GENETIC VARIABILITY STUDIES IN GRAIN COWPEA
(*Vigna unguiculata* (L.) Walp.)

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(2018-11-039)

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by

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THESIS

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KERALA, INDIA
2020

DECLARATION

I, hereby declare that this thesis entitled **"Genetic variability studies in grain cowpea (*Vigna unguiculata* (L.) Walp.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani **Darshana A. S.**
Date: (**2018 - 11- 039)**

CERTIFICATE

Certified that this thesis, entitled **“Genetic variability studies in grain cowpea (*Vigna unguiculata* (L.) Walp.)”** is a record of research work done independently by **Ms. Darshana A. S. (2018-11-039)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Darshana A. S. (2018-11-039)**, a candidate for the degree of **Master of Science in Agriculture** with major in Plant Breeding and Genetics, agree that the thesis **"Genetic variability studies in grain cowpea (*Vigna unguiculata* (L.) Walp.)"** may be submitted by **Ms. Darshana A. S. (2018-11-039)**, in partial fulfilment of the requirement for the degree.

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Darshana A. S.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

et al.	And others
cm	Centimetre
CD	Critical Difference
CGR	Crop growth rate
cv.	Cultivar
°C	Degree Celsius
d.f.	Degrees of freedom
Fig.	Figure
GA	Genetic advance
GAM	Genetic advance as per cent of mean
g	Gram
GCV	Genotypic coefficient of variation
KAU	Kerala Agricultural University
kg	Kilo gram
kg ha^{-1}	Kilogram per hectare
LAD	Leaf area duration
LAI	Leaf area index
LAR	Leaf area ratio
mg	Milligram
viz.	Namely
No.	Number
%	Per cent
PCV	Phenotypic coefficient of variation
RGR	Relative growth rate
Sl.	Serial
SLA	Specific leaf area
SLW	Specific leaf weight
SE	Standard Error

cm^2	Square centimeters
ssp.	Sub species
i.e.	That is
via	Through

Introduction

1. INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is a versatile food legume belonging to the family Fabaceae, also known as “poor man’s meat” due to the high protein content in seeds and leaves. Cowpea is an annual legume commonly known by the names lobia, barbati, black eyed pea, southern pea etc. It is a diploid species with chromosome number 2n=22. The genus *Vigna* comprises of more than 150 species and the species name *unguiculata* is derived from the Latin word “unguis” meaning “shell claw” referring to the shape of the hilum in cowpea seeds.

According to FAO (2018), cowpea is cultivated in an area of 12.5 million hectares with the production of 7.3 million tonnes. In India, cowpea is an underutilized pulse crop cultivated in an area of 0.5 million ha with an average productivity of 600-750 kg grains per ha (IIPR, 2017-‘18).

Cowpea seeds contain 22-24% protein, 0.08-0.11% calcium, 0.005% iron, essential amino acids *viz*., lysine, leucine, and phenylalanine but they are deficient in methionine and cystine (DPR, 2016). Being a cheaper source of protein, cowpea not only complements staple cereals and starchy tuber crops, but also provides fodder for livestock, improves soil through nitrogen fixation and benefits households in the form of cash and income diversity. Cowpea fixes around 30-40 kg N per ha and leaves it to be available to the succeeding crop. Cowpea is grown as sole crop, inter-crop, mix-crop and in agro-forestry combinations mainly in the arid and semi-arid tracts of Rajasthan, Karnataka, Kerala, Tamil Nadu, Maharashtra and Gujarat. It is also grown as a floor crop in the homestead gardens of Kerala throughout the year.

Homestead gardens are popular in Kerala due to the low average landholding size of 0.22ha where coconut is the most dominant and important tree crop (John, 2014). The peculiar arrangement of leaves in the coconut crown along with the height of palm permits only a part of the incident light to pass through its canopy during different growth periods and the amount of light transmitted by coconut palm varies with age, spacing and system of planting. In case of palms less than 8 years old, 30 to 80 per cent of incident light is transmitted through its canopy, those between 8 and 20 year age group, only 20 per cent of light is transmitted and at the age of 30 it increases progressively to about 30 per cent, at the age of 40 to about 50 per cent and at the age of 70 to about 84 per cent (Das, 1988). Coconut based homesteads ensure ample interspaces for intercropping of annuals since it tops all other crops but the inter crops should be selected and planted in such a way that it can make the best use of interspaces, sunlight, nutrients and moisture available in the homestead (Devi *et al*., 2011). The moderate shade tolerance of cowpea makes it a compatible intercrop with several plantation crops (Singh *et al*., 2003). Family acceptance, availability of seed material and wide adaptability are the major contributing factors for preferring cowpea in homestead garden. Important characteristics required for grain cowpea variety suited to the homesteads are medium duration (85-90 days), short to medium stature (40-50 cm), tolerance to shade, pests and diseases and high yield with good quality.

In this context, this study entitled “Genetic variability studies in grain cowpea (*Vigna unguiculata* (L.) Walp.)” was undertaken with the following objectives.

- To evaluate and select shade tolerant grain cowpea genotypes suited to the coconut based homesteads.
- To evaluate the genotypes for physiological characters associated with shade tolerance
- To evaluate cowpea genotypes for duration, pest and disease incidence, quality and yield for homestead cultivation.
- To identify the superior parental lines for future breeding programmes.

Review of Literature

2. REVIEW OF LITERATURE

2.1. COWPEA - ORIGIN AND IMPORTANCE

Cowpea (*Vigna unguiculata* (L.) Walp.), a native of South Africa, is one of the resilient and versatile food legumes among crop plants. Cowpea is a multifunctional legume chiefly used as a grain crop, for animal fodder, green manure and as a vegetable. In rural areas the tender green leaves are also consumed as vegetable by small scale farmers. It is a protein-rich grain that supplements staple cereal and starchy tuber crops.

Cowpea is believed to have moved to Asia more than 2000 years ago from Africa, the centre of origin and reached India from Eastern Africa before 150 BC. Indian subcontinent is considered as the third centre of diversity of cowpea (Singh, 2014).

Now cowpea has become a part of the local cropping systems of more than 100 countries in the tropics and subtropics due to its adaptability to varying climatic conditions and management practices. The popularity of cowpea among resource poor farmers in almost all the continents is attributed by the unique ability of its root nodules to fix atmospheric nitrogen and to extract bound phosphorous when available phosphorous is limited in the soil thereby improving soil fertility. It also grows well in sandy soil, soils with variable pH, low organic matter and low fertility. The fast growing nature and moderate shade tolerance makes it compatible as an intercrop with cereals, millets, tubers, and plantation crops. The major environmental factors affecting cowpea yield include drought, heat, cold, shade, and low fertility. Cowpea is subjected to low light intensity in intercropped systems which causes significant yield losses (Singh, 2014).

2.2. TAXONOMY

Earlier *Vigna unguiculata* (L.) Walp. had more than 20 synonyms, including *V. sinensis, V. cylindrica, V. catjang, Dolichos unguiculata,* and *Dolichos sinensis*. Cowpea belongs to the order - Fabaceae, subfamily - Faboideae (synonym Papillionoideae), tribe - Phaseoleae, subtribe - Phaseolinae, and genus - *Vigna*. More than 150 species are included under the genus *Vigna* which is again divided into several subspecies out of which the cultivated cowpeas belongs to *Vigna unguiculata* ssp. *unguiculata*. The subspecies comprises of four cultigroups – *unguiculata*, *biflora* (or *cylindrica*), *sesquipedalis* and *texilis*. Dry seeds of cultigroups *unguiculata*, *biflora* (or *cylindrica*) are commonly used as pulses and cultigroup *sesquipedalis* is used for vegetable purpose.

2.3. BOTANY

Cowpea is an annual, short day plant which exhibits high variability for growth habit, leaf type, flower colour, pod type, pod colour, maturity, seed type, and seed colour. Root system of cultivated cowpea are characterized by strong, deep taproot with many branches. Numerous smooth, spherical nodules are seen on the taproot and its main branches. Shoot system consists of slightly ribbed, twisted, glabrous, cylindrical stem. Various patterns of pigmentation is observed on the stem, petioles and peduncles – from none or localized purple at nodes (joint pigmentation) to solid purple. The leaves are trifoliate arranged alternately on the main stem on grooved petioles, with spurred stipules. Leaflet shape varies from, ovate to lanceolate or hastate. The terminal leaflets of each trifoliate are symmetrical with two asymmetrical side leaflets. Two deciduous bracteoles are seen on the short peduncles. The short pedicles bear two deciduous bracteoles.

At the terminal end of peduncles several flowers are borne on an unbranched axillary raceme. The calyx is tubular, green or purple in colour depending on the variety. The corolla is papillionaceous, with standard, keel and wing petals. The standard petal is erect and opens only at the time of flower opening. In the corolla, the pattern of pigmentation varies depending on the variety *viz.*, white or yellow, purple patch on wings only, purple margins on standard and wings or solid purple colour on standard and wings. The keel petal is boat shaped enclosing the gynoecium and androecium and is always white in colour. The wing petals are seen adhered to the keel petal.

The stamens form a tube around the gynoecium and are diadelphous (9+1), with nine fused and one free stamen. The pod length also varies depending on the variety and the pattern of pigmentation varies from light green to dark green and solid purple, with or without purple tips at the immature stage, and straw to straw with dull black splashes to deep purple or dark brown at maturity.

In case of seeds, its size, shape, nature of seed coat, colour of seed coat and eye patterns vary. The seed shape varies from square to kidney-shaped and may be laterally compressed. The seed coat may be smooth, rough, or wrinkled. There is a wide range of seed coat colours and eye patterns.

2.4. EFFECT OF SHADE ON IMPORTANT BIOMETRIC CHARACTERS OF PULSES

Cowpea recorded the highest yield (300 to 500 kg/ha) under rainfed condition where green gram, black gram, red gram, horse gram and cowpea was tried as intercrops at different areas and further studies to identify suitable shade tolerant cowpea varieties were suggested (Gopalasundaram and Nelliat, 1979). According to Adedipe and Ormrod (1975), the response of cowpea plant to different light intensities depend on the cultivar, growth stage, growth characteristics and plant constituents. Studies in mungbean varieties under partially shaded conditions revealed that selection of varieties for shade tolerance can be done by using certain morpho-physiological and agronomic parameters such as higher specific leaf weight, higher leaf area ratio, lower leaf area, leaf area duration at six weeks after emergence (or early maturity), higher harvest index, greater pod number per plant and determinate growth habit (Abilay and Lantican, 1982).

2.4.1. Light intensity

The major determinant factor of yield is the amount of light intercepted by the plant and not the amount of light incident on the field (Watson, 1952). According to Nair (1979), in a coconut garden at ground level the light intensity is always higher than 6700 lux at all the periods of the year. The peculiar structure of coconut crown and leaf orientation allows only a part of available solar radiation to pass through the canopy and reach the ground (Dhanapal, 2010).

The incident PAR below the coconut canopy was 40 to 50% less than the open. Around 30% of light penetration is allowed by coconut palms through their fixed canopies. The sun fleck areas in the under storey of coconut palms receive a PAR as high as 80% of the total PAR in the open and increase in the height of palms influence the amount of sunlight reaching the ground. The lower light intensity reaching into the canopy is the main reason for ineffective utilization of the available inputs by component crops as compared to open condition (Bai, 2010).

2.4.2. Biometric characters

2.4.2.1. Days to 50% flowering

Danlami *et al.* (2015) reported the negative effect of shading on days to flowering while evaluating two cowpea varieties under 100% light and different shade levels.

In a variability study conducted by Sivan (2019) in horse gram under open and partially shaded conditions, considerable difference was observed for days to 50% flowering in genotypes between the two growing conditions. Flowering was delayed in most of the horse gram genotypes under partial shade.

Singh and Alam (2010) and Masaku *et al.* (2018) also reported increase in days to flowering in green gram at different shade regimes.

2.4.2.2. Number of primary branches per plant

Wien (1977) reported fewer branches and lesser number of nodes with reproductive buds in cowpea when grown under 50% shade intensity.

According to Terao *et al.* (1997), the most serious effect of shade in cowpea is in the branch initiation stage, which inhibits branching significantly. One of the strategies to increase the yield in cowpea under intercropping is to develop varieties that branch well even under severe shading.

Danlami *et al.* (2015) and Kumar and Kishor (2015) reported lesser number of branches under shaded condition compared to full sunlight in cowpea and soybean respectively.

In contrary Sivan (2019) reported minimal effect of shade stress on this character in horse gram as the number of branches were statistically on par for the genotypes under open and partially shaded condition.

2.4.2.3. Height of plant (cm)

Adedipe and Ormrod (1975) observed increase in plant height in cowpea genotypes under low light intensity at different growth stages. The increase in plant height due to longer internodes and change in plant habit from erect to trailing was reported in cowpea by Adelusi and Aileme (2006) under shaded condition. According to Danlami *et al.* (2015) the increase in plant height in cowpea due to shading had negative impact on grain and fodder yield.

Under partially shaded conditions the increase in plant height due to inter-nodal elongation was also reported in green gram, black gram, horse gram and soybean (Babu and Nagarajan, 1993; Islam *et al.*, 1993; Lakshmamma and Rao, 1996; Kumar and Kishor, 2015; Hossain *et al.*, 2017; Sivan, 2019)

In contrary Eriksen and Whitney (1984) reported no effect of shading on plant heights of cowpea.

2.4.2.4. Number of pods per plant

Eriksen and Whitney (1984) reported that pods per plant is the main component of yield affected by shade in cowpea and soybean. The reduction in number of branches in shade limits both the number of leaves (source) and number of pods (sink) (Terao *et al.*, 1997).

Danlami *et al.* (2015) observed significantly fewer pods in cowpea plants grown under shade compared to plants grown in unshaded conditions.

Abilay and Lantican (1982) suggested that in green gram the decrease in number of mature pods per plant is due to the delay in flowering and pod maturity under partial shade compared to open condition and greater number of pods per plant as one of the characters associated with shade tolerance.

Significant difference was observed for number of pods per plant between genotypes under partially shaded and open conditions in green gram and horse gram (Hossain *et al.*, 2017; Masaku *et al.*, 2018; Sivan, 2019).

Philip (1987) stated that in blackgram, the model for plant selection under partial shade should be of taller ones, with more number of branches and pods per plant.

2.4.2.5. Number of seeds per pod

Hossain *et al.* (2017) and Masaku *et al.* (2018) reported significant influence of shade on mungbean varieties for number of seeds per pod whereas Summerfield *et al.* (1976), Eriksen and Whitney (1984) and Sivan (2019) observed little effect of shading on this character in cowpea and horse gram.

2.4.2.6. 100 seed weight (g)

Abilay and Lantican (1982) and Danlami *et al.* (2015) reported a decrease in seed weight under shaded condition in green gram and cowpea whereas Summerfield *et al.* (1976) reported an increase in mean seed weight in cowpea under shade treatment. Eriksen and Whitney (1984) and Sivan (2019) observed no effect of shading on seed weight.

Hossain *et al.* (2017) evaluated the performance of four mungbean varieties under different shade levels and observed no effect of shading on tolerant genotypes but a reduction in seed weight was observed in sensitive genotypes. It was concluded that heavier grains are one of the reasons for stable performance of tolerant genotypes under shade.

2.4.2.7. Seed yield per plant (g)

Summerfield *et al.* (1976) observed a significant reduction in seed yield per plant in cowpea grown under shade stress from emergence to pod maturity compared to control (no shading).

Singh (1997) observed a marked reduction in grain yield in green gram under shaded condition. Hossain *et al.* (2017) reported no change or reduction in grain yield per plant with lowering the light intensity but the rate of reduction varied among different genotypes in green gram.

2.4.2.8. Seed yield per unit area (kg ha^{-1})

Tarila *et al.* (1977) reported severe decline in the seed yield of cowpea under low light intensity. Wien (1977) reported a yield reduction by about 65% in cowpea under 50% shade throughout the growth period. In a study conducted by Eriksen and Whitney (1984) the response of different legumes to varying levels of shade was analysed and severe yield reduction was observed in cowpea compared to other legumes. The yield of cowpea at 27% light intensity was only 9% of the grain yield at 100% intensity.

