated PTU by soybean was highest in sole treatment i.e. (T₈) than intercropped (T₃).

Correlation coefficient between weather parameters and seed yield at different phenophases of Pigeon pea.

The rainfall was positively correlated with seed yield at P₂ and P₅ stages however; it was negatively correlated at P₄ stage. The rainy days was positively correlated at P₂ and P₅ stages however, it was negatively correlated at P₁ and P₄ stages. The temperature maximum was positively correlated with seed yield at P₄ stage. The temperature minimum was positively correlated with seed yield at P₂, P₃ and P₅ stages however, it was negatively correlated at P₄ stage. The relative humidity II was positively correlated with seed yield at P₃ and P₅ stages however, it was negatively correlated with seed yield at P₄ stage. The evaporation was positively correlated with seed yield at P₁ and P₅ stages. The BSS was positively correlated with P₄ stage however; it was negatively correlated with seed yield at P₃ and P₅ stages. The wind velocity was positively correlated with seed yield at P₃ stage.

Correlation coefficient between weather parameters and seed yield at different phenophases of Sorghum.

The rainfall was negatively correlated with seed yield at P₇ stage however, the rainy days was negatively correlated at P₅ stage. The temperature

maximum was positively correlated with seed yield at P₆ and P₇ stages and negatively correlated at P₄ and P₅ stages however, the temperature minimum was positively correlated with seed yield at P₆ stage and negatively correlated at P₅ stage. The relative humidity I was positively correlated with seed yield at P₆ stage however, the relative humidity II was positively correlated with seed yield at P₄ and P₆ stages and negatively correlated with seed yield at P₇ stage. The evaporation was positively correlated with seed yield at P₃ and P₇ stages and negatively correlated at P₆ stage. The BSS was positively correlated with P₇ stage however, it was negatively correlated with seed yield at P₅ and P₆ stages. The wind velocity was positively correlated with seed yield at P₅ stage however, the negatively at P₇ stage.

Correlation coefficient between weather parameters and seed yield at different phenophases of Maize.

The rainfall was positively correlated with seed yield at P₅ stage and negatively correlated at P₂ and P₄ stage however, the rainy days was negatively correlated at P₂, P₃ and P₄ stages. The temperature maximum was positively correlated with seed yield at P₄ stage and negatively correlated at P₂ and P₅ stages however, the temperature minimum was positively correlated with seed yield at P₅ and P₆ stages and negatively correlated at P₂ stage. The relative humidity I was positively correlated with seed yield at P₂ and P₆ stages and negatively correlated at P₄ stage however, the relative humidity II was positively correlated with seed yield at P₂, P₅ and P₆ stages and negatively correlated at P₄ stage. The evaporation was positively correlated with seed yield at P₄ stage however, it was negatively correlated at P₂ and P₆ stages. The BSS was positively correlated with P₄ stage, it was negatively correlated at P₂ and P₅ stages. The wind velocity was positively correlated with seed yield at P₅ stage however, the negatively at P₂ stage.

Correlation coefficient between weather parameters and seed yield at different phenophases of Soybean.

The rainfall was positively correlated with seed yield at P₅ stage, it was negatively correlated at P₆ stage however, the rainy days was positively correlated at P₃ stage. The temperature maximum was positively correlated with seed yield at P₄ and P₆ stages and negatively at P₃ stage however, the temperature minimum was positively correlated with seed yield at P₅ stage and negatively correlated at P₃ and P₆ stages. The relative humidity I was positively correlated with seed yield at P₃ stage and negatively correlated at P₆ stage however, the relative humidity II was negatively

correlated with seed yield at P₆ stage. The evaporation was positively correlated with seed yield at P₆ stage and negatively correlated with seed yield at P₃ stage. The BSS was positively correlated with seed yield at P₅ and P₆ stages however, it was negatively correlated at P₄ stage. The wind velocity was negatively correlated with seed yield at P₃, P₅ and P₆ stages.

Correlation coefficient between weather parameters and seed yield at different phenophases of Sesamum.

The rainfall was negatively correlated with seed yield at P₅ stage. The temperature maximum was negatively correlated with seed yield at P₅ stage however, the temperature minimum was negatively correlated with seed yield at P₅ stage.