About 68% and 30% yield reduction was reported in mungbean (Lantican and Catedral, 1986) and soybean (Catedral and Lantican, 1986) respectively under 50% shade compared to full sun. The reduction in yield varied among genotypes in both the crops. Islam *et al.* (1993) also reported a yield reduction of 63.88% at 75% shading and even at 15% shading, a yield reduction 10.12% was observed in green gram.

According to Lakshmamma and Rao (1996), the decrease in seed yield with increased shading was due to increased flower drop in black gram.

On the contrary, Abilay and Lantican (1982) reported no significant change in the grain yield of mungbean varieties under partial shade and open conditions.

2.4.2.9. Crop duration (days)

Sivan (2019) observed an increase in crop duration under partial shade in horsegram and the genotypes varied significantly under open and partially shaded conditions with respect to this character.

Under shaded condition, a delay in days to maturity was reported by Danlami *et al.* (2015) in cowpea.

In contrast, Masaku *et al.* (2018) observed no significant influence of shade on the number of days to maturity in green gram.

2.4.2.10. Harvest index

N’tare and Williams (1992) studied the performance of cowpea varieties under intercropping and concluded that the low yield of local spreading type is due to low harvest index and inadequate root system. They also suggested that cowpea varieties better adapted to intercropping can be developed without reducing its adaptability to shading by improving these two characters.

A study conducted by Saxena and Sheldrake (1980) to study the effect of shading in chickpea at two different locations revealed that harvest index (HI) is greatly influenced by climatic conditions and the reduction in HI was observed with the increase in shading levels at both locations. Eriksen and Whitney (1984) also reported a severe reduction in harvest index with decreasing radiation in cowpea.

Abilay and Lantican (1982) suggested higher harvest index as one of the characters associated with shade tolerance in green gram. They observed higher harvest index for shade tolerant green gram varieties under partial shade. Singh (1997) and Hossain *et al.* (2017) reported that the decrease in harvest index in green gram was due to the influence of low radiation on the partitioning of assimilates from source to sink.

According to Abraham (1988), an ideal plant type of black gram under partial shade should have high LAI at 50 per cent flowering, with high dry matter accumulation, resulting in high harvest index.

2.4.2.11. Pest and disease incidence

Coconut based cropping system provides a habitat for a variety of insects and soil organisms by encouraging the biodiversity. According to Altieri (1994), the pest outbreaks are limited by this biodiversity. The severe pest outbreaks in intercropping are also prevented by the diverse natural enemies prevalent in the system, maintaining biotic balance and preventing pest population below economic injury levels (Nair and Kumar, 2010). Relatively lower pest and disease attack was also observed in the homesteads due to plant diversity (John, 2014; Jaslam *et al*., 2017).

2.4.2.12. Leaf area and dry matter production at vegetative, flowering and harvesting stages

In cowpea, Dart and Mercer (1965) reported significant influence of shading on leaf area and dry matter production. They observed an increase in leaf area and a decrease in dry matter production in cowpea under shade. Eriksen and Whitney (1984) observed 75 per cent reduction in dry matter accumulation in the cowpea varieties evaluated which exhibited its sensitiveness to low light intensities.

According to Sundari (2009), shade tolerant and sensitive genotypes differ in the leaf characters. The shade tolerant mungbean genotypes showed better response to light stress and had bigger and thicker leaves than the sensitive genotypes so that the low light availability can be compensated through increased light interception by increased leaf area.

Kubota and Hamid (1992) compared the performance of green gram and black gram at different light intensities and observed a decrease in dry matter production and leaf area of black gram with shade, while green gram showed a different pattern. In green gram, the highest dry matter production and leaf area were recorded at moderate shade compared to control and heavy shade.

Araki *et al.* (2014) studied the effect of shade on growth of green gram cultivars and observed reduction in plant dry weight under shade in all the cultivars due to decrease in leaf and root dry weights. The study revealed that the common feature of shade sensitive cultivars were reduction in root dry weight and maintenance of leaf area. Hossain *et al.* (2017) observed an increase in leaf area under low light intensity invariably in all the green gram genotypes evaluated but the increment varied among genotypes.

Kumar and Kishor (2015) evaluated the sensitiveness of two soybean cultivars to different light regimes and observed a decrease in dry matter accumulation with decrease in light intensity. Both varieties showed a reduction in leaf area which proved their non-adaptability to shading.

2.4.3. Physiological characters (Recorded at vegetative, flowering and harvest stage)

2.4.3.1. Specific leaf area (cm^2 g^{-1})

Specific leaf area is the area per unit weight of leaf lamina and is used as a measure of leaf density. According to Wahua *et al.* (1981), SLA is a highly sensitive attribute that reflects slight degrees of shading. When grown under shade, sun plants like cowpea produced greater leaf area and thinner leaves which enhanced the light utilization efficiency and hence the degree of shading can be evaluated by measuring SLA- the greater the shading, the larger the SLA.

The study of morphological and physiological characteristics of tolerant and sensitive mungbean genotypes to shading carried out by Sundari (2009) confirmed that specific leaf area at four weeks after planting could be used as shading tolerant indicator of mungbean. The SLA value of shading sensitive genotypes were greater than that of tolerant genotypes which indicated thicker leaves in tolerant genotypes compared to sensitive ones.

A comparative study in green gram and black gram conducted by Kubota and Hamid (1992) revealed that in both species, specific leaf area increases with the reduction in light intensity.

2.4.3.2. Specific leaf weight (mg cm^{-2})

Specific leaf weight is the weight per unit area of leaf and indicates the relative thickness of the leaf of different genotypes. A study in mungbean conducted by Abilay and Lantican (1982) revealed that SLW can be used a rapid and economical method to identify lines with high photosynthetic potential since it is positively correlated with RuBP carboxylase activity. The SLW values were found to be lower under partial shade and higher SLW is a character associated with shade tolerance in mungbean.

In green gram and soybean, a drastic reduction in SLW values were observed in plants under low light intensity compared to control (Gourdon and Planchon, 1982; Islam *et al.*, 1993; Singh, 1997).

2.4.3.3. Leaf area index (LAI)

Leaf area index is defined as the functional leaf area over unit land area and represents the leafiness in relation to land area. Evaluation of different pulses under varied sunlight levels by Manoj (2017) revealed significant decrease in leaf area index under 75 per cent shade compared to open sunlight in cowpea, black gram, pigeon pea and lab lab. LAI at 50 per cent shade was found to be intermediate in all the pulses.

Babu and Nagarajan (1993) also reported a decrease in LAI under shade in soybean and also considerable variation was showed by cultivars for this trait.

2.4.3.4. Leaf area ratio (LAR)

Leaf area ratio also called as capacity factor is a measure of the proportion of the plant which is engaged in photosynthetic process. It represents the leafiness character of the plant on area basis and is defined as the ratio between leaf area in square centimeters and total plant dry weight.

Abilay and Lantican (1982) suggested higher leaf area ratio as one of the characters associated with shade tolerance in green gram and LAR tend to increase under partial shaded condition compared to full sunlight.

Nomoto *et al.* (1961) also reported an increase in LAR with decreasing light intensity in green gram and the LAR decreased as the plants grew under full sunlight and shaded conditions.

In soybean an increase in LAR with reduction in light intensity was reported by Kumar and Kishor (2015) and it was observed that greater survival potential with higher LAR was attained by the variety JS-335 under 70 per cent light.

2.4.3.5. Leaf area duration (days) (LAD)

The leaf area duration is the leaf area integrated over time and is the measure of persistence of the assimilatory surface. In green gram varieties with lower leaf area duration at six weeks after emergence (or early maturity) were considered as shade tolerant and the LAD values tend to increase under partial shade condition compared to full sunlight (Abilay and Lantican, 1982).

2.4.3.6. Crop growth rate (CGR)

Crop growth rate is defined as the increase of dry matter in grams per unit area per unit time. The analysis of important growth components in green gram by Islam *et al.* (1993) indicated that the crop growth rate was reduced in shaded plants and it declined with the growth of plant. Babu and Nagarajan (1993) also observed similar trend in CGR in soybean under partial shade in coconut garden.

Kubota and Hamid (1992) reported a decrease in plant growth rate with an increase in shade in black gram whereas in green gram the highest value for PGR was observed under moderate shade followed by control (no shading) and heavy shading.

2.4.3.7. Relative growth rate (RGR)

Relative growth rate also known as efficiency index is the rate of increase in dry matter per unit of dry matter already present and also provides a valuable overall index of plant growth.

In shaded plants, the relative growth rate was found to be lower compared to the plants under open condition and it was due to the lowering of net assimilation rate (Islam *et al.*, 1993).

According to Nomoto *et al.* (1961), RGR under 20% light was only half of the value observed under full light. Similarly, the decrease in RGR with an increase in shade was reported in black gram and soybean (Kubota and Hamid, 1992; Kumar and Kishor, 2015).

2.4.4. Quality character of seeds

2.4.4.1. Total protein content of seeds (%)

Bellaloui *et al.* (2012) evaluated the effect of shade on seed quality in soybean and reported the lowering of protein content under shaded environments.

On the contrary, Sivan (2019) reported no significant difference for protein content in horsegram under partially shaded and open conditions.

2.5. STATISTICAL ANALYSIS

The observations recorded during the study is analyzed using various statistical procedures. The literature available on various characters are reviewed under following headings:

1. Variability
2. Heritability and genetic advance
3. Correlation analysis
4. Path analysis
5. Genetic divergent analysis

2.5.1. Variability

The existence and magnitude of genetic variability for yield and yield traits in the basic breeding material determines the efficacy of selection (Adewale *et al.*, 2010). The observable variation present in a population, *i.e.*, phenotypic variability is influenced by both genotypic and environmental factors.

Studies conducted in cowpea to estimate the variability in phenotypic and yield characters revealed highly significant difference for all the traits observed. Greater influence of environment was observed on genotypes as indicated by the relative higher values of phenotypic variance than genotypic variance for all the morphological traits (Nwofia *et al*., 2012; Gerrano *et al.*, 2015).

An evaluation of 169 cowpea genotypes by Viswanatha and Yogeesh (2017) reported high PCV and GCV for traits like days to 50 per cent flowering, number of branches per plant, number of pods per plant and seed yield per plant.

Richard *et al.* (2016) studied the level of variation in seed protein content of 101 cowpea genotypes and observed highly significant genotypic differences among the cultivars. The results showed that majority of the cowpea genotypes (72.28%) were of medium protein content with values ranging from 19.95 to 31.20%. Only 20 genotypes (19.8%) were high protein lines (29.65 to 40.97%) whereas only 8 genotypes (7.92%) were of low protein content (14.81 to 22.07%).

Abraham (1988) conducted a variability study in 19 varieties of black gram under partial shade in coconut plantations and reported high PCV and GCV values for number of branches per plant, leaf area index at 50 per cent flowering and accumulation of dry matter at 50 per cent and 100 per cent flowering. High PCV with low GCV values were observed for number of pods per plant, grain yield per plant and harvest index indicating the greater influence of environmental factors on these characters.

Rajeswari (1998) studied the variability among 25 green gram genotypes under partial shade and reported maximum difference between PCV and GCV for the characters like branches per plant, harvest index and grains per pod indicating the greater influence of environment on these characters. Negligible effect of environment was observed on the characters like days to blooming, days to final harvest, pods per plant and LAI (pod formation) as indicated by least difference between PCV and GCV.

2.5.2. Heritability and genetic advance

For selection to be effective the variability present in the population should be carried over to future generations. Heritability and genetic advance gives an idea about how much of the variability is heritable and also the superiority of the selected individuals over base population.

Aramendiz *et al.* (2018) estimated the genetic parameters of ten quantitative characters associated with yield in cowpea and revealed high heritability (broad sense) for number of pods per plant (95.48%) and weight of 100 seeds (98.51%). Pods per plant (36.06%), 100 seed weight (84.11%) and days to harvest (87.07%) showed high genetic advance which indicated the potential of these characters as selection criteria for future breeding programs.

Viswanatha and Yogeesh (2017) estimated medium to high genetic advance for all the characters studied. High heritability with high genetic advance was observed for the characters like days to 50 per cent flowering, number of branches, number of pods per plant, seeds per pod and seed yield per plant revealing additive gene action on these characters.

Under partial shade, the number of branches per plant showed moderate to high heritability and genetic gain (Philip, 1987) whereas the characters number of days to blooming, leaf area index at 50 per cent flowering, accumulation of dry matter at 50 per cent and 100 per cent flowering exhibited high heritability coupled with high genetic advance indicating the presence of additive gene action in black gram (Abraham, 1988)

Sivan (2019) conducted variability studies in horse gram under partially shaded conditions and reported moderate heritability for harvest index (54.56%) and crude protein (44.65%). Moderate genetic advance was reported for number of primary branches, seeds per pod, 100 seed weight and crop duration and lowest values of genetic advance were observed for crude protein indicating the control of these characters by non-additive genes.

2.5.3. Correlation analysis

The main breeding objective in almost all breeding programs is higher yield which is regarded as a polygenic character as it is influenced by many associated traits. Correlation studies measures the degree and direction of association of two traits in a population.

A study conducted by Zainab and Ajeigbe (2014) to evaluate the performance of 27 cowpea lines under three shading levels reported higher values of phenotypic correlation coefficients for vegetative growth parameters observed more influence of shading on growth characters than yield characters.

Forty cowpea genotypes were evaluated by Dhanasekhar and Pandey (2005) to study the correlation of leaf area to agronomic attributes and positive correlation was reported between leaf area and yield or yield components *viz.*, seeds per pod, yield per plant and days to maturity. Leaf area showed insignificant positive correlation with branches and pods per plant and 100 seed weight.

According to Abraham (1988) grain yield had high positive genotypic correlation with number of branches per plant, number of pods per plant, number of seeds per pod, LAI at 50 per cent and 100 per cent flowering, dry matter accumulation at 50 per cent flowering and harvest index in black gram under partial shade in coconut plantation.

Correlation studies in green gram by Rajeswari (1998) reported negative correlation between days to blooming, grains per pod with grain yield. For all the characters genotypic correlation coefficients were higher than the phenotypic correlation coefficients which was due to the modifying effect of environment on association of characters.

2.5.4. Path analysis

The basic step in crop improvement is the selection of genotypes with high yield and other desired qualities and it can be achieved only by analyzing the actual contribution of different traits to yield. The information on contribution of traits is provided by partitioning the total correlation into direct and indirect effects.

Manggoel *et al.* (2012) estimated the direct and indirect effects of reproductive characters on grain yield and reported highest positive effect of 100 seed weight followed by number of flowers per plant and seeds per pod. Negative direct effects was contributed by days to 50 per cent flowering and number of pods per plant on grain yield.

Study conducted by Abraham (1988) in black gram under partial shade revealed maximum direct contribution of LAI at 50 per cent flowering for harvest index, followed by number of pods per plant and number of seeds per pod.

In a trial conducted by Philip (1987) in 20 varieties of black gram under partial shade on seed yield high positive direct effect was exerted by number of pods per plant and 100 seed weight followed by days to 50 per cent flowering, plant height and number of branches per plant.

2.5.5. Genetic divergence analysis

Genetic divergence studies are important in hybridization programmes since hybrids developed by crossing lines of diverse characteristics show higher levels of heterosis. Divergent studies also aids in measuring the contribution of each character to total divergence.

Khan and Viswanatha (2016) studied the genetic divergence among 196 cowpea genotypes using Mahanalobis D^2 statistics and grouped the genotypes into 22 clusters. Highest intra cluster distance was recorded in the cluster XXII (2767.30) and minimum in cluster II (4.19). Maximum inter cluster distance was observed between the clusters I and XIX (4343.52) whereas the minimum D^2 value was between the clusters II and VI (34.66). The maximum contribution to total genetic divergence was observed by seed yield per plant (35.82) followed by the characters test weight (26.99) and days to 50% flowering.

Genetic diversity among 44 grain cowpea genotypes was assessed by Pandey (2007) for seed yield and related traits and the genotypes were grouped into nine clusters. Maximum genetic distance was contributed by number of pods per plant, followed by number of seeds per plant, plant height, number of primary branches and number of secondary branches. Cluster VII and clusters IX were the most diverse with maximum intercluster distance (48.592) followed by cluster V and IX (46.612).

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled "Genetic variability studies in grain cowpea (*Vigna unguiculata* (L.) Walp.)" was done to evaluate and select shade tolerant grain cowpea genotypes suited to the coconut based homesteads. The experiment was carried out at Farming Sytems Research Station, Sadanandapuram during 2019-2020.