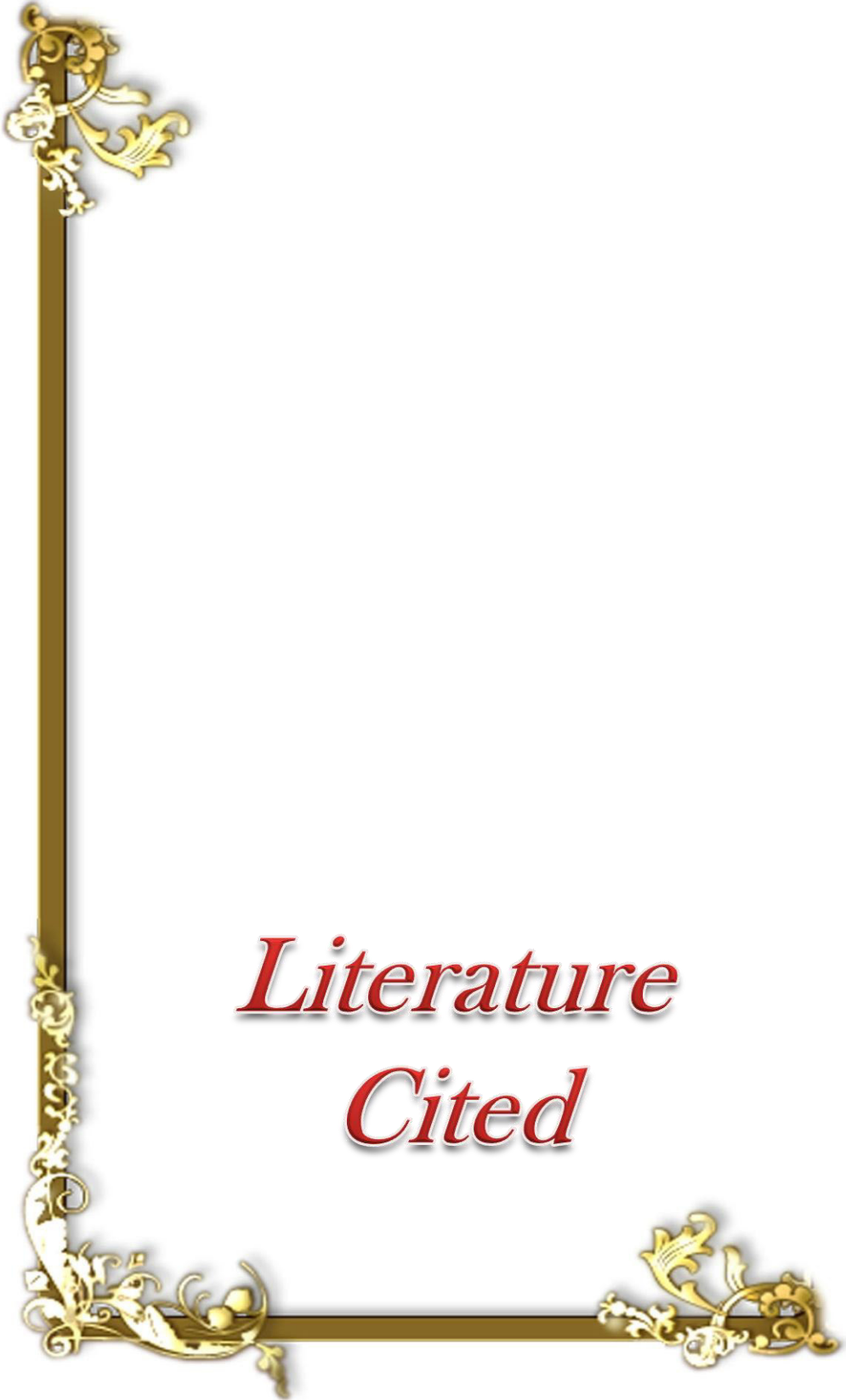
The relative humidity II was positively correlated with seed yield at P₅ stage. The evaporation was positively correlated with seed yield at P₂ stage. The BSS was negatively correlated with seed yield at P₅ stage and the wind velocity was positively correlated with seed yield at P₅ stage. The wind velocity was positively correlated with seed yield at P₅ stages.

CONCLUSIONS

Based on the result and discussions of present investigation, the following conclusions may be drawn.

1. Low canopy temperature and high relative humidity during crop growing period created favourable microclimatic condition in treatment T₃ i.e. Pigeon pea + soybean resulted into higher yield compared to other intercropping treatments.
2. Weather parameters viz. rainfall, rainy days temperature, relative humidity, evaporation, bright sunshine hours and wind velocity positively correlated with treatment T₃ resulted into higher yield.
3. Treatment T₃ performed better than other treatments and this treatment was better in terms of growth and yield attributing characters.

(Experimental finding done on one year work basis)



*Literature
Cited*

LITERATURE CITED

- Ahmadvand, A., Nsiri-Mahalati, M., koocheki, A.R. (2006). Effect of light competition and nitrogen fertilizer on canopy structure of wheat and wild oat. *Journal of Agricultural Science an natural resource*. 6: 1-12.
- Ali, (1990). Light Interception and Growth of Intercropped Soybean into Winter Wheat. The Ohio State University.
- Anthony R. S. and Rene C.V., (2008). Land equivalent ratios, light interception, and water in annual intercrops in the presence or absence of in-crop herbicides. *Agronomy Journal*. 100: 1145-1154.
- Awal, M.A., Koshi H. and Ikeda T. (2006). Radiation interception and use by maize/peanut intercrop canopy. *Agr. Forest Mereorol*. 139, 74-83.
- Barthwal, A., Singh, V.K., Prasad, S., Rawat, N. and Shah, H. (2018). Productivity and profitability of pigeon pea (*Cajanus cajan*) in pigeonpea based cropping system under different integrated nutrient management practices in *Tarai* region of uttarakhand. *International Journal of Chemical Studies*. 6(2): 3488-3492.
- Chaudhary, S.K. and Thakur, S.K. (2005). Productivity of pigeonpea based intercropping system. *Indian Journal of Agricultural Science*. 75: 496-497.
- Dahmardeh, M. and Khashayar, R. (2013).The influence of intercropping maize (*zea mays* L.) green gram (*Vigna radiata* L.) on the changes of soil temperature, moisture and nitrogen. *International Journal of Ecosystem*. 3(2): 13-17.
- Dasbak, M.A.D. and Asiegbu, J.E. (2009). Performance of pigeon pea genotypes intercropped with maize under humid tropical ultisol condition. *Journal of Animal and Plant Sciences*. 4(2): 329-340.
- Dhandayuthapani, U.N., Loganathan, V. and Latha, K.R. (2015).Growth parameters of pigeonpea and greengram as influenced by different cropping geometry and intercropping ratio. *Environ. We Int. J. Sci. Tech*. 0975-7112.

- Donald, F.W., and Upchurch D.R. (1997). Accounting for humidity in canopy-temperature-controlled irrigation scheduling. *Agricultural water management*. Vol. 34, Issue 3, 217-231.
- Dudhade D.D., Deshmukh G.P., Harer P.N., and Patil J.V. (2009). Studies On Intercropping of Pulse Crops with Pigeon Pea Under Rainfed Condition. *Legume Res.* 32 (3) :215-217.
- Dwivedi, A., Dev, I., Kumar, V., Yadav, S.R., Yadav, M., Gupta, D., Singh, A., and Tomar, S.S. (2015). Potential role of maize-legume intercropping systems to improve soil fertility status under smallholder farming systems for sustainable agriculture in India. *Int. J. Life Sci. Biotech. Pharm. Res.* Vol. 4, No. 3.
- Egbe, O.M. and Bar-Anyam, M.N., (2010).Pigeon pea / sorghum intercropping in Souther Guinea Savanna. Effects of planting density of pigeon pea. *Nature and Science*, 8(11).naturesciencej@gmail.com.
- Egbe, O.M. and Idoko, A.J. (2012). Evaluation of pigeonpea genotypes for intercropping with maize and sorghum in Southern Guinea Savanna: Economic benefits. *International Journal of Agriculture and Forestry*. 2(1): 108-114.
- Emefiene, M.E., Salaudeen, A.B., and Yaroson, A.Y. (2013). The use of pigeon pea for drought mitigation in Nigeria. *International Letters of Natural Sciences*. 2300-9675. Available at- www.ilns.pl.
- Ghanbari G., Dahmardeh, M., Siahisar, B.A. and Ramroudi, M. (2010).Effect of Maize (*Zea mays* L.)-cowpea (*Vigna unguiculata* L.)Intercropping on Light Distribution, Soil Temperature and Soil Moisture in Arid Environment. *Journal of Food Agriculture and Environment*.Vol.8(1):102-108.
- Gudadhe, N. N., Neeraj Kumar, Pisal, R. R., Mote, B. M. and Dhode, M. B.(2013).Evaluation of agro meteorological indices in relation to crop phenology of cotton (*Gossippium* spp.) and chickpea (*Cicer aritinum* L.) at Rahuri region of Maharashtra. *Trends in Biosciences* 6(3): 246-250.
- Hanming, H., Lei, Y., Liming, F., Lihua, Z., Han, W., Yang, J. and Chengyun, L. (2012). The effect of intercropping of maize and soybean on microclimate. *ResearchGate* 369, 257-263.