The details of materials and methods adopted for the study are described below under different subheads.

3.1. EVALUATION OF GENOTYPES IN THE HOMESTEADS

3.1.1. Materials

Light intensity meter is used for measuring light intensity of the experimental field. The planting materials used in the study comprises of 33 grain cowpea genotypes collected from research stations under KAU and agricultural universities of different states. The genotypes and location of collection are listed in Table 1. Characterisation of the genotypes was carried out using the guidelines developed by PPV and FRA for the conduct of DUS test in cowpea.

3.1.2. Methods

3.1.2.1. Location

The study was conducted in the coconut based homestead garden of Farming Systems Research Station, Sadanandapuram where coconuts are 30 – 40 years old. The station is located at 8°58' N latitude, 76°48' E longitude and an altitude of 76m above mean sea level.

3.1.2.2. Season

The experiment was conducted from December 2019 to March 2020.

Table 1: List of grain cowpea (*Vigna unguiculata* (L.) Walp) genotypes used in the study

Sl.No	**Name of genotype**	**Source**	**Sl.No.**	**Name of genotype**	**Source**
1	Hridya	KAU, Kerala	18	CP VBN 3	NPRC, Vamban
2	Sreya	KAU, Kerala	19	HC 46	CCSHAU, Haryana
3	Subhra	KAU, Kerala	20	CHESCP-03	CHES, Gujarat
4	DC 15	UAS, Dharwad	21	CHESCP-07	CHES, Gujarat
5	KYLMVU-1	KAU, Kerala	22	CHESCP-09	CHES, Gujarat
6	KYLMVU- 3	KAU, Kerala	23	CHESCP-13	CHES, Gujarat
7	KYLMVU-4	KAU, Kerala	24	CHESCP-17	CHES, Gujarat
8	KYLMVU- 6	KAU, Kerala	25	CHESCP-19	CHES, Gujarat
9	KYLMVU- 7	KAU, Kerala	26	CHESCP-21	CHES, Gujarat
10	KYLMVU-10	KAU, Kerala	27	CHESCP-22	CHES, Gujarat
11	TC 55-1	BARC, Trombay	28	CHESCP-23	CHES, Gujarat
12	PL-1 (Pant Lobia-1)	GBPUA&T, Pantnagar	29	CHESCP-29	CHES, Gujarat
13	PL-2 (Pant Lobia-2)	GBPUA&T, Pantnagar	30	CHESCP-32	CHES, Gujarat
14	PL-3 (Pant Lobia-3)	GBPUA&T, Pantnagar	31	IC 300039	CHES, Gujarat
15	PL-4 (Pant Lobia-4)	GBPUA&T, Pantnagar	32	IC 39853	CHES, Gujarat
16	PL-5 (Pant Lobia-5)	GBPUA&T, Pantnagar	33	IC 52110	CHES, Gujarat
17	CP VBN 1	NPRC, Vamban			

3.1.2.3. Layout and conduct of field experiment

The experiment was conducted in a randomized block design with three replications in the coconut based homestead garden. The field was divided into three blocks and each block was divided into 33 plots of size $4.5m^2$. The genotypes were considered as treatments and were randomly allotted to each block .A control block with all the treatments were maintained under open condition for comparison.

The planting material used were seeds. Soaked seeds were sown on raised beds at a spacing of 30 cm between rows and 15 cm between plants in a row. Agronomic practices were done as per the "Package of Practices Recommendations Crops 2016" of Kerala Agricultural University (KAU, 2016).

3.1.3. Observations recorded

3.1.3.1. Light intensity

The light intensity at ten random points in the experimental field under shade and open condition was measured using light intensity meter at 11.45 am and mean was worked out. Shade intensity was calculated using the formula

$$\text{Shade intensity} = \frac{\text{Light intensity at open} - \text{Light intensity at shade}}{\text{Light intensity at open}} \times 100$$

3.1.3.2. Biometric observations

The observations were taken on following characters.

3.1.3.2.1. Days to 50 per cent flowering

The number of days from the date of sowing to the day at which 50 per cent of the plants in each plot attained flowering was recorded.

Five plants were randomly selected and tagged as observational plants from each plot for recording of observations of the following characters. The average was calculated and statistical analysis was done with the values obtained.

Plate 1. General field view

3.1.3.2.2. Number of primary branches per plant

The number of branches arising from the main stem of the plants were recorded at physiological maturity.

3.1.3.2.3. Height of plant (cm)

The height of the plant from the ground level to the tip of the stem was recorded using metre scale at physiological maturity of the plant and expressed in centimetres.

3.1.3.2.4. Number of pods per plant

The number of pods from five observational plants in each plot was recorded.

3.1.3.2.5. Number of seeds per pod

The number of seeds in ten randomly selected pods at harvesting stage from each observational plant was recorded.

3.1.3.2.6. 100 seed weight (g)

The weight of 100 uniform sized, well dried seeds from each plot was recorded and expressed in grams.

3.1.3.2.7. Seed yield per plant (g)

The seed yield from observational plants in each plot was taken and expressed in grams.

3.1.3.2.8. Seed yield per unit area (kg ha^{-1})

The seed yield from each plot was recorded and expressed in kg ha^{-1}.

3.1.3.2.9. Crop duration (days)

The number of days from sowing to final harvest was observed and recorded.

3.1.3.2.10. Harvest index

Harvest index was worked out using the given formula as the ratio of seed yield to total biological yield.

$$\text{Harvest index (HI)} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.1.3.2.11. Pest and disease incidence

The pest and disease incidence in the crop during experimental period was observed and recorded.

3.1.3.2.12. Leaf area and dry matter production at vegetative, flowering and harvest stages

Three plants were randomly selected from each plot at vegetative, flowering and harvesting stages and uprooted. Single trifoliate leaf of each plant was traced on a graph paper and area was calculated (L_1). The dry weight of the leaf (W_1) and whole leaves of the single plant (W_2) were taken by oven drying at 72°C for 48h. The total leaf area of each plant was worked out using the formula given below and the average of the three selected plants was calculated and recorded.

$$L_2\,(\text{cm}^2) = \frac{L_1 \times W_2}{W_1}$$

Where, L_2 = Total leaf area of plant

L_1 = Single leaf area

W_1 = Known weight of single leaf

W_2 = Total leaf dry weight of plant

Dry matter production at vegetative, flowering and harvesting stages of three plants from each plot was found out separately after oven drying the plant for 48h at 72°C and the average was calculated.

3.1.3.3. Physiological observations (Recorded at vegetative, flowering and harvest stage)

Leaf area, leaf dry weight and whole plant dry weight recorded in 3.1.3.2.12.were used for calculating the following parameters.

3.1.3.3.1. Specific leaf area (cm^2 g^{-1})

$$\text{Specific leaf area (SLA)} = \frac{\text{Leaf area}}{\text{Leaf dry weight}}$$

3.1.3.3.2. Specific leaf weight ($mgcm^{-2}$)

$$\text{Specific leaf weight (SLW)} = \frac{\text{Leaf dry weight}}{\text{Leaf area}}$$

3.1.3.3.3. Leaf area index

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area}}{\text{Ground area}}$$

3.1.3.3.4. Leaf area ratio (cm^2 g^{-1})

$$\text{Leaf area ratio (LAR)} = \frac{\text{Leaf area / plant}}{\text{Whole plant dry weight}}$$

3.1.3.3.5. Leaf area duration (days)

$$\text{Leaf area duration (LAD)} = \frac{(A_1 + A_2)(t_2 - t_1)}{2}$$

Where, A_1 and A_2 are leaf area indices at times t_1 and t_2

3.1.3.3.6. Crop growth rate (g m^{-2} day^{-1})

$$\text{Crop growth rate (CGR)} = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

Where, W_1 and W_2 are plant dry weights at times t_1 and t_2 and P is spacing in m^2

3.1.3.3.7. Relative growth rate (g g^{-1} day^{-1})

$$\text{Relative growth rate (RGR)} = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are plant dry weights at times t_1 and t_2

3.1.3.4. Crude protein content of seeds (%)

The protein content in seeds was estimated by Kjeldahl method as reported by Mckenzie and Wallace (1954).

3.1.4. Statistical analysis

3.1.4.1. Analysis of Variance

For all the characters studied, Analysis of Variance (Panse and Sukhatme, 1967) was done to evaluate the variation present among the genotypes and to estimate the variance components.

Sources of variation	**d.f**	**Sum of squares**	**Mean squares**	**F ratio**
Treatment	t-1	SSR	MSR	MSR/MSE
Replications	r-1	SST	MST	MST/MSE
Error	(t-1)(r-1)	SSE	MSE	
Total	rt-1			

Where,

r = number of replications

t = number of treatments

SSR = sum of squares for replications

SST = sum of squares for treatments

SSE = sum of squares for error

TSS = total sum of squares

MSR= mean squares for replication

MST = mean squares for treatment

MSE = mean squares for error

Critical Difference, CD= $t_\alpha\sqrt{\frac{2MSE}{r}}$

Where, t_α = students't table value distribution at error d.f

α = level of significance (1% or 5%)

3.1.4.2. Estimation of Genetic Parameters

3.1.4.2.1. Genetic components of variance

The phenotypic and genotypic components of the variance were estimated for each character by equating the expected value of the mean squares (MS) with the components of the respective variance (Jain, 1982).

Genotypic Variance (V_G) = $\frac{\text{MST}-\text{MSE}}{\text{r}}$

Environmental Variance (V_E) = MSE

Phenotypic Variance (V_P) = $V_G + V_E$

3.1.4.2.2. Coefficient of variation

Genotypic, Phenotypic and Environmental Coefficient of Variation were estimated from V_P, V_G and V_E for each trait and expressed in percentage for each trait.

i. Genotypic coefficient of variation, GCV $= \frac{\sqrt{V_G}}{\bar{X}}\times 100$

ii. Phenotypic coefficient of variation, PCV $=\frac{\sqrt{V_P}}{\bar{X}}\times 100$

iii. Environmental coefficient of variation, ECV $=\frac{\sqrt{V_E}}{\bar{X}}\times 100$

Where, $\bar{X}$ = grand mean

Classification of range of variation by Sivasubramanian and Menon (1973):

Low : less than 10%

Moderate : 10 - 20%

High : more than 20%

3.1.4.2.3. Heritability (broad sense)

Heritability in the broad sense is the ratio of genotypic variance to phenotypic variance and can be estimated using the formula given by Burton (1952) and Johnson *et al*. (1955) and is expressed as a percentage.

Heritability, $H^2 = \frac{V_G}{V_P} \times 100$

Classification of range of variability by Johnson *et al*. (1955):

Low : less than 30%

Medium : 30 - 60%

High : more than 60%

3.1.4.2.4. Genetic Advance

Genetic advance is a measure of expected genetic gain or improvement that can be achieved in the succeeding generation by selecting a superior genotype. Genetic advance was estimated using the formula proposed by Johnson *et al*. (1955).

$$GA = k.H^2\sqrt{V_P}$$

Where,

k = standardized selection differential (2.06 at 5% selection intensity)

Genetic advance as per cent of mean = $\frac{GA}{\overline{X}} \times 100$

Classification of range of GA as per cent of mean by Johnson *et al*. (1955):

Low : less than 10%

Moderate : 10 - 20%

High : more than 20%

3.1.4.3. Correlation Analysis

Correlation coefficient a statistically measure the degree and direction of relationship between two or more variables. Genotypic, phenotypic and error correlation coefficients can be calculated using the formula suggested by Falconer (1964):

Genotypic coefficient of correlation = $r_g = \frac{GCOV_{xy}}{\sqrt{GVx.GVy}}$

Phenotypic coefficient of correlation = $r_p = \frac{PCOV_{xy}}{\sqrt{PVx.PVy}}$

Where $GCOV_{xy}$ and $PCOV_{xy}$denotes respectively phenotypic, genotypic and error co-variances between the two characters x and y. GVx and PVx denotes the phenotypic and genotypic variance for the character x and GVy and PVy denotes phenotypic and genotypic variance for the character y respectively.

3.1.4.4. Path Coefficient Analysis

Path coefficient analysis is a standardized partial regression coefficient which partitionsthe correlation coefficient into measures of direct and indirect effects (Dewey and Lu, 1959). It was used to measurethe direct and indirect contribution of the component characters on yield as proposed by Wright (1954).

$r_{1y} = P_{1y}\, r_{11}+P_{2y}r_{12}+P_{3y}r_{13}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots+P_{ny}r_{1n}$

$r_{2y} = P_{2y}\, r_{21}+P_{2y}r_{22}+P_{3y}r_{23}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots+P_{ny}r_{2n}$

$r_{ny} = P_{1y}\, r_{n1}+P_{2y}r_{n2}+P_{3y}r_{n3}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots+P_{ny}r_{nn}$

Where,

1, 2…………..n = independent variables

y = dependent variable

r_{1y}, r_{2y}………r_{ny} = coefficient of correlation between independent variables 1 to n on dependent variable y.

P_{1y}, P_{2y}…….P_{ny} = direct effect of character 1 to n on character y.

In the matrix form

$$\begin{bmatrix} r_{1y} \\ r_{2y} \\ \vdots \\ \vdots \\ \vdots \\ r_{ny} \end{bmatrix} \begin{bmatrix} 1 & r_{12} & r_{13} & \cdots & \cdots & r_{1n} \\ r_{21} & 1 & r_{23} & \cdots & \cdots & r_{2n} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ r_{n1} & r_{n2} & r_{n3} & \cdots & \cdots & 1 \end{bmatrix} \begin{bmatrix} p_{1y} \\ p_{2y} \\ \vdots \\ \vdots \\ \vdots \\ p_{ny} \end{bmatrix}$$

Then B=C^{-1}A, where $C^{-1}=\begin{bmatrix} C_{11} & C_{12} & C_{13} & \cdots & \cdots & C_{1n} \\ C_{21} & C_{22} & C_{23} & \cdots & \cdots & C_{2n} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ C_{n1} & C_{n2} & C_{n3} & \cdots & \cdots & C_{nn} \end{bmatrix}$

Residual effect, PRy = $\sqrt{1-r^2}$

Where, $r^2 = (P1yr1y+ P2yr2y+P3yr3y\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots+Pnyrny)$

P_{iy}= direct effect of x_i on y

r_{iy}= correlation coefficient of x_i on y

i = 1, 2, 3…..n

Classification of direct and indirect effects by Lenka and Mishra (1973):

0.00 – 0.09 : Negligible

0.10 – 0.19 : Low

0.20 – 0.29 : Moderate

0.30 - 1.00 : High

more than 1.00 : Very high

3.1.4.5. Genetic Divergence

The genetic divergence present in the population was estimated using Mahalanobis D^2 statistics. Using D^2 values, different genotypes were grouped into various clusters following Tocher’s method as suggested by Rao (1952).

Results

4. RESULTS

The experiment entitled "Genetic variability studies in grain cowpea (*Vigna unguiculata* (L.) Walp.)"was conducted at Farming Systems Research Station, Sadanandapuram, Kottarakkara. Thirty three grain cowpea (*Vigna unguiculata* (L.) Walp.) genotypes were evaluated in coconut based homestead garden where coconuts are of 30-40 years with an objective to select shade tolerant genotype suited to coconut based homesteads. Observations were recorded on biometric, physiological and quality characters. Statistical analysis of the data was conducted and results are presented in this chapter.

4.1. LIGHT INTENSITY

The average light intensity in the field was 0.719 W/m^2 and shade intensity was 33.49 per cent.

4.2. CHARACTERISATION OF GENOTYPES

Characterisation of the genotypes were carried out for sixteen selected morphological characters and presented in Table 2.

4.3. ANALYSIS OF VARIANCE AND MEAN PERFORMANCE

Observations on thirty three genotypes were recorded and analysis of variance was conducted and presented in Table 3. Significant difference was exhibited by the genotypes for all the characters under study.

The mean values of thirty three genotypes for the different characters studied are presented in Table 4.