- He, H., Yang L., Liming F., Lihua, Z., Han W., Yang J., and Chengyun L. (2012). The effect of intercropping of maize and soybean on microclimate, CCTA 2011, Part 2, IFIP AICT 369, pp.257-263.
- Iqbal, N., Hussain, S., Ahmed, Z., Yang, F., Wang, X., Liu, W., Yong, T. Du, J., Shu, K., Yang, W. and Liu, J. (2018). Comparative analysis of maize-soybean strip intercropping system: A review. *Plant Protection Science*. <https://www.tandfonline.com/loi/tpps20>.
- Ito, O., Matsunaga, R., Tovita, S., Rao, T.P. and Gayatri Devi, Y. (1993). Spatial distribution of root activity and nitrogen fixation in sorghum/pigeonpea intercropping on an Indian Alfisols. *Plant and Soil*. 155-156:341-344.
- Jaya, K.D., Bell, C.J. and Sale, P.W. (1998). Modification of within-canopy microclimate in maize for intercropping in the lowland tropics. La Trobe University, Victoria. Fakultas Pertanian Universitas Mataram, Jl. Majapahit 62, Mataram 83125 Indonesia.
- Jaya. K. D., Bell, C.J. and Sale P. W. (2008), Modification of within canopy microclimate in safflower for intercropping in the lowland tropics. <http://www.regional.org.au>.
- Jena, S., Nath, R., Mazumdar, D., Bandyopadhyay, P. and Chakraborty, P.K. (2010). Pattern of absorption and interception of photosynthetically active radiation in sesamum-green gram intercropping system. *Research Journal of Agronomy*. 4(2): 10-17. ISSN: 1815-9354.
- Kanton, R.A.L. and Dennett, M.D. (2004). Water uptake and use by Morphologically Contrasting Maize/pea Cultivars in Sole and Intercrops in Temperate Conditions. *Experimental Agriculture*. 40:201-214.
- Karale, G., Biradar, S.A., Desai, B.K., Ajithkumar, K. and Rajanna. (2018). Effect of intercepted radiation and planting geometry on growth and yield of safflower and linseed intercropping system under rainfed condition. *International Journal of Chemical Studies*. 6(2): 2056-2061.
- Kathmale, D. K., Dhadge, S. M., Stpute, S. V., Patil, G., Ravindra, C., Rao, C. S., Jadhav, J. D., and Kadam, J. R. (2014). Evaluation pigeonpea based intercropping systems under Semi-arid Vertisol in Scarcity Zone of Maharashtra. *Indian J. Dryland Agric. Res. and Dev*. 29(1): 27-34.
- Keating, B.A., and Carberry, P.S. (1993). Resource capture and use in intercropping: solar radiation. *Field Crops Research*. 34, 273-301.