Table 2. DUS based characterisation of grain cowpea genotypes

Sl. No.	Genotypes	Stem colour	Terminal leaflet shape	Peduncle colour	Flower colour	Calyx colour	Pod colour	Seed colour	Seed shape
1	Hridya	Green	Globose	Green	White	Green	Green	Straw	Ovoid
2	Sreya	Green stem with purple at internodes	Globose	Purple at base of peduncle	Light violet	Green	Purple	Buff	Kidney
3	Subhra	Green	Sub-globose	Purple	White	Green	Green	White	Ovoid
4	DC 15	Purple	Sub-globose	Purple	White	Green	Green	Brown	Rhomboid
5	KYLMVU-1	Purple streaks on main stem	Sub-globose	Purple	Purple	Green	Green	Cream	Kidney
6	KYLMVU- 3	Purple streaks on main stem	Sub-globose	Green	Purple	Green	Green	Dark brown	Ovoid
7	KYLMVU-4	Green	Sub-globose	Green	Purple	Green	Green	Cream	Kidney
8	KYLMVU- 6	Green stem with purple at nodes	Sub-globose	Green	Purple	Green	Green	Brown	Rhomboid
9	KYLMVU- 7	Green	Hastate	Green	Purple	Green	Green	Brown	Kidney
10	KYLMVU-10	Green	Sub-hastate	Purple	Purple	Red	Green	Black	Kidney
11	TC 55-1	Green	Sub-hastate	Purple	White	Red	Green with purple tip	White	Rhomboid

12	PL-1	Green	Sub-globose	Purple	White	Red	Green	White	Ovoid
13	PL-2	Green	Hastate	Purple at base of peduncle	Purple	Green	Green	Brown	Ovoid
14	PL-3	Green	Globose	Purple at base and tip of peduncle	Purple	Green	Green	Brown	Ovoid
15	PL-4	Purple streaks on main stem	Sub-globose	Purple at base and tip of peduncle	White	Red	Green with purple tip	White	Ovoid
16	PL-5	Green	Sub-globose	Purple at base and tip of peduncle	Deep purple	Green	Green	Brown	Rhomboid
17	CP VBN 1	Green	Sub-globose	Purple	White	Green	Green	Cream	Kidney
18	CP VBN 3	Green	Sub-globose	Green	Purple	Green	Green	Brown	Kidney
19	HC 46	Green	Sub-globose	Green	White	Green	Green	Cream	Kidney
20	CHESCP-03	Green	Globose	Purple at base of peduncle	Purple	Green	Green	Brown	Rhomboid
21	CHESCP-07	Green	Globose	Purple	Purple	Red	Green	Brown	Ovoid
22	CHESCP-09	Green	Sub-globose	Purple at base of peduncle	Purple	Green	Green	Brown	Rhomboid
23	CHESCP-13	Green	Sub-globose	Purple	Purple	Green	Green	Brown	Kidney

24	CHESCP-17	Green	Sub-hastate	Purple	Purple	Green	Green	Brown	Kidney
25	CHESCP-19	Purple streaks on main stem	Sub-hastate	Purple	Purple	Green	Green	Brown	Ovoid
26	CHESCP-21	Green	Globose	Purple at base of peduncle	Purple	Green	Green	Brown	Kidney
27	CHESCP-22	Green	Sub-globose	Green	Purple	Green	Green	Brown	Rhomboid
28	CHESCP-23	Purple streaks on main stem	Sub-globose	Green	White	Red	Green	White	Ovoid
29	CHESCP-29	Green	Globose	Purple streak	White	Green	Green	Cream	Ovoid
30	CHESCP-32	Green	Sub-hastate	Green	Purple	Green	Green	Brown	Kidney
31	IC 300039	Green stem with purple at nodes	Sub-hastate	Purple at base and tip of peduncle	Purple	Red	Green with purple tip	Brown and cream	Rhomboid
32	IC 39853	Purple streaks on main stem	Sub-globose	Purple at base of peduncle	Purple	Green	Green	Brown	Ovoid
33	IC 52110	Green	Sub-hastate	Purple at base of peduncle	White	Red	Green with purple tip	Cream	Ovoid

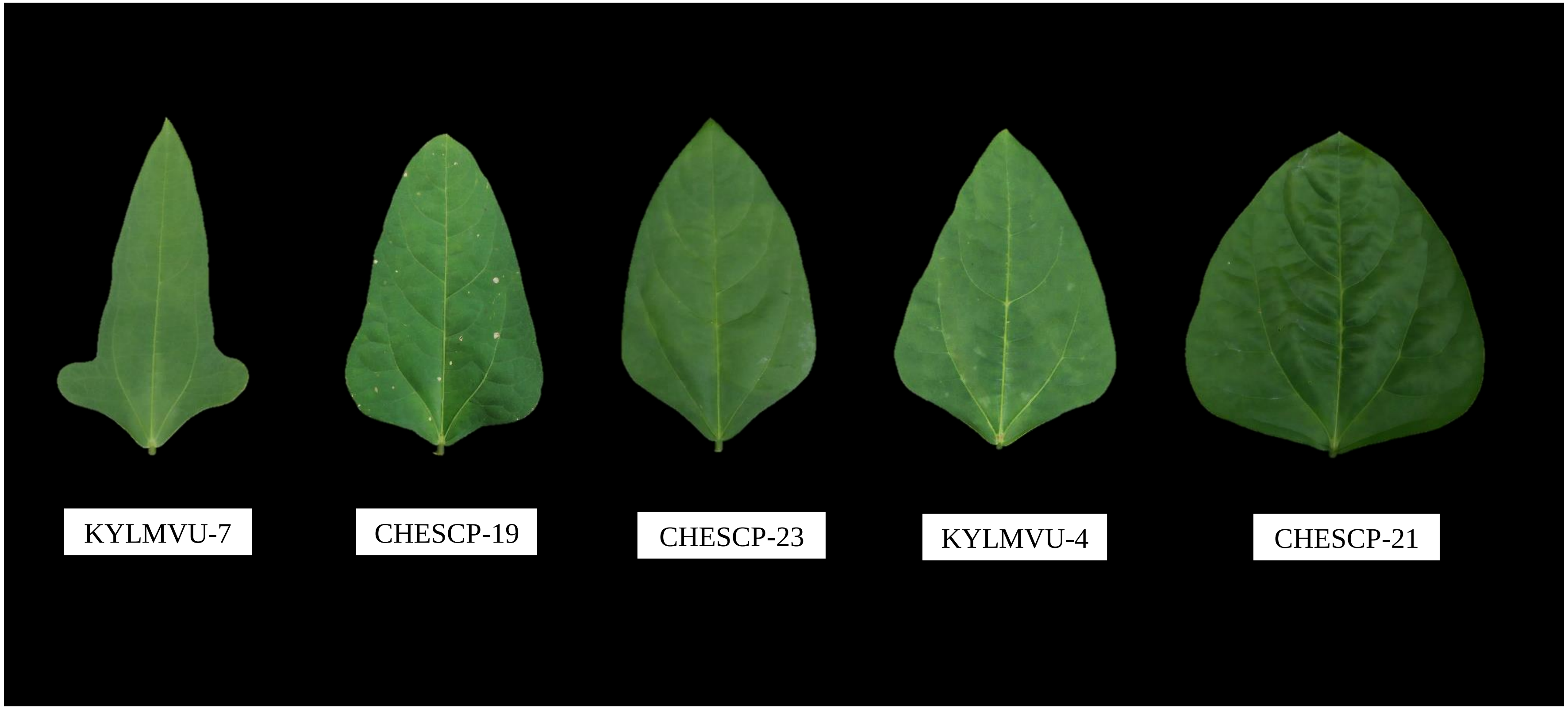


Plate 2. Variation in terminal leaflet shape

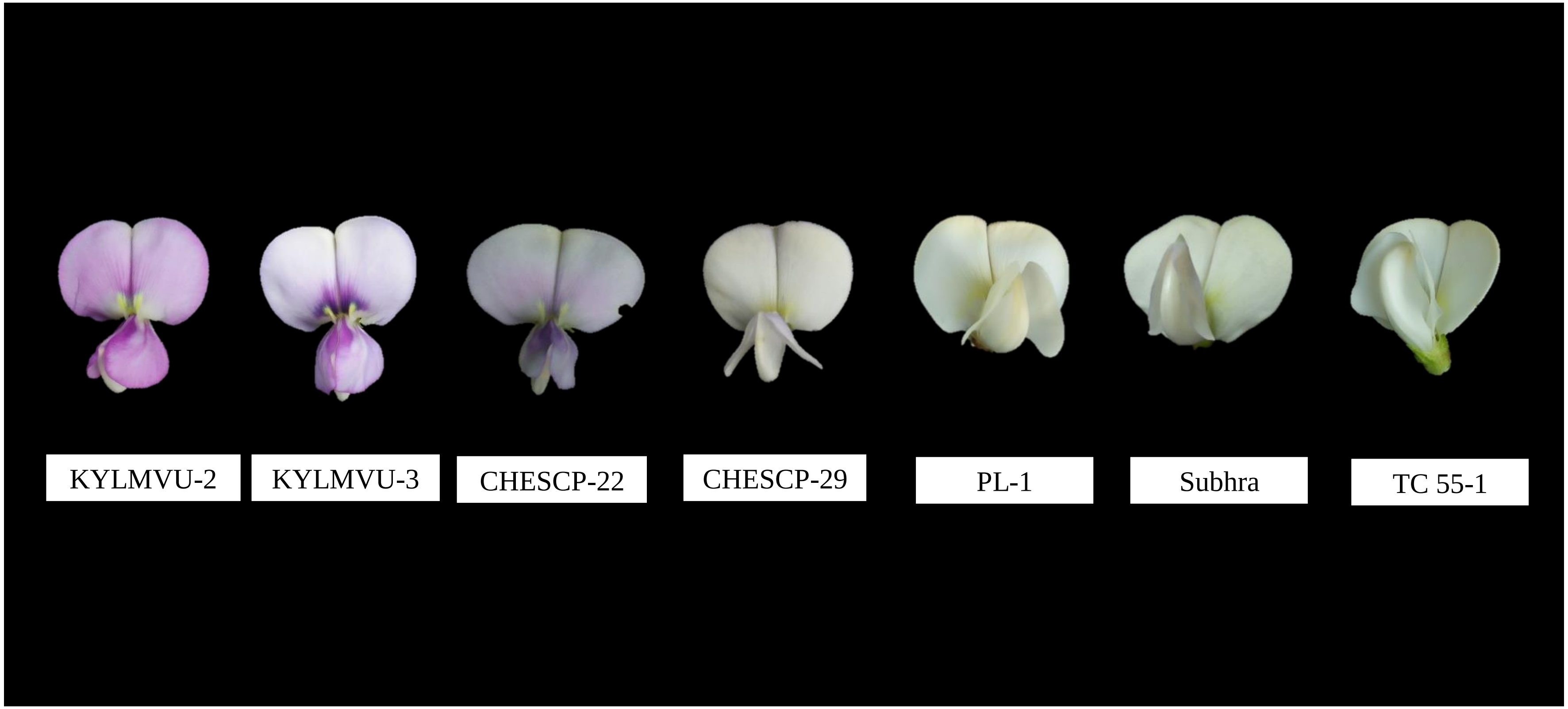


Plate 3. Variation in flower colour

Plate 4. Variation in calyx colour

Plate 5. Variation in immature pods

Plate 6. Variation in seeds of 33 grain cowpea genotypes


PL-2 PL-3 PL-4 PL-5

VBN-1 VBN-3 HC 46 CHESCP-03

CHESCP-07 CHESCP-09 CHESCP-13 CHESCP-17

Plate 6. Variation in seeds of 33 grain cowpea genotypes (Contd)


CHESCP-19


CHESCP-21


CHESCP-22


CHESCP-23


CHESCP-29


CHESCP-32


IC 300039


IC 39853


IC 52110

Plate 6. Variation in seeds of 33 grain cowpea genotypes (Contd)

Table 2. DUS based characterisation of grain cowpea genotypes (Contd)

Sl. No	**Genotypes**	**Plant height**	**No. of primary branches**	**Pod length**	**No. of pods per plant**	**No. of seeds per pod**	**100 seed weight**	**Pod yield per plant (g)**	**Crop duration**
1	Hridya	Short	High	Short	Low	Low	Small	Low	Early
2	Sreya	Short	Medium	Medium	Medium	Medium	Bold	High	Late
3	Subhra	Medium	High	Medium	Medium	Medium	Medium	High	Early
4	DC 15	Short	High	Medium	Low	Medium	Bold	High	Late
5	KYLMVU-1	Short	High	Medium	Low	Medium	Bold	High	Late
6	KYLMVU- 3	Medium	High	Medium	Low	Low	Bold	High	Late
7	KYLMVU-4	Short	High	Medium	Low	Medium	Bold	High	Late
8	KYLMVU- 6	Medium	High	Medium	Low	Medium	Bold	High	Late
9	KYLMVU- 7	Short	High	Medium	Low	Low	Bold	Low	Late
10	KYLMVU-10	Short	Medium	Short	Low	Low	Small	Low	Early
11	TC 55-1	Short	Medium	Medium	Low	Low	Bold	High	Medium
12	PL-1	Short	High	Medium	Low	Low	Bold	High	Medium
13	PL-2	Short	Medium	Medium	Low	Low	Bold	High	Medium
14	PL-3	Medium	High	Medium	Low	Low	Bold	High	Medium
15	PL-4	Short	Medium	Medium	Low	Low	Bold	Low	Medium
16	PL-5	Short	High	Medium	Low	Low	Bold	High	Medium

17	CP VBN 1	Short	Medium	Medium	Low	Medium	Bold	High	Medium
18	CP VBN 3	Short	High	Medium	Low	Medium	Bold	High	Late
19	HC 46	Medium	High	Short	Low	Low	Bold	High	Medium
20	CHESCP-03	Short	High	Medium	Medium	Medium	Bold	High	Late
21	CHESCP-07	Short	Medium	Short	Medium	Low	Medium	High	Late
22	CHESCP-09	Short	High	Medium	Low	Medium	Medium	High	Medium
23	CHESCP-13	Short	High	Long	Low	Low	Bold	High	Late
24	CHESCP-17	Short	High	Medium	Low	Low	Bold	High	Medium
25	CHESCP-19	Short	Medium	Medium	Low	Low	Bold	High	Late
26	CHESCP-21	Medium	High	Medium	Low	Medium	Medium	Medium	Late
27	CHESCP-22	Short	High	Medium	Low	Medium	Bold	High	Late
28	CHESCP-23	Short	Medium	Medium	Low	Medium	Bold	High	Late
29	CHESCP-29	Short	Medium	Medium	Low	Low	Bold	High	Medium
30	CHESCP-32	Short	High	Medium	Low	Medium	Bold	High	Medium
31	IC 300039	Short	High	Short	Low	Medium	Medium	Low	Late
32	IC 39853	Short	Medium	Short	High	Low	Medium	Medium	Medium
33	IC 52110	Short	High	Short	Low	Low	Bold	Medium	Late

Table 3. Analysis of variance of different characters of grain cowpea in the field experiment

Characters	**Mean Sum of Square**		
	Replication	**Genotype**	**Error**
Days to 50% flowering	144.364	84.413**	9.853
No. of primary branches per plant	0.084	9.147**	0.551
Height of plant (cm)	12.281	147.055**	17.548
No. of pods per plant	21.260	64.673**	2.691
No. of seeds per pod	2.416	9.631**	0.605
100 Seed weight (g)	0.067	26.717**	0.253
Seed yield per plant (g)	20.159	111.075**	5.128
Seed yield per unit area (kg/ha)	32350.610	236062**	1207.57
Crop duration (days)	28.313	466.669**	8.063
Harvest Index	0.087	0.076**	0.010
Leaf area at vegetative stage (cm^2)	568.765	111765**	239.478
Leaf area at flowering stage (cm^2)	261.932	344358**	926.909
Leaf area at harvesting stage (cm^2)	318.045	255965**	352.487
Dry matter production at vegetative stage (g)	0.061	1.225**	0.06
Dry matter production at flowering stage (g)	0.314	9.501**	0.196
Dry matter production at harvesting stage (g)	0.267	72.646**	0.682
Specific leaf area at vegetative stage (cm^2 g^{-1})	491.347	72092**	644.619
Specific leaf area at flowering stage (cm^2 g^{-1})	14.011	51951.6**	787.733
Specific leaf area at maturity stage (cm^2 g^{-1})	139.658	18326.6**	20.864

Specific leaf weight at vegetative stage (mgcm^{-2})	0.006	1.158**	0.014
Specific leaf weight at flowering stage (mgcm^{-2})	0.003	9.612**	0.071
Specific leaf weight at maturity stage (mg cm^{-2})	0.019	4.316**	0.008
Leaf Area Index at vegetative stage	0.042	0.553**	0.008
Leaf Area Index at flowering stage	0.048	1.703**	0.094
Leaf Area Index at harvesting stage	0.001	1.263**	0.001
Leaf Area Ratio at vegetative stage(cm^{2} g^{-1})	291.488	22227**	1273.91
Leaf Area Ratio at flowering stage(cm^{2} g^{-1})	14.480	7808.71**	204.451
Leaf Area Ratio at harvesting stage(cm^{2} g^{-1})	10.405	1443.46**	24.449
Leaf area duration at flowering stage (days)	37.233	584.344**	24.811
Leaf area duration at harvesting stage (days)	1.709	1197.47**	1.178
Crop Growth Rate at flowering stage (g m^{-2} day^{-1})	0.224	5.681**	0.406
Crop Growth Rate at harvesting stage (g m^{-2} day^{-1})	0.540	14.116**	0.249
Relative Growth Rate at flowering stage (g g^{-1} day^{-1})	0.0001	0.001**	0.0001
Relative Growth Rate at harvesting stage (g g^{-1} day^{-1})	0.001	0.009**	0.001
Protein Content (%)	0.877	15.347**	0.3

** Significant at 1% level

Table 4. Mean values of 35 characters of thirty three grain cowpea genotypes

Genotypes	DF	PB	HT (cm)	NPP	SPP	100SW (g)	SYP (g)	SYA (kg/ha)	CD (days)	HI	LA(V) (cm^2)	LA(F) (cm^2)	LA(H) (cm^2)
	1	2	3	4	5	6	7	8	9	10	11	12	13
Hridya	37.00	6.5	31.78	10.76	11.1	5.17	5.07	804.60	58.33	0.38	193.04	251.86	153.56
Sreya	49.67	5.67	45.1	14.23	14.06	14.05	26.55	1543.04	99.33	0.74	357.21	830.12	211.56
Subhra	49.67	6.57	53.74	16.50	15.90	8.25	15.34	1020.35	67.33	0.51	416.81	749.97	531.29
DC 15	50.67	6.77	47.5	4.82	14.60	11.43	5.24	744.87	87.67	0.37	370.06	703.23	303.31
KYLMVU-2	51.33	8.67	47.73	6.44	14.27	15.46	13.4	991.93	98.00	0.55	323.19	521.42	265.87
KYLMVU-3	52.33	10.73	59.47	5.64	13.47	11.14	7.16	846.67	85.67	0.47	187.09	895.35	159.3
KYLMVU-4	49.33	8.83	47.97	7.74	14.53	15.71	12.54	925.24	89.67	0.54	527.32	609.2	271.53
KYLMVU-6	51.00	8.83	54.32	12.35	15.5	11.46	18.37	1117.72	97.33	0.48	326.04	760.83	593.26
KYLMVU-7	49.00	9.73	53.34	4.49	13.77	11.83	6.98	797.17	86.67	0.23	367.6	1037.2	577.09
KYLMVU-10	37.67	6.1	33.99	13.68	11.27	5.70	4.22	717.22	57.00	0.34	120.99	193.02	94.43
TC 55-1	47.67	4.73	42.92	3.56	12.27	13.65	3.27	506.38	75.33	0.32	182.6	531.44	108.67
PL-1	47.33	8.47	47.03	13.07	12.08	16.59	4.65	751.57	76.67	0.25	350.42	658.8	275.3
PL-2	46.33	4.47	42.27	4.73	12.27	14.17	3.72	604.34	81.33	0.29	245.71	526.87	283.99
PL-3	42.67	6.67	58.43	8.19	13.46	11.87	11.45	933.52	78.33	0.55	371.39	1159.09	584.63
PL-4	46.33	4.82	41.63	6.29	12.57	18.79	6.22	904.15	78.67	0.36	159.82	377.67	222.7
PL-5	46.33	6.21	49.73	4.16	10.03	14.91	10.73	856.93	81.67	0.59	224.28	362.55	309.49
CP VBN 1	51.67	5.8	41.23	2.33	14.2	12.78	2.07	324.88	79.33	0.23	217.51	676.12	257.55
CP VBN 3	49.33	8.53	45.37	7.21	14.47	10.88	7.16	828.72	93.33	0.68	265.28	284.67	227.99
HC 46	57.67	6.27	54.9	11.34	9.80	10.27	6.38	909.39	81.67	0.40	255.69	535.44	251.29
CHESCP-03	64.00	9.54	47.87	15.25	14.97	10.67	18.99	1354.15	93.33	0.77	117.09	287.17	660.47

Table 4. Contd.

CHESCP-07	46.33	4.78	39.37	17.73	11.74	8.15	11.87	849.15	87.33	0.44	197.18	564.03	407.12
CHESCP-09	58.67	7.17	52.03	5.37	15.79	9.36	5.61	794.27	80.67	0.26	142.83	539.58	218.15
CHESCP-13	49.33	6.99	35.27	4.83	9.17	12.67	5.61	800.71	101.3	0.37	143.1	455.14	283.12
CHESCP-17	49.67	8.41	47.47	13.94	12.99	16.17	17.58	1066.08	78.33	0.76	174.49	328.34	112.4
CHESCP-19	47.67	4.22	42.53	12.8	12.73	11.83	18.95	1241.07	102.7	0.76	684.99	843.9	353.96
CHESCP-21	48.33	7.56	54.5	5.64	14.4	9.70	5.93	904.02	98.67	0.38	513.01	658.05	205.98
CHESCP-22	49.33	6.46	51.87	8.41	15.00	10.59	10.42	913.08	105.7	0.54	320.52	371.6	228.88
CHESCP-23	46.33	4.43	41.7	13.35	14.13	11.79	15.82	1042.73	92.67	0.61	373.23	410.4	191.91
CHESCP-29	43.33	4.7	42.03	11.51	13.14	10.75	10.04	906.51	81.33	0.47	441.2	556.66	383.49
CHESCP-32	49.67	8.98	36.27	10.34	16.07	11.88	15.82	1025.88	79.67	0.63	632.18	882.4	185.33
IC 300039	44.33	6.36	39.13	7.37	15.63	9.53	1.87	245.04	86.67	0.18	193.28	312.34	230.6
IC 39853	46.67	5.51	35.73	20.18	12.3	9.06	13.52	1015.40	82.67	0.50	235.8	570.66	359.76
IC 52110	48.33	6.13	37.43	3.67	12.91	10.29	2.27	207.61	93.33	0.34	325.02	410.12	194.29
Mean	48.45	6.84	45.92	9.21	13.35	11.71	9.84	857.4058	85.38	0.46	301.70	571.37	293.89
S. E.	1.80	0.43	2.42	0.95	0.45	0.29	1.31	20.07	1.64	0.06	10.84	17.58	8.93
C. D. (5%)	5.121	1.21	6.83	2.67	1.27	0.82	3.70	56.69	4.63	0.17	30.63	49.70	25.25

DF	Days to 50% flowering
PB	No. of primary branches per plant
HT	Height of plant (cm)
NPP	No. of pods per plant
SPP	No. of seeds per pod
100SW	100 seed weight (g)
SYP	Seed yield per plant (g)
SYA	Seed yield per unit area (kg/ha)
CD	Crop duration (days)
HI	Harvest index
LA(V)	Leaf area at vegetative stage (cm^2)
LA(F)	Leaf area at flowering stage (cm^2)
LA(H)	Leaf area at harvesting stage (cm^2)

Table 4. Contd.

Genotypes	DM (V) (g)	DM (F) (g)	DM (H) (g)	SLA (V) (cm^2g^{-1})	SLA (F) (cm^2g^{-1})	SLA (H) (cm^2g^{-1})	SLW (V) ($mgcm^{-2}$)	SLW (F) ($mgcm^{-2}$)	SLW (H) ($mgcm^{-2}$)	LAI (V)	LAI (F)	LAI (H)
	14	15	16	17	18	19	20	21	22	23	24	25
Hridya	1.44	2.37	5.66	371.93	333.55	143.02	2.69	3.00	7.00	0.43	0.56	0.34
Sreya	1.53	4.59	25.67	625.23	284.63	226.26	1.60	3.51	4.42	0.79	1.84	0.47
Subhra	1.30	8.51	12.29	706.44	276.54	183.15	1.42	3.62	5.46	0.93	1.67	1.18
DC 15	1.42	5.77	8.13	755.41	424.67	361.43	1.32	2.35	2.77	0.82	1.56	0.67
KYLMVU-2	1.46	5.41	5.91	620.66	433.79	310.51	1.61	2.31	3.22	0.72	1.16	0.59
KYLMVU-3	1.83	3.39	6.03	653.36	316.96	231.48	1.53	3.17	4.32	0.42	1.99	0.35
KYLMVU-4	2.14	2.9	6.97	708.45	430.40	380.55	1.41	2.33	2.63	1.17	1.35	0.60
KYLMVU-6	1.60	6.19	18.02	615.30	372.00	294.35	1.63	2.69	3.40	0.72	1.69	1.32
KYLMVU-7	2.40	4.74	22.59	481.86	384.39	302.69	2.08	2.61	3.30	0.82	2.30	1.28
KYLMVU-10	0.77	2.84	7.8	392.23	326.11	172.50	2.55	3.08	5.80	0.27	0.43	0.21
TC 55-1	1.64	3.61	6.31	818.40	273.51	346.57	1.22	3.66	2.89	0.41	1.18	0.24
PL-1	4.06	4.76	12.26	469.18	320.65	163.46	2.13	3.13	6.12	0.78	1.46	0.61
PL-2	1.86	3.45	8.27	499.59	299.42	270.31	2.00	3.34	3.70	0.55	1.17	0.63
PL-3	1.71	5.73	8.75	698.64	537.36	307.11	1.44	1.87	3.26	0.83	2.58	1.30
PL-4	1.57	7.13	8.27	350.90	368.52	193.21	2.85	2.73	5.18	0.36	0.84	0.49
PL-5	1.62	2.34	4.04	520.13	384.37	248.84	1.92	2.60	4.02	0.50	0.81	0.69
CP VBN 1	1.4	5.35	6.67	452.78	377.07	332.27	2.21	2.65	3.01	0.48	1.50	0.57
CP VBN 3	1.61	3.86	5.13	410.65	310.82	285.47	2.44	3.22	3.50	0.59	0.63	0.51
HC 46	1.83	2.8	8.57	394.28	376.82	383.49	2.56	2.66	2.61	0.57	1.19	0.56
CHESCP-03	1.1	3.11	8.37	263.57	391.78	393.89	3.80	2.55	2.54	0.26	0.64	1.47
CHESCP-07	0.85	6.33	11.68	330.51	342.14	267.43	3.04	2.95	3.74	0.44	1.25	0.90

Table 4. Contd.

CHESCP-09	0.45	5.82	14.07	395.59	115.99	364.64	2.55	8.73	2.74	0.32	1.20	0.48
CHESCP-13	1.33	4.67	8.21	369.04	427.78	206.56	2.71	2.35	4.84	0.32	1.01	0.63
CHESCP-17	1.25	5.79	7.62	384.93	99.56	294.63	2.60	10.04	3.40	0.39	0.73	0.25
CHESCP-19	2.67	5.69	7.52	630.20	364.12	380.33	1.59	2.75	2.63	1.52	1.88	0.79
CHESCP-21	1.59	3.45	8.34	445.89	669.92	375.08	2.26	1.50	2.67	1.14	1.46	0.46
CHESCP-22	1.22	3.97	5.69	739.23	296.86	346.16	1.36	3.80	2.89	0.71	0.83	0.51
CHESCP-23	1.88	3.28	9.43	487.79	679.76	284.30	2.05	1.47	3.52	0.83	0.91	0.43
CHESCP-29	2.16	7.21	7.77	789.78	194.82	215.18	1.27	5.12	4.66	0.98	1.24	0.85
CHESCP-32	2.28	7.35	7.68	737.30	573.72	186.21	1.36	1.74	5.37	1.40	1.96	0.41
IC 300039	1.07	3.46	5.59	693.75	217.98	335.53	1.44	4.61	2.98	0.43	0.69	0.51
IC 39853	1.23	8.93	14.48	452.01	516.63	424.99	2.21	1.94	2.35	0.52	1.27	0.80
IC 52110	1.24	2.77	3.62	596.74	519.32	371.63	1.68	1.93	2.69	0.72	0.91	0.43
Mean	1.62	4.77	9.32	541.26	370.97	290.40	2.02	3.21	3.75	0.67	1.27	0.65
S. E.	0.14	0.25	0.48	14.65	16.20	2.64	5.87	5.58	5.66	0.053	0.18	0.015
C. D. (5%)	0.4	0.72	1.35	41.40	45.80	7.50	0.196	0.435	0.141	0.15	0.50	0.04

DM(V) Dry matter production at vegetative stage (g)

DM(F) Dry matter production at flowering stage (g)

DM(H) Dry matter production at harvesting stage (g)

SLA(V) Specific leaf area at vegetative stage (cm^2g^{-1})

SLA(F) Specific leaf area at flowering stage (cm^2g^{-1})

SLA(H) Specific leaf area at harvesting stage (cm^2g^{-1})

SLW(V) Specific leaf weight at vegetative stage (g cm^{-2})

SLW(F) Specific leaf weight at flowering stage (g cm^{-2})

SLW(H) Specific leaf weight at harvesting stage (g cm^{-2})

LAI(V) Leaf area index at vegetative stage

LAI(F) Leaf area index at flowering stage

LAI(H) Leaf area index at harvesting stage

Table 4. Contd.

Genotypes	LAR (V) (cm^{2}g^{-1})	LAR (F) (cm^{2}g^{-1})	LAR (H) (cm^{2}g^{-1})	LAD (F) (days)	LAD (H) (days)	CGR (F) (gm^{-2}day^{-1})	CGR (H) (gm^{-2}day^{-1})	RGR (F) (gg^{-1}day^{-1})	RGR (H) (gg^{-1}day^{-1})	PC (%)
	26	27	28	29	30	31	32	33	34	35
Hridya	144.63	106.42	27.34	9.74	14.41	1.36	2.38	0.027	0.027	23.26
Sreya	238.99	46.12	32.51	18.98	57.91	2.28	9.37	0.031	0.038	22.42
Subhra	322.12	88.39	43.43	38.99	52.65	5.34	2.27	0.063	0.01	26.57
DC 15	263.41	209.17	37.33	52.49	61.93	3.22	1.42	0.047	0.009	23.59
KYLMVU-2	223.15	184.61	45.09	44.82	52.92	2.93	0.39	0.044	0.003	19.55
KYLMVU-3	508.04	55.33	26.44	36.11	14.24	1.15	1.59	0.021	0.016	21.2
KYLMVU-4	247.46	94.35	87.49	26.64	48.93	0.57	1.81	0.01	0.017	22.8
KYLMVU-6	207.58	95.74	42.31	30.61	55.67	3.4	7.1	0.045	0.029	24.51
KYLMVU-7	154.80	121.84	45.98	31.44	89.68	1.74	7.93	0.023	0.031	23.59
KYLMVU-10	159.12	33.47	24.81	4.68	10.22	2.29	3.45	0.065	0.032	22.29
TC 55-1	324.99	51.19	17.29	23.98	11.98	1.46	1.62	0.026	0.015	22.81
PL-1	162.32	73.78	22.63	33.63	34.76	0.48	3.33	0.005	0.019	21.77
PL-2	132.19	82.48	64.04	17.7	45.05	1.18	2.14	0.021	0.017	20.58
PL-3	218.47	205.88	67.31	51.09	71.69	2.98	1.81	0.04	0.011	18.68
PL-4	104.96	31.2	45.72	12.79	24.68	4.12	0.68	0.051	0.004	24.37
PL-5	140.51	132.34	89.81	17.83	27.63	0.53	1.02	0.012	0.015	20.92
CP VBN 1	155.98	126.94	38.73	29.8	38.38	2.92	0.79	0.045	0.006	19.69
CP VBN 3	165.93	75.74	44.64	18.28	21.08	1.67	0.77	0.029	0.008	23.58
HC 46	150.79	95.96	63.28	16.88	43.71	0.72	2.57	0.014	0.023	24.42
CHESCP-03	107.66	95.63	79.69	13.52	38.96	1.49	3.16	0.034	0.027	25.31
CHESCP-07	119.59	89.41	35.08	22.06	39.92	4.06	3.22	0.068	0.017	17.68