- Kogbe, J.O.S. and Adediran, J. A. (2003). Influence of nitrogen, phosphorus and potassium application on the yield of maize in the savanna zone of Nigeria. *African Journal of Biotechnology*. Vol. 2, No. 10, pp 345-349.
- Koocheki, A. Mahallti, M.N., Solouki, H. and Karbor, S. (2016). Evaluation of substitution intercropping of sesame and mung bean. *Advances in Plants and Agriculture Research*. Vol.3, 3(5):00 109.
- Knorzer, H., Grozinger, H., Graeff-Honninger, S., Hartung, K., Piepho, P.H. and Claupein, W.(2011). Integrating a simple shading algorithm into CERES-wheat and CERES-maize with particular regard to a changing microclimate within a relay-intercropping system. *Field Crop Research*. 121, 24-285.
- Kresnatita, S., Ariffin, H.D. and Sitawati. (2018). Micro climate behavior on cauliflower plant canopy in intercropping system with sweet corn in Central Kalimantan. *International Journal of Scientific and Research Publications*. Vol. 8, Issue 4, ISSN 2250-3153.
- Kumar, B. and Kumar, S. (2018). Utilization of waste cultivable upland through intercropping of fodder with pigeon pea (*Cajanus cajan*): multi remedial approaches in agricultural system of Jharkhand. *International Journal of Chemical Studies*. 6(5):382-386.
- Lanfontaine, O.H., Vercambre, G. and Tournebize, R. (1997). Radiation and transpiration partitioning in a maize-sorghum intercrop: Test and evaluation of two models. *Field Crops Research*. 49, 127-145.
- Lemma, D., (2002). Tomatoes: Research experiences and production prospects. Ethiopian Agricultural Research Organization, Report, (43): 1-47. Addis Ababa, Ethiopia.
- Lingaraju B.S., Marer B.S. and Chandrashekar S.S. (2007). Studies on Intercropping of Maize and Pigeon Pea under Rainfed Condition in Northern Transitional Zone of Karnataka. *Karnataka J. Agric. Sci.* 21(1) (1-3), Available at atbslraj@yahoo.com.
- Liu, X., Rahman, T., Song, C., Su, B., Yang, F., Yong, T., Wu, Y., Zhang, C., and Yang, W. (2017). Change in light environment, morphology, growth and yield of soybean in maize-soybean intercropping systems. *Field Crops Research*. 200 38-46.

- Lott, J.E., Ong, C.K. and Black, C.R. (2009). Understorey microclimate and crop performance in a *Grevillea robusta*-based agroforestry system in semi-arid Kenya. *Agric. Forest Meteorol.* 149:1140-1151.
- Luo, Q. (2011), "Temperature Threshold and crop production: A Review," *Climate Change*. vol. 109, nos, 3-4, pp. 583-98.
- Marshall, B. and Willey, R.W. (1983) Radiation interception and growth in an intercrop of pearl millet/groundnut. *Field Crops Research*. 7, 141-160.
- Mead, R. and Willey, R.W. (1980). The concept of a "Land Equivalent Ratio" and advantages in yields from intercropping. *Expl. Agric.*, Vol 16 pp. 217-228.
- Mohsen Z. and Jafar V., (2015). Investigating light absorption and some canopy properties in monocultures and intercropping culture of safflower and chickpea. *International Journal of Agriculture Innovations and Research*. Vol. 3, Issue 4, ISSN 2319- 1473.
- Nandini K.M., Sridhara S. and Kiran Kumar (2017). Dry Matter Production, photosynthetically Active Radiation and Radiation Use efficiency Response of Cluster Bean as influenced by Genotypes and planting Density. *International Journal of Pure and Applied Bioscience*. 5(1):504-512.
- Naresh, R.K., Singh, S.P., Kumar, P., Singh, B. Singh, P.K., Chauhan, P. and Rathore, R.S. (2014). Sustainability of maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system under legumes intercropping and effect of nitrogen level on light distribution, soil temperature and crop productivity. *Indian Journal of Agricultural Sciences*. 84 (6): 695-701.
- Nuttonson, M.Y. (1955). Wheat climatic relationship and use of phenology in ascertaining the thermal and photothermal requirements of wheat. *American Institute of Crop Ecology*. Washington D.C.
- Oroka and Frank, O. (2016). Cassava-groundnut intercropping under mineral fertilizer and vermicomposts: effect on below ground microclimate, nitrogen mineralization and cassava foliage. *Journal of Natural Science Research*. ISSN 2224-3186 (paper) ISSN 2225-0921 (online), Vol. 6, No. 2.
- Pablo, S., Harmand, J.M., Vaast, P. (2009). Effects of *Inga densiflora* on the microclimate of coffee (*Coffea Arabica* L.) and overall biomass under