CHESCP-09	95.80	37.47	110.4	8.74	72.26	3.98	4.95	0.085	0.024	18.24
CHESCP-13	109.27	98.51	34.6	19.91	30.35	2.47	2.13	0.042	0.015	24.39
CHESCP-17	142.24	19.75	43.34	9.56	18.12	3.37	1.1	0.051	0.008	22.25
CHESCP-19	257.71	148.48	47.1	50.96	49.25	2.24	1.1	0.025	0.007	22.82
CHESCP-21	134.22	191.68	61.7	28.78	48.14	1.37	2.94	0.026	0.024	26.33
CHESCP-22	270.63	57.7	65.41	18.26	24.69	2.03	1.03	0.04	0.01	24.56
CHESCP-23	219.06	115.01	20.3	26.13	23.2	1.03	3.69	0.018	0.029	25.35
CHESCP-29	257.94	61.21	50.45	33.23	45.82	3.9	0.25	0.041	0.001	23.85
CHESCP-32	280.43	120.1	24.32	50.45	43.87	3.81	0.2	0.039	0.001	25.12
IC 300039	292.77	55.88	41.51	16.87	17.4	1.77	1.28	0.039	0.013	22.22
IC 39853	193.23	154.63	24.95	53.59	71.14	5.7	3.33	0.066	0.013	22.8
IC 52110	263.30	148.95	54.37	24.48	24.82	1.21	0.51	0.028	0.007	20.49
Mean	205.13	100.16	47.25	27.06	40.16	2.39	2.46	0.037	0.016	22.67
S. E.	20.60	8.25	2.85	2.87	0.63	0.21	0.29	0.004	0.002	6.30
C. D. (5%)	58.20	23.3	8.1	8.13	1.8	1.04	0.814	0.011	0.005	0.89

LAR(V) Leaf area ratio at vegetative stage (cm^2g^{-1})

LAR(F) Leaf area ratio at flowering stage (cm^2g^{-1})

LAR(H) Leaf area ratio at harvesting stage (cm^2g^{-1})

LAD(F) Leaf area duration at flowering stage (days)

LAD(H) Leaf area duration at harvesting stage (days)

CGR(F) Crop growth rate at flowering stage ($gm^{-2}day^{-1}$)

CGR(H) Crop growth rate at harvesting stage ($gm^{-2}day^{-1}$)

RGR(F) Relative growth rate at flowering stage ($gg^{-1}day^{-1}$)

RGR(H) Relative growth rate at harvesting stage ($gg^{-1}day^{-1}$)

PC Protein content (%)

S. E. Standard error

C.D. Critical difference

4.3.1. Days to 50% flowering

The genotypes differed significantly for days to 50 per cent flowering and the value ranged from 37.00 to 64.00 days with an average of 48.45 days. Seventeen genotypes recorded less number of days than the average value. The genotype Hridya recorded the lowest value (37 days) and it was statistically on par with KYLMVU-10 and PL-3 i.e., 37.67 days and 38.67 days respectively. Highest value (64.00 days) was recorded by the genotype CHESCP-03. The control plants flowered earlier than shaded plants in all genotypes.

4.3.2. Number of primary branches per plant

Significant difference was observed among the genotypes for number of primary branches per plant. It ranged from 4.22 to 10.73 with an average of 6.83. Thirteen genotypes recorded higher value than the average and maximum number of primary branches per plant was produced by the genotype KYLMVU-3 (10.73) which was statistically on par with KYLMVU-7 (9.73) and CHESCP-03 (9.54). Lowest number of primary branches were produced by the genotype CHESCP-19 which was on par with CHESCP-23 (4.43). The control plants produced more number of primary branches compared to shaded plants.

4.3.3. Height of plant (cm)

Plant height differed significantly among the genotypes and ranged between 31.78 and 59.47 cm with an average of 45.92 cm. Eighteen genotypes recorded a height greater than the average value and KYLMVU-3 recorded maximum height (59.47 cm) and lowest height was noted for the genotype CHESCP-29 (32.03 cm). The treatment plants were taller than the control plants.

4.3.4. Number of pods per plant

Significant variation was observed among the genotypes for number of pods per plant. The range was between 2.33 and 20.18 and the mean value is 9.21. Fourteen genotypes had number of pods per plant higher than the average and highest number of pods per plant was observed in the genotype IC 39853 which was statistically on par with CHESCP-03 (17.73). Minimum number of pods was observed in the genotype CP VBN 1 followed by TC 55-1 (3.56) and IC 52110 (3.67). The control plants produced more number of pods per plant compared to shaded plants.

4.3.5. Number of seeds per pod

Number of seeds per pod differed significantly among the genotypes studied and the values ranged from 9.17 to 16.07. The general mean for the character was 13.35 and eighteen genotypes had the values above general mean. Among the genotypes highest number of seeds per pod was recorded by CHESCP-32 (16.07) which was statistically on par with Subhra (15.90) and CHESCP-09 (15.79). Lowest number of seeds per pod was recorded for CHESCP-13 (9.17). In the control plants more number of seeds per pod was observed compared to shaded plants.

4.3.6. 100 seed weight (g)

Significant variation was observed among genotypes for 100 seed weight. The 100 seed weight ranged from 5.7 to 18.79g with an average of 11.71g. Sixteen genotypes had 100 seed weight higher than the mean 11.71g. The genotype PL-4 (18.79g) recorded highest 100 seed weight and the lowest value was for Hridya (5.70g).

4.3.7. Seed yield per plant (g)

The genotypes differed significantly for seed yield and the yield ranged from 1.87 to 26.55g per plant with an average of 9.84g. Sixteen genotypes had seed yield greater than the mean value. Highest yield was recorded for the genotype Sreya (26.55g) which was significantly higher than all other genotypes. Lowest seed yield was recorded for IC 300039 (1.87g).

In this study, yield was reduced in all the genotypes under 33.49 per cent shade intensity but the rate of reduction varied among the genotypes. The per cent of yield reduction in thirty three grain cowpea genotypes were computed and presented in Table 5.

Table 5. Per cent of yield reduction in thirty three grain cowpea genotypes

	Genotypes	Seed yield per plant (g) (Control)	Seed yield per plant (g) (Shade)	Yield reduction (%)
1	Hridya	6.8	5.07	25.4
2	Sreya	37.8	26.55	29.8
3	Subhra	28.4	15.34	46.0
4	DC 15	28	5.24	81.3
5	KYLMVU-1	34.4	13.4	61.0
6	KYLMVU- 3	32.3	7.16	77.8
7	KYLMVU-4	37	12.54	66.1
8	KYLMVU- 6	29.4	18.37	37.5
9	KYLMVU- 7	9	6.98	22.4
10	KYLMVU-10	5.6	4.22	24.6
11	TC 55-1	28.2	3.27	88.4
12	PL-1	7.8	4.65	40.4
13	PL-2	12.4	3.72	70.0
14	PL-3	39.6	11.45	71.1
15	PL-4	8.3	6.22	25.1
16	PL-5	17.2	10.73	37.6
17	CP VBN 1	19	2.07	89.1
18	CP VBN 3	29.2	7.16	75.5
19	HC 46	13.6	6.38	53.1
20	CHESCP-03	21.84	18.99	14.8
21	CHESCP-07	23.2	11.87	48.8
22	CHESCP-09	15.8	5.61	64.5
23	CHESCP-13	18.4	5.61	69.5
24	CHESCP-17	20.1	17.58	12.5
25	CHESCP-19	29	18.95	34.7
26	CHESCP-21	13.8	5.93	57.0
27	CHESCP-22	34.2	10.42	69.5
28	CHESCP-23	19.2	15.82	17.6
29	CHESCP-29	18.4	10.04	45.4
30	CHESCP-32	17.4	15.82	9.1
31	IC 300039	4.67	1.87	60.0
32	IC 39853	20.2	13.52	33.1
33	IC 52110	10.6	2.27	78.6

4.3.8. Seed yield per unit area (kg ha^{-1})

Seed yield per unit area exhibited a range between 207.61 and 1543.04 kg ha^{-1}. Highest seed yield was recorded for the genotype Sreya (1543.04 kg ha^{-1}) and lowest for IC 52110 (207.61 kg ha^{-1}). By comparing the yield of early, medium and late duration genotypes separately, it was noted that Subhra recorded the highest yield (1020.35 kg ha^{-1}) among the early types, CHESCP-17 among the medium types (1066.08 kg ha^{-1}) and Sreya among the late types (1543.04 kg ha^{-1}).

4.3.9. Crop duration (days)

Significant difference was observed among genotypes for crop duration. Based on duration, the genotypes can be classified as early (up to70 days), medium (70-80 days) and late (more than 80days). The genotypes selected for this study comprises of three early, thirteen medium and seventeen late types. The crop duration ranged from 57.00 to 105.67 days with an average of 85.38 days. Seventeen genotypes had crop duration greater than the mean value. Longest duration was observed for the genotype CHESCP-22 (105.67 days) which was statistically on par with CHESCP-19 (102.67 days) and CHESCP-13 (101.33 days). Genotype KYLMVU-10 (57 days) had the shortest duration. The plants raised in the open area completed the life cycle earlier than those in the shaded areas.

4.3.10. Harvest index

Harvest index exhibited significant variation among the genotypes and the value ranged from 0.18 to 0.77 with a mean of 0.46. Seventeen genotypes had HI values greater than the mean value. Maximum harvest index was observed for the genotype CHESCP-03 which was on par with CHESCP-19 (0.76) and CHESCP-17 (0.757). Minimum value for harvest index was observed for the genotype IC 300039. For most of the genotypes, harvest index was higher for control plants compared to shaded ones.

4.3.11. Leaf area (cm^2)

Considerable variation was observed among the genotypes for leaf area at vegetative, flowering and harvest stages.

The values for leaf area at vegetative stage ranged between 117.09 and 684.99cm^2.Thirteen genotypes had leaf area above the general mean of 301.70 cm^2. Highest leaf area was observed for CHESCP-19 (684.99cm^2) followed by CHESCP-32 (632.18 cm^2) and lowest leaf area was observed for CHESCP-03 (117.09cm^2).

At flowering stage, leaf area values ranged from 193.02 to 1159.09 cm^2. Twelve genotypes had leaf area greater than the mean for this character (571.37 cm^2).The genotype PL-3 (1159.09 cm^2) had the maximum leaf area followed by KYLMVU-7 (1037.2 cm^2). Genotype KYLMVU- 10 had the lowest leaf area (193.02cm^2).

Leaf area at harvest stage ranged between 94.43 and 660.47 cm^{2}with a mean of 293.89 cm^{2}and eleven genotypes recorded leaf area values greater than the mean. Genotype CHESCP-03 had the maximum leaf area (660.47 cm^2) and the genotype KYLMVU-10 had the lowest leaf area (94.43 cm^2).

Leaf area of control plants were greater than the shaded ones for most of the genotypes.

4.3.12. Dry matter production (g)

The genotypes varied significantly for dry matter production at vegetative, flowering and harvest stages.

Dry matter production per plant at vegetative stage range between 0.45 and 4.06g. Twelve genotypes had dry matter production at vegetative stage greater than the mean value of 1.62 g. Highest dry matter production was recorded for the genotype PL-1 followed by CHESCP-19 (2.67g). Lowest dry matter production was recorded for the genotype CHESCP-09.

Dry matter production at flowering stage ranged from 2.34 to 8.93 g with a mean value of 4.77 g and fourteen genotypes had dry matter production values above the general mean. The genotype IC 39853 had the highest value for dry matter production at flowering stage (8.93 g) which was statistically on par with Subhra (8.51 g) and PL-5 showed the lowest value (2.34 g).

At harvest stage, the dry matter production varied between 3.62 and 25.67 g with a mean of 9.32 g and dry matter production of nine genotypes were greater than the mean value. Maximum value for dry matter production was noted for the genotype Sreya (25.67 g) and lowest for IC 52110 (3.62 g).

For all the genotypes, the dry matter production was greater in control plants compared to shaded plants.

4.3.13. Specific leaf area (SLA) (cm^2 g^{-1})

All the genotypes differed significantly for specific leaf area (SLA) at vegetative, flowering and harvest stages.

The values at vegetative stage varied from 263.57 cm^2 g^{-1} in CHESCP-03 to 818.4 cm^2 g^{-1} in TC 55-1. SLA of genotype CHESCP-29 (789.78 cm^2 g^{-1}) was on par with TC 55-1 and fifteen genotypes had higher values greater than the mean (541.26 cm^2 g^{-1}).

At flowering stage, SLA was highest for the genotype CHESCP-23 (679.76cm^2 g^{-1}) and lowest for CHESCP-17 (99.56 cm^2 g^{-1}). The genotype CHESCP-21 (669.92cm^2 g^{-1}) was on par with CHESCP-23 and CHESCP-09 (115.99cm^2 g^{-1}) was on par with CHESCP-17. The specific leaf area values of fifteen genotypes were greater than the mean (370.97 cm^2 g^{-1}).

Among the thirty three genotypes, IC 39853 recorded the highest specific leaf area at harvest stage (424.99 cm^2 g^{-1}) followed by CHESCP-03 (393.89 cm^2 g^{-1}) and Hridya recorded the lowest value (143.02 cm^2 g^{-1}). The mean value for the character was 290.40 cm^2 g^{-1} and eighteen genotypes had specific leaf area above the mean value.

In control, lower specific leaf area was observed for most of the genotypes compared to treatment plants.

4.3.14. Specific leaf weight (SLW) (mg cm^{-2})

Specific leaf weight **(**SLW) at vegetative, flowering and harvest stages showed significant differences among the genotypes.

At vegetative stage genotype CHESCP-03 recorded highest SLW (3.80 mg cm^{-2}) followed by CHESCP-07 (3.04 mg cm^{-2}) and TC 55-1 recorded the lowest value (1.22 mg cm^{-2}).

Mean value for SLW at flowering stage was maximum (10.36 mg cm^{-2}) for CHESCP-17 followed by CHESCP-09 (0.00892 g cm^{-2}) and minimum (1.47 mg cm^{-2}) for CHESCP-23.

Genotype Hridya recorded highest SLW at harvest stage (7.0 mg cm^{-2}) followed by PL-1 (6.12 mg cm^{-2}) and lowest SLW (2.35 mg cm^{-2}) was recorded for the genotype IC 39853.

In case of control, the specific leaf weight was greater compared to shaded plants for most of the genotypes.

4.3.15. Leaf area index (LAI)

Significant difference was recorded by the genotypes for LAI at vegetative, flowering and harvest stages.

In the case of LAI at vegetative stage the mean values varied from 0.26 in CHESCP-03 to 1.52 in CHESCP-19. LAI of CHESCP-03 was on par with KYLMVU-10 (0.27). Thirteen genotypes had LAI values greater than the mean value (0.67).

LAI at flowering stages ranged from 0.43 for KYLMVU-10 to 2.58 forPL-3. PL-3 was found to be statistically on par with the genotype KYLMVU-7 (2.30). LAI values were higher than the mean value (1.27) for twelve genotypes.

Genotype CHESCP-03 recorded maximum value (1.47) for LAI at harvest stage followed by KYLMVU-6 (1.32) and KYLMVU-10 recorded the minimum value (0.21). The general mean for the character was 0.65 and was lower than the mean values of eleven genotypes.

The LAI of control plants were found to be greater than that of shaded plants.

4.3.16. Leaf area ratio (LAR) ($cm^2 g^{-1}$)

All the genotypes exhibited considerable variation for LAR at vegetative, flowering and harvest stages.

LAR at vegetative stages varied between 95.8 cm^2g^{-1} and 508.04 cm^2g^{-1} respectively for CHESCP-09 and KYLMVU-3. CHESCP-09 was statistically on par with the genotype PL-4 (104.96 cm^2 g^{-1}). The mean for the character was 205.13 cm^2 g^{-1} and sixteen genotypes had values higher than the general mean of the character.

LAR at flowering stage was highest (209.17 cm^2 g^{-1}) for the genotype DC15 which was statistically on par with PL-3 (205.88 cm^2 g^{-1}) and CHESCP-21 (191.68 cm^2 g^{-1}). Lowest LAR was observed for the genotype CHESCP-17. Thirteen genotypes had LAR values higher than the general mean of the character (100.16 cm^2 g^{-1}).

In the case of LAR at harvest stage, the value was highest (110.4 cm^2g^{-1}) for the genotype CHESCP-09 and lowest for TC 55-1 (17.29 cm^2 g^{-1}).

The control plants exhibited lower LAR compared to treatment plants.

4.3.17. Leaf area duration (LAD) (days)

The genotypes significantly differed for LAD at flowering and harvest stages.

The mean values for LAD at flowering was highest for IC 39853 (53.59 days) and lowest for KYLMVU-10 (4.68 days). Genotypes DC 15 (52.49 days) and PL-3 (51.09 days) were statistically on par with IC 39853. The general mean for the character was 27.06 days and fourteen genotypes recorded mean values higher than the general mean.

The mean values for LAD at harvest varied from 10.22 days in KYLMVU-10 to 89.68 days in KYLMVU- 7. The genotype TC 55-1 (11.98 days) was statistically on par with KYLMVU-10. Sixteen genotypes recorded mean values higher than the general mean of the character (40.16 days).

The LAR was greater in case of control plants compared to shaded ones.

4.3.18. Crop growth rate (CGR) (g m^{-2} day^{-1})

Significant difference was observed among the genotypes for CGR at flowering and harvest stages.

The highest mean value for CGR at flowering was recorded by IC 39853 (5.70g m^{-2} day^{-1}) which was statistically on par with Subhra (5.34 g m^{-2} day^{-1}) and the lowest mean was recorded for PL-1 (0.47 g m^{-2} day^{-1}) which was on par with the genotypes PL-5 (0.53 g m^{-2} day^{-1}) and KYLMVU-4 (0.57 g m^{-2} day^{-1}). The mean values of fourteen genotype were greater than the general mean for the character (2.39 g m^{-2} day^{-1}).

Mean values for CGR at harvest ranged from 0.20 in CHESCP-32 to 9.37 gm^{-2} day^{-1} in Sreya. CHESCP-32 was statistically on par with the genotypes CHESCP-29 (0.25 g m^{-2} day^{-1}) and DC 15 (0.39 g m^{-2} day^{-1}). The general mean for the character was 2.46 g m^{-2} day^{-1} and the mean values of twelve genotypes were greater than the general mean.

The control plants exhibited greater crop growth rate for most of the genotypes than shaded plants.

4.3.19. Relative growth rate (RGR) (g g^{-1} day^{-1})

The genotypes differed significantly for RGR at flowering and harvest stages.

The RGR at flowering varied between 0.005 in PL-1 and 0.085g g^{-1} day^{-1} in CHESCP-09. The mean values of fifteen genotypes were greater than the general mean for the character (0.037 g g^{-1} day^{-1}).

The highest value for RGR at harvest was exhibited by the genotype Sreya (0.038 g g^{-1} day^{-1}) and the lowest RGR (0.001 g g^{-1} day^{-1}) was exhibited by the genotypes CHESCP-29 and CHESCP-32. The mean values of fourteen genotypes were higher than the mean for the character (0.016g g^{-1} day^{-1}).

4.3.20. Total protein content of seeds (%)

The genotypes differed significantly for protein content. Among the genotypes, Subhra (26.57%) recorded highest protein content which was on par with CHESCP-21 (26.33%) and CHESCP-07 (17.68%) recorded the lowest protein content. Fifteen genotypes had protein content above general mean (22.67%).

4.3.21. Pest and disease incidence

No pest attack was observed in the crop. Mild incidence of collar rot caused by *Rhizoctonia solani* was observed in all the genotypes at seedling stage which was managed by soil drenching with Saaf (Carbendazim 12% + Mancozeb 63% WP) @ 2g/L.

Sreya (T2)

Plate 7. Superior genotype in coconut based homestead

Subhra (T3)

CHESCP-21 (T26)

Plate 8. Seeds of genotypes with high protein content

4.4. GENETIC VARIABILITY PARAMETERS

Genetic parameters *viz.*, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2) and genetic advance for 12 characters were estimated and recorded in table 6.

The PCV and GCV values for the characters ranged from 7.06 to 63.61 and 6.85 to 59.41 respectively. High PCV and GCV was recorded for number of primary branches per plant, number of pods per plant, 100 seed weight, harvest index, leaf area duration and crop growth rate. Moderate PCV and GCV was recorded for days to 50% flowering, height of plant, number of seeds per pod and crop duration whereas it was low for protein content. High heritability was recorded for the twelve characters considered. 100 seed weight had highest heritability (97.22%) and harvest index had lowest (67.5%). Genetic advance as per cent of mean was high for all the characters except days to 50% flowering (17.93%) and protein content (13.72%) which showed moderate genetic gain.

PCV, GCV and GA were highest for seed yield per plant and lowest for protein content. High heritability coupled with high GA was observed for number of primary branches per plant, height of plant, number of pods per plant, number of seeds per pod, 100 seed weight, crop duration, harvest index, LAD at flowering, CGR at flowering and seed yield per plant.

Table 6. Genetic parameters of yield and yield contributing characters of grain cowpea

Character	Mean	PCV	GCV	H^2 (%)	GAM (%)
Days to 50% flowering	48.45	12.16	10.29	71.61	17.93
No. of primary branches / plant	6.84	27.04	24.76	83.86	46.71
Height of plant (cm)	45.92	16.67	14.31	71.1	24.85
No. of pods per plant	9.21	52.48	49.36	88.48	95.64
No. of seeds per pod	13.35	14.24	12.99	83.26	24.42
100 seed weight (g)	11.71	25.72	25.36	97.22	51.50
Crop duration (days)	85.17	14.89	14.52	94.9	29.15
Harvest index	0.46	39.40	32.37	67.50	54.78
LAD (flowering) (days)	27.06	53.72	50.47	88.26	93.67
CGR (flowering) (g m^{-2} day^{-1})	2.39	58.85	56.85	93.34	91.46
Protein content (%)	22.67	7.06	6.85	94.35	13.72
Seed yield per plant (g)	9.84	63.61	59.41	87.22	96.18

Fig 1. PCV and GCV of 12 characters in grain cowpea

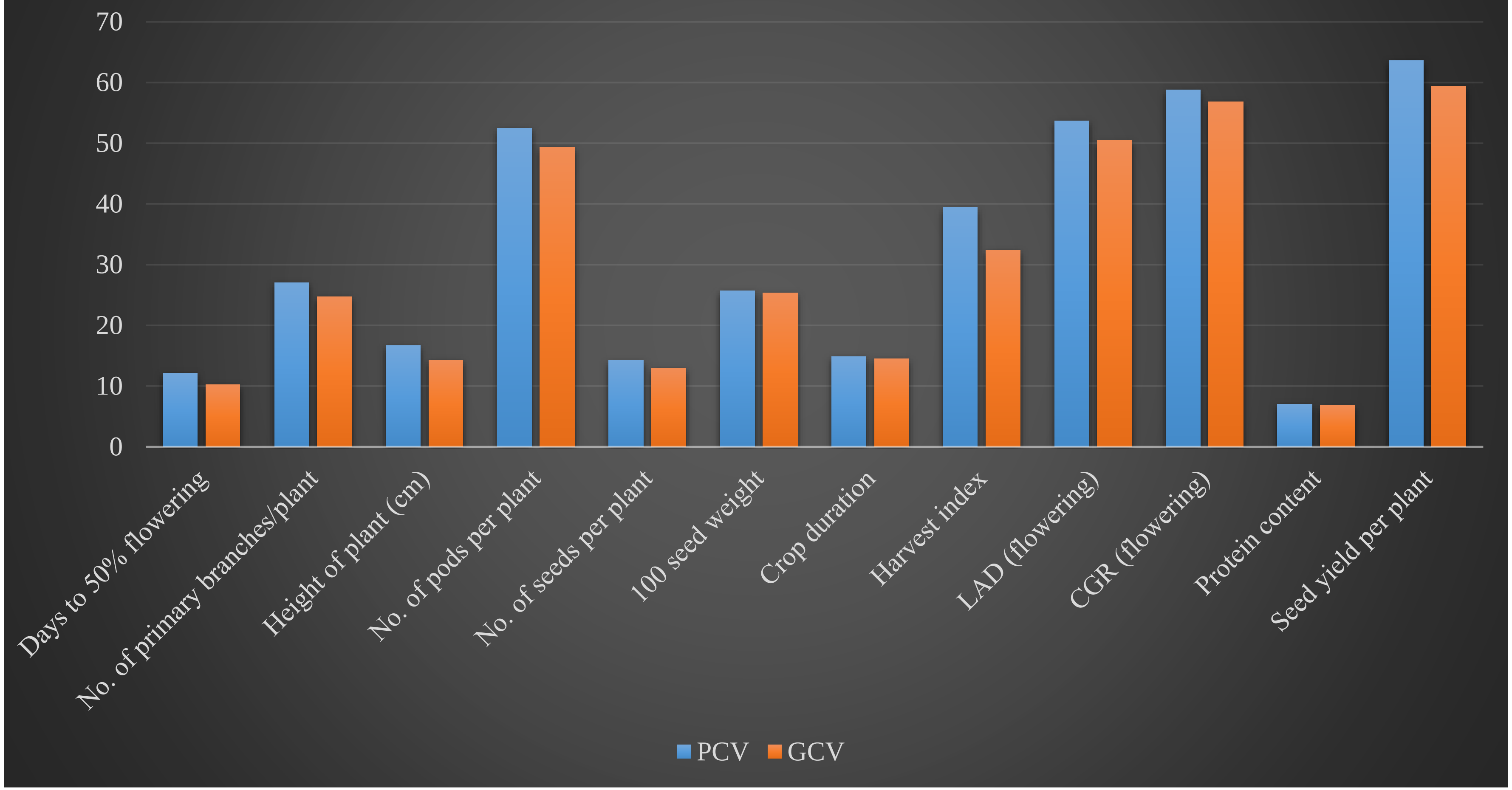
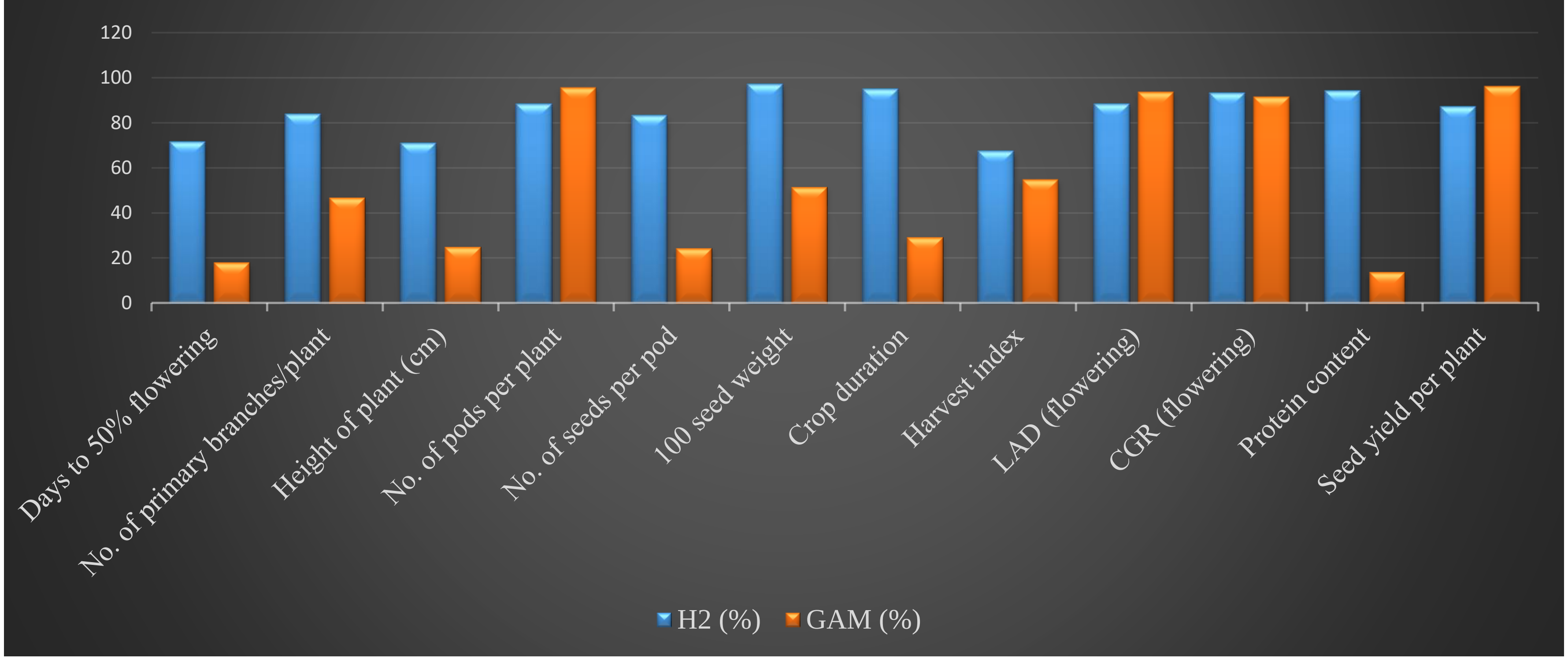


Fig 2. Heritability and Genetic advance of 12 characters in grain cowpea



4.5. CORRELATION STUDIES

The association between twelve characters in all possible combinations was worked out. The genotypic and phenotypic correlation coefficients for the yield and yield contributing characters are presented in Table 7 and 8 respectively.

4.5.1. Seed yield per plant (g)

Highly significant positive genotypic correlation was recorded between harvest index and seed yield per plant (0.760) followed by number of pods per plant (0.629), number of seeds per pod (0.290), CGR at flowering (0.287), days to 50% flowering (0.252), LAD at flowering (0.242), protein content (0.237) and crop duration (0.219).

4.5.2. Days to 50% flowering

Days to 50% flowering showed significant positive genotypic correlation with number of primary branches per plant (0.456) followed by number of seeds per pod (0.377), crop duration (0.313), height of the plant (0.281), seed yield per plant (0.252) and harvest index (0.226).

4.5.3. Number of primary branches per plant

Number of primary branches per plant had significant positive genotypic correlation with height of the plant (0.562) followed by days to 50% flowering (0.456) and number of seeds per pod (0.355).

4.5.4. Height of plant (cm)

Significant positive genotypic correlation was noted between height of the plant and number of primary branches per plant (0.562) followed by days to 50% flowering (0.281) and number of seeds per pod (0.237) whereas this trait exhibited negative correlation with CGR at flowering (-0.264).

4.5.5. Number of pods per plant

Number of pods per plant showed highly significant positive genotypic correlation with seed yield per plant (0.629) followed by harvest index (0.434), CGR at flowering (0.419) and protein content (0.215) whereas it showed negative correlation with crop duration (-0.321) followed by 100 seed weight (-0.310).

4.5.6. Number of seeds per pod

It was observed that number of seeds per pod had significant positive genotypic correlation with days to 50% flowering (0.377) followed by number of primary branches per plant (0.355), seed yield per plant (0.290), CGR at flowering (0.283), LAD at flowering (0.271) and harvest index (0.237).

4.5.7. 100 seed weight (g)

100 seed weight possessed positive significant correlation with crop duration (0.348) and negative correlation with number of pods per plant (-0.310).

4.5.8. Crop duration

Crop duration exhibited significant positive correlation with 100 seed weight (0.348) followed by days to 50% flowering (0.313), LAD at flowering (0.261) and seed yield per plant (0.219). The trait had negative correlation with number of pods per plant (-0.321).

4.5.9. Harvest index

Very high positive correlation was observed between harvest index and seed yield per plant (0.760) followed by number of pods per plant (0.434), protein content (0.280), days to 50% flowering (0.226) and LAD at flowering (0.204).

4.5.10. Leaf area duration at flowering (days)

LAD at flowering exhibited significant positive correlation with CGR at flowering (0.353) followed by number of seeds per pod (0.271), crop duration (0.261) and seed yield per plant (0.242).

4.5.11. Crop growth rate at flowering (g m^{-2} day^{-1})

It was observed that CGR at flowering possessed significant positive correlation with number of pods per plant (0.419) followed by LAD at flowering (0.353), seed yield per plant (0.287), number of seeds per pod (0.283) and had negative correlation with height of the plant (-0.264).