- optimal growing conditions in Costa Rica. *Agroforest Syst.* 78: 269-286.
- Padhy, A.K., Sahod, B.K. and Das, K.C. (1992). Productivity of rainfed pigeonpea (*Cajanus cajan*) based intercropping system. *Indian J. of Agricultural Sci.* 62(9): 594-598.
- Patel, N.R., Meata, A.N. and Shekh, A.M. (2001). Canopy temperature and water stress quantification in rainfed pigeon pea (*Cajanus cajan*(L.) Milsp.). *Agricultural Forest Meteorology.* 109: 223-242.
- Patel, N.R., Meata, A.N., Venkatesh, H., Shekh, A.M. and Patel, J.R. (1999). Quantification of soil temperature in sole and intercropped pigeon pea (*Cajanus cajan* L. Millsp.) using meteorological parameters. *MAUSAM*, 50, 77-82.
- Polthanee, A. and Vidhaya, T. (2003). Growth, yield and land use efficiency of corn and legumes grown under intercropping systems. *Plant Production Science.* 6(2): 139-146.
- Qiang, C., Hao, Z. Xian, W. and You – Zhi, L. (2015). An insight into the sensitivity of maize to photoperiod changes under controlled conditions. *Plant, Cell and Environment.* 38, 1479-1489.
- Rachie, K.O. and Silvestre, P. (1977). Grain legumes. In: *Food crops of the lowland Tropics*. Ed. CLA Leakey and J. B. Wills Oxford University Press. Waalton Street Oxford pp 41-74.
- Radke, J.K. and Hagstrom, R.T. (1976). Strip intercropping for wind protection. *Multiple cropping, ASA, Special pub. 27:* 201-220.
- Rao, A.R. (1982). Intercropping in cotton. *Cotton Development*, 12(1/2), 33-34.
- Rao, J. V., Khan, I. A. and Sujatha (Eds). (2003). Critical review of research on intercropping systems in rainfed regions of India. National Agricultural Technology Project, CRIDA, Hyderabad, India, pp.1-100.
- Reddy, V., Koppalkar, B.G. and Rjun, M. (2015). Growth and yield advantages of pigeonpea with sesame intercropping system influenced by nutrient management. *International Quarterly Journal of Environmental Sciences.* vol. VII: 01-05, ISSN; 0974-0376.
- Rekha, M.S. and Dhurua, S. (2009). Productivity of pigeon pea + soybean intercropping systems as influenced by planting patterns and duration

- of pigeonpea varieties under rainfed conditions. *Legume Res.* 32(1): 51-54, 2009.
- Reynolds, P. E., Simpson, J.A., Theyathasan, N.V. and Gordon, A.M. (2006). Effects of tree competition on corn and soybean photosynthesis, growth and yield in a temperate tree-based agroforestry intercropping system in southern Ontario, Canada *Ecol. Eng.* Doi: 10. 1016/J. ecoleng. 2006. 09. 024.
- Rodrigo, V.H.L., Stirling, C.M., Teklehaimanot, Z. and Nugawela A. (2001). Intercropping with banana to improve fractional interception and radiation use efficiency of immature rubber plantation. *Field Crops Research.* 69, 237-249.
- Schlenker, W., and Roberts, M. j. (2009), "Nonlinear Temperature Effects Indicate Severe Damages to U. S. Crop Yields under Climate Change," *Proceedings of the National Academy of Sciences.* vol. 106, no. 37, pp. 15594-98.
- Selvaraju, R. and Balasubramanian T.N. (2001). Effect of moisture conservation practices on water use, microclimate and productivity of intercropping in dryland vertisols. *Jour. Agric. Physics.* Vol. 1, pp. 112-116.
- Shamim, M., Singh, R., Rao, V.U.M. and Singh, D.(2008). Microclimatic profiles in soybean-pearl millet intercropping systems. *Journal of Agrometeorology.* 10(2): 151-157.
- Sharaiha, R.K. and Battikhi, A. (2002). Potato/corn intercropping-microclimate modification and yield advantages. *Dirasat, Agric. Sci.* Vol. 29, No. 2; 997-108.
- Sharaiha, R.K. and Hadidi, N.A. (2002). Environmental impact on yield of pea and okra grown under intercropping. *Lucrari Stiintifice.* Vol. 50.
- Shetty S.V.R., Ntare B.R., Bationo A. and Renard C. (1995). Millet and cowpea in mixed farming of Sahel. A review of strategies for increased productivity and sustainability. Pages 293-304 in *Livestock and sustainable nutrient cycling in mixed farming systems of sub-Saharan Africa*, edited by J.M.Powell, S. Fernandez Revira, T.O. Williams, and C. Renard. *Proceedings International Conference, ILCA, Addis Ababa, Ethiopia.*




- Sikirou, S. and Wydra, K. (2008). Effect of Intercropping Cowpea with Maize or Cassava on Cowpea Bacterial Blight and Yield. *Journal of Plant Diseases and Protection*. 114(4): 145-151.
- Singh, G., Narwal, S.S., Rao, V.U.M. and Daiya, D.S. (1990). Effect of sowing date on requirement of growing degree days, heliothermal units and photothermal units on phenology of winter maize (*Zea mays*). *Indian J. Agric. Sci.* 60(11):723-731.
- Singh, P., Brajesh, S. and Singh, K.M. (2016). Trends of pulses production, consumption and import in India: Current scenario and strategies. *SSRN Electronic Journal*. DOI: 10.2139.
- Singh, R.A. and Singh, A.K. (1994). Comparative performance of different intercropping systems with pigeonpea under rainfed conditions of Vindhya region. *Indian Journal of Agronomy*. 39:623-615.
- Snedecore, G.W. and Cochran, W.G. (1968). *Statistical methods*. The Iowa State University press; Ames, Iowa U.S.A. Pp 507.
- Soetedjo, P., Maetin, L.D. and Tennt, D. (1998). Productivity and water use of intercrops of yield pea and canola proceeding of the Agronomy Conference, Regional Institute. ASA: 1-4.
- Thimmegowda, M.N., Ramachandrappa, B.K., Devaraja K., Savitha M.S., Srikanth Babu, P.N., Gopinath, K.A., Chary, R.G. and Rao, S.C. (2016). Climate resilient intercropping systems for rainfed red soils of Karnataka. *Indian J. Dryland Agric. Res. and Dev.* 31 (2): 39-44.
- Tiwari, D., Sharma, B.B. and Debey, P.K. (2012). Integrated nutrient management in pigeonpea based intercropping system under Tarai conditions of Uttarakhand. *Research journal of Agricultural Sciences*. 3(1); 014-018.
- Tomar, J., Singh, H.B., Vivek and Tripathi, S.S. (2004). Integrated weed management in intercropping of mungbean and cowpea fodder with pigeonpea under western U.P. condition. *Indian Journal of Weed Science*. 36: 133-134.
- Triveni, B., Muneendra, B., Reddy, P.G and Munaswamy, V. (2017). Performance of pearl millet (*Pennisetum Glaucum* (L.)R. Br. Emend Stuntz)-legume intercropping systems under rainfed conditions.

- Tsubo, M., Walker, S. and Mukhala, E. (2001). Comparisons of radiation use efficiency of mono-/inter-cropping systems with different row orientations. *Field Crop Research*. 71, 17-29.
- Vittal, K. P. R., Rao, K. V., Sharma, K. L., Victor, U. S., Ravindra, C. G., Nehru, D. S., and Panduranga (Eds). (2005). Potentials of intercropping in dry land farming. 100p. All Coordinated Research Project for Dryland Agriculture, Bangalore, India.
- Waghmare, A.B., Krishan, T.K. and Singh, S.P. (1982). Crop compatibility and spatial arrangement in sorghum-based intercropping system. *Journal of Agricultural Science. (Camb)*, 99: 621-629.
- Wang Q., Dongbao, S., Hong, H., Xuejiao, Z., Weiping, H., Qiong, L..(2015). Photosynthetically Active Radiation Determining Yields For an Intercrop of Maize With Cabbage. *Science Direct ,Agronomy*. 69, 32-40. www.elsevier.com/locate/fcr.
- Willey, R.W. (1979). Intercropping-its importance and research needs. Part 1. Competition and yield advantages. *Field Crops Abstr*. 32: 1-10.
- Wolfswinkel. (2003). Intercropping of annual food crops Agroref. No. 4 Agromisa Foundation, The Netherlands.
- Xiaobang, P., Thevathasan, V.N., Gordon, M.A., Mohammed, I. and Gao, P. (2015). Photosynthetic response of soybean to microclimate in 26-year-old tree-based intercropping systems in southern Ontario, Canada. *PLOS ONE*|DOI: 10.1371/journal. Pone. 0129467.
- Xin, L., Tanzeelur, R., Feng, Y., Chun, S., Taiwen, Y., Jiang, L., Cuiying, Z. and Wenyu, Y. (2017). PAR interception and utilization in different maize and soybean intercropping patterns. *PLOS ONE* 12(1), DOI: 10.1371.
- Yahuza, I. 2011. Review of radiation interception and radiation use efficiency in intercropping in relation to the analysis of wheat/faba bean intercropping system. *J. Bio. & Env. Sci*. Vol. 1, ISSN: 2220-6663.
- Yildirim, E. and Guvenc, I. (2005). Intercropping based on cauliflower: more productive, profitable and Highly sustainable. *European Journal of Agronomy*. 22:11-18.
- Zhang, L., Werf der, V.W., Bastiaans, L., Zhang, S., Li, B. and Spiertz J.H.J. (2008). Light interception and utilization in relay intercrops of wheat and cotton. *Field Crops Research*. 107, 29-42.



*Thesis
Abstract*

THESIS ABSTRACT

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ABSTRACT

“Effect of microclimate on Pigeon pea (*Cajanus cajan* L.) based intercropping system”

By

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A candidate for the degree of

MASTER OF SCIENCE (AGRICULTURE)

In

Agricultural Meteorology

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A field investigation entitled “Effect of microclimate on Pigeon pea (*Cajanus cajan* L.) based intercropping system” was conducted at Experimental farm, Department of Agricultural Meteorology, located at college of Agriculture, V.N.M.K.V, Parbhani during *kharif* season of 2019-20 to study the objectives to study the effect of different Pigeon pea based intercrops on microclimate and to study the effect of weather parameters on growth and yield of Pigeon pea based intercropping system. The experiment was laid out in RBD with three replication, under this study there were nine treatments viz. T₁ (Pigeon pea + Sorghum), T₂ (Pigeon pea + Maize), T₃ (Pigeon pea + Soybean), T₄ (Pigeon pea + Sesamum), T₅ (Pigeon pea), T₆ (Sorghum), T₇ (Maize), T₈ (Soybean), T₉ (Sesamum) are in 4:2. In present investigation the biometric observations viz. plant height, number of leaves and dry matter production per plant were recorded fifteen days interval in Sorghum, Maize, Soyben and Sesamum, whereas, in Pigoen pea at thirty days interval upto harvest. The micrometeorological condition in different treatments studied by using soil moisture, canopy temperature and relative humidity at thirty days interver from sowing upto

harvest. The canopy temperature and humidity was measured with the help of Infrared Thermometer and 4-in-1 Precision Humidity and Temperature meter respectively. The agro meteorological indices i.e. GDD, HTU and PTU, also the correlation of weather parameters with grain yield were studied.

Among different treatment it was observed that, the biometric observation was superior in the intercropping treatment like Pigeon pea + Soybean (T₃) followed by Pigeon pea + sesamum (T₄). The low canopy temperature and high relative humidity created favourable microclimatic condition in treatment T₃ i.e. Pigeon pea + soybean resulted into higher yield compared to other intercropping treatments. Weather parameters viz. rainfall, rainy days temperature, relative humidity, evaporation, bright sunshine hours and wind velocity positively correlated with treatment T₃ resulted into higher yield. Treatment T₃ performed better than other treatments and this treatment was better in terms of growth and yield attributing characters.



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VITAE


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