4.5.12. Protein content (%)

Significant positive correlation existed between protein content and harvest index (0.280) followed by seed yield per plant (0.237) and number of pods per plant (0.215).

4.6. PATH ANALYSIS

The correlation of different characters on yield was partitioned and the direct and indirect effects of traits on seed yield was estimated. Seed yield per plant was taken as the dependent character and the component characters considered were days to 50% flowering, number of pods per plant, number of seeds per plant, crop duration, harvest index, LAD at flowering and CGR at flowering. The direct and indirect effects are presented in Table 9.

4.6.1. Direct effects

Number of pods per plant showed highest direct effect on seed yield per plant (0.508) followed by harvest index (0.478). Moderate and low direct effects were recorded by crop duration (0.269) and number of seeds per pod (0.169) respectively whereas positive but negligible direct effect was recorded by CGR at flowering (0.023) and days to 50% flowering (0.014). The direct effects of LAD at flowering and protein content were negative and negligible.

Table 7. Genotypic correlation of yield and yield contributing characters of grain cowpea

	DF	**PB**	**HT**	**NPP**	**SPP**	**100SW**	**CD**	**HI**	**LAD(F)**	**CGR(F)**	**PC**	**SYP**
DF	1											
PB	0.456^{**}	1										
HT	0.281^{**}	0.562^{**}	1									
NPP	-0.023	-0.089	-0.131	1								
SPP	0.377^{**}	0.355^{**}	0.237^{*}	0.012	1							
100SW	0.187	0.087	-0.019	-0.310^{**}	-0.041	1						
CD	0.313^{**}	-0.018	-0.031	-0.321^{**}	0.179	0.348^{**}	1					
HI	0.226^{*}	0.180	0.123	0.434^{**}	0.134	0.129	0.178	1				
LAD(F)	-0.050	0.093	-0.017	0.045	0.271^{**}	0.071	0.261^{**}	0.204^{*}	1			
CGR(F)	-0.032	-0.187	-0.264^{**}	0.419^{**}	0.283^{**}	-0.161	-0.155	0.094	0.353^{**}	1		
PC	0.126	0.120	0.012	0.215^{*}	0.174	-0.084	0.063	0.280^{**}	0.023	-0.023	1	
SYP	0.252^{*}	0.115	0.108	0.629^{**}	0.290^{**}	0.151	0.219^{*}	0.760^{**}	0.242^{*}	0.287^{**}	0.237^{*}	1

* significant at 5%
** significant at 1%

DF	Days to 50% flowering	SPP	No. of seeds per pod	LAD(F)	Leaf area duration at flowering
PB	No. of primary branches/ plant	100SW	100 seed weight	CGR(F)	Crop growth rate at flowering
HT	Height of plant	CD	Crop duration	PC	Protein content
PPP	No. of pods per plant	HI	Harvest index	SYP	Seed yield per plant

Table 8. Phenotypic correlation of yield and yield contributing characters of grain cowpea

	DF	**PB**	**HT**	**NPP**	**SPP**	**100SW**	**CD**	**HI**	**LAD(F)**	**CGR(F)**	**PC**	**SYP**
DF	1											
PB	0.325^{**}	1										
HT	0.232^{*}	0.407^{**}	1									
NPP	-0.060	-0.047	-0.109	1								
SPP	0.278^{**}	0.319^{**}	0.136	0.023	1							
100SW	0.179	0.089	-0.013	-0.295^{**}	-0.038	1						
CD	0.255^{*}	-0.013	-0.032	-0.287^{**}	0.158	0.342^{**}	1					
HI	0.147	0.146	-0.015	0.311^{**}	0.149	0.090	0.118	1				
LAD(F)	-0.029	0.061	0.009	0.040	0.242^{*}	0.069	0.233^{*}	0.163	1			
CGR(F)	-0.011	-0.149	-0.214^{*}	0.383^{**}	0.268^{**}	-0.161	-0.126	0.068	0.305^{**}	1		
PC	0.099	0.105	0.003	0.197^{*}	0.142	-0.075	0.066	0.195	0.019	-0.010	1	
SYP	0.192	0.083	0.027	0.531^{**}	0.280^{**}	0.129	0.187	0.765^{**}	0.220^{*}	0.254^{*}	0.202^{*}	1

* significant at 5%
** significant at 1%

DF	Days to 50% flowering	SPP	No. of seeds per pod	LAD(F)	Leaf area duration at flowering
PB	No. of primary branches/ plant	100SW	100 seed weight	CGR(F)	Crop growth rate at flowering
HT	Height of plant	CD	Crop duration	PC	Protein content
PPP	No. of pods per plant	HI	Harvest index	SYP	Seed yield per plant

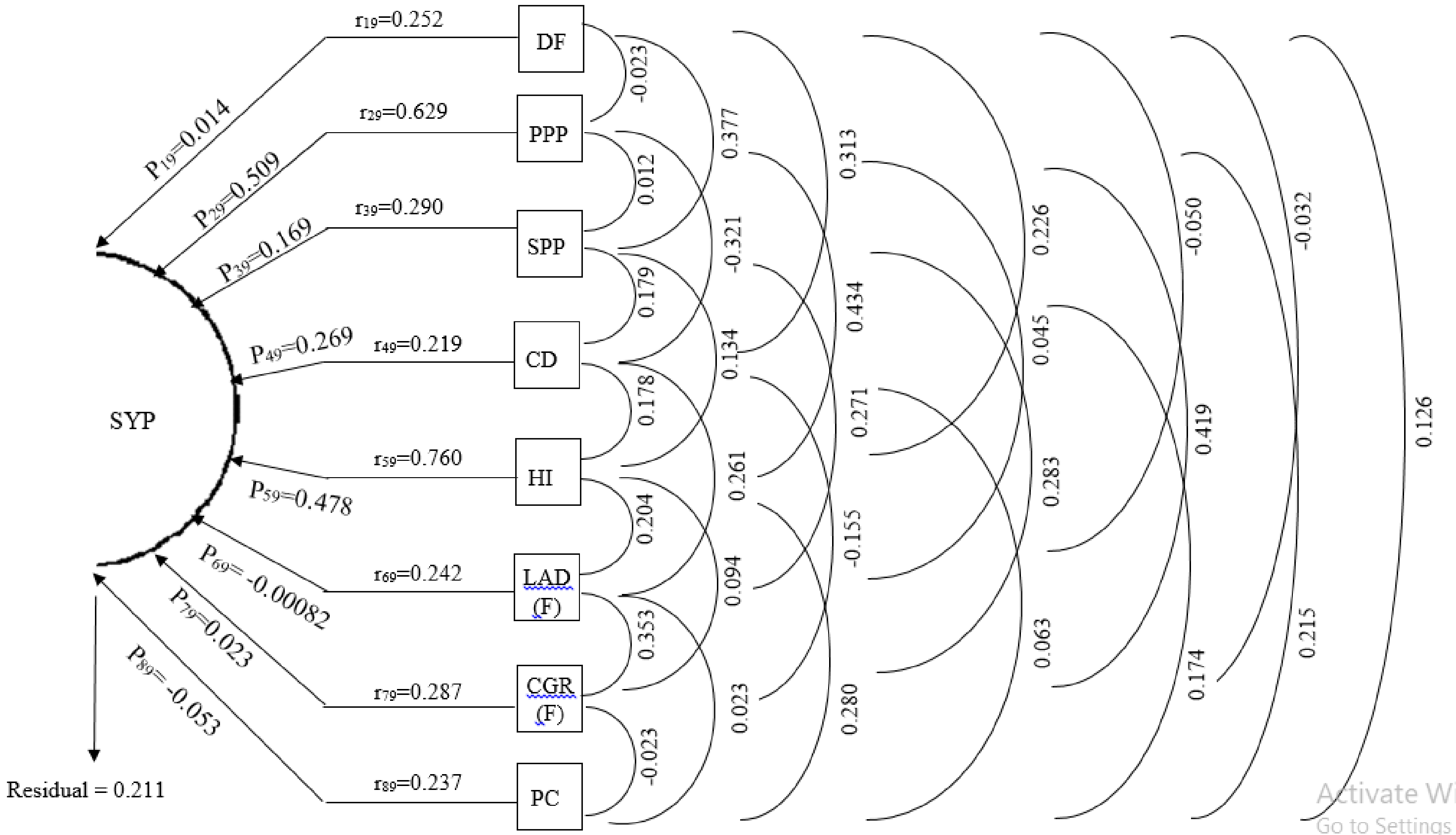
Table 9. Direct and indirect effects of different characters on yield

	DF	**NPP**	**SPP**	**CD**	**HI**	**LAD(F)**	**CGR(F)**	**PC**	**Genotypic Correlation**
DF	**0.014**	-0.012	0.064	0.084	0.108	0.00004	-0.001	-0.007	0.252
NPP	-0.0003	**0.509**	0.002	-0.086	0.207	-0.00004	0.009	-0.012	0.629
SPP	0.005	0.006	**0.169**	0.048	0.064	-0.00022	0.006	-0.009	0.290
CD	0.005	-0.163	0.030	**0.269**	0.085	-0.00021	-0.004	-0.003	0.219
HI	0.003	0.221	0.023	0.048	**0.478**	-0.00017	0.002	-0.015	0.760
LAD(F)	-0.001	0.023	0.046	0.070	0.098	**-0.00082**	0.008	-0.001	0.242
CGR(F)	-0.001	0.213	0.048	-0.042	0.045	-0.00029	**0.023**	0.001	0.287
PC	0.002	0.109	0.029	0.017	0.134	-0.00002	-0.0005	**-0.053**	0.237

Residual = 0.211

DF	Days to 50% flowering	HI	Harvest index
NPP	No. of pods per plant	LAD(F)	Leaf area duration at flowering
SPP	No. of seeds per pod	CGR(F)	Crop growth rate at flowering
CD	Crop duration	PC	Protein content

Fig.3: Path diagram showing direct effects and genotypic correlations in grain cowpea



DF	Days to 50% flowering	CD	Crop duration	CGR(F)	Crop growth rate at flowering
NPP	No. of pods per plant	HI	Harvest index	PC	Protein content
SPP	No. of seeds per pod	LAD(F)	Leaf area duration at flowering	SYP	Seed yield per plant

4.6.2. Indirect effects

Highest positive indirect effect was observed by harvest index *via* number of pods per plant (0.221) followed by CGR at flowering *via* number of pods per plant (0.213).

LAD at flowering had positive genotypic correlation (0.242) with seed yield per plant but negative direct effect. However it had negligible but positive indirect effects *via* number of pods per plant (0.023), number of seeds per pod (0.046), crop duration (0.070), harvest index (0.098) and CGR at flowering (0.008) which accounts for the positive genotypic correlation.

The direct effect of CGR at flowering was positive but negligible (0.023) whereas it had moderate indirect effect *via* number of pods per plant (0.213).

Protein content showed negligible negative direct effect (-0.053) on seed yield per plant, but its genotypic correlation was positive (0.237). It was due to its positive indirect effects *via* number of pods per plant (0.109) and harvest index (0.134).

The residual effect obtained was 0.211.

4.7. GENETIC DIVERGENCE ANALYSIS

The genotypes were subjected to Mahanalobis D^2 analysis to estimate the genetic divergence present among them. Clustering was done based on the characters days to 50% flowering, number of primary branches, height of the plant, number of pods per plant, number of seeds per plant, 100 seed weight, crop duration, harvest index, LAD at flowering, CGR at flowering, protein content and seed yield per plant. Thirty three genotypes were grouped into nine clusters following Tocher's method of clustering. The distribution of thirty three genotypes into different clusters are depicted in table 10.

Cluster II with 10 genotypes was the largest followed by cluster I and cluster V (8 genotypes each), cluster III (2 genotypes) and clusters IV, VI, VII, VIII, IX were solitary. Cluster I accommodated genotypes PL-2, PL-5, TC 55-1, CP VBN 1, CHESCP-13, DC 15, IC 52110 and IC 300039. The genotypes KYLMVU-3, KYLMVU-7, CP VBN 3, CHESCP-22, CHESCP-21, HC 46, CHESCP-23, KYLMVU-4, CHESCP-19 and KYLMVU-6 were grouped as cluster II. Cluster III was constituted by two genotypes Hridya and KYLMVU-10 whereas cluster IV had only one genotype PL-1. Cluster V accommodated genotypes CHESCP-29, CHESCP-32, IC 39853, Subhra, PL-3, CHESCP-07, CHESCP-09 and KYLMVU-2. Clusters VI, VII, VIII, and IX were solitary constituted by the genotypes CHESCP-03, CHESCP-17, Sreya and PL-4 respectively.

Table 10. Distribution of grain cowpea genotypes into different clusters

Cluster	**No. of genotypes**	**Genotypes**
I	8	PL-2, PL-5, TC 55-1, CP VBN 1, CHESCP-13, DC 15, IC 52110, IC 300039
II	10	KYLMVU-3, KYLMVU-7, CP VBN 3, CHESCP-22, CHESCP-21, HC 46, CHESCP-23, KYLMVU-4, CHESCP-19, KYLMVU-6
III	2	Hridya, KYLMVU-10
IV	1	PL-1
V	8	CHESCP-29, CHESCP-32, IC 39853, Subhra, PL-3, CHESCP-07, CHESCP-09, KYLMVU-2
VI	1	CHESCP-03
VII	1	CHESCP-17
VIII	1	Sreya
IX	1	PL-4

The average intra and inter cluster distances based on D^2 values were estimated and the results are presented in table 11. The highest intra cluster distance was recorded among the genotypes of cluster V (16.6) and lowest in cluster III (9.09) whereas highest inter cluster distance was observed between the genotypes of the clusters III and IX (32.27) followed by clusters VI and IX (31.9) and clusters III and VIII (30.84).

In case of cluster I, maximum divergence was observed from cluster IX (23.86) followed by cluster VIII (23.48), cluster VI (21.35), cluster III (21.13), cluster VII (20.63), cluster V (18.09), cluster IV (15.91) and cluster II (15.7). Cluster II exhibited maximum divergence from cluster IX (29.43) followed by cluster VII (23.08), cluster III (22.55), cluster VIII (21.51), cluster V (20.56), cluster IV (19.46) and cluster VI (15.6). Maximum divergence of cluster III was recorded from cluster IX (32.27) followed by cluster VIII (30.84), cluster VII (27.39), cluster IV (24.86), cluster V (21.84) and cluster VI (21.05). Cluster IV was found to be highly divergent from cluster VI (21.45) followed by cluster VIII (19.56), cluster V (18.74), cluster IX (17.15) and cluster VII (11.87). Cluster V had maximum divergence from cluster IX (24.34) followed by cluster VI (22.01), cluster VIII (21.63) and cluster VII (18.89). Cluster VI was highly divergent from cluster IX (31.9) followed by cluster VII (22.54) and cluster VIII (20.72). Cluster VII showed maximum divergence from cluster VIII (17.6) followed by cluster IX (13.4).

4.7.1. Cluster means

The cluster means for the twelve characters are presented in table 12. Cluster VI exhibited highest cluster means for the characters days to 50% flowering (64.00), number of primary branches per plant (9.54), number of pods per plant (15.25), number of seeds per pod (14.97), harvest index (0.77) and protein content (35.31). Highest cluster means for crop duration (99.33) and seed yield per plant (25.22) was shown by cluster VIII whereas highest cluster means for 100 seed weight (18.79) and CGR at flowering (4.12) was shown by cluster IX. Height of the plant (50.60) and LAD at flowering (37.87) had the highest cluster means in clusters II and V respectively.

Table 11. Average intra and inter cluster D^2 values

	I	II	III	IV	V	VI	VII	VIII	IX
I	**12.27**	15.7	21.13	15.91	18.09	21.35	20.63	23.48	23.86
II		**13.34**	22.55	19.46	20.26	15.6	23.08	21.51	29.43
III			**9.09**	24.86	21.84	21.05	27.39	30.84	32.27
IV				**0.00**	18.74	21.45	11.87	19.56	17.15
V					**16.6**	22.01	18.89	21.63	24.34
VI						**0.00**	22.54	20.72	31.9
VII							**0.00**	17.6	13.4
VIII								**0.00**	26.96
IX									**0.00**

Fig 4. Cluster diagram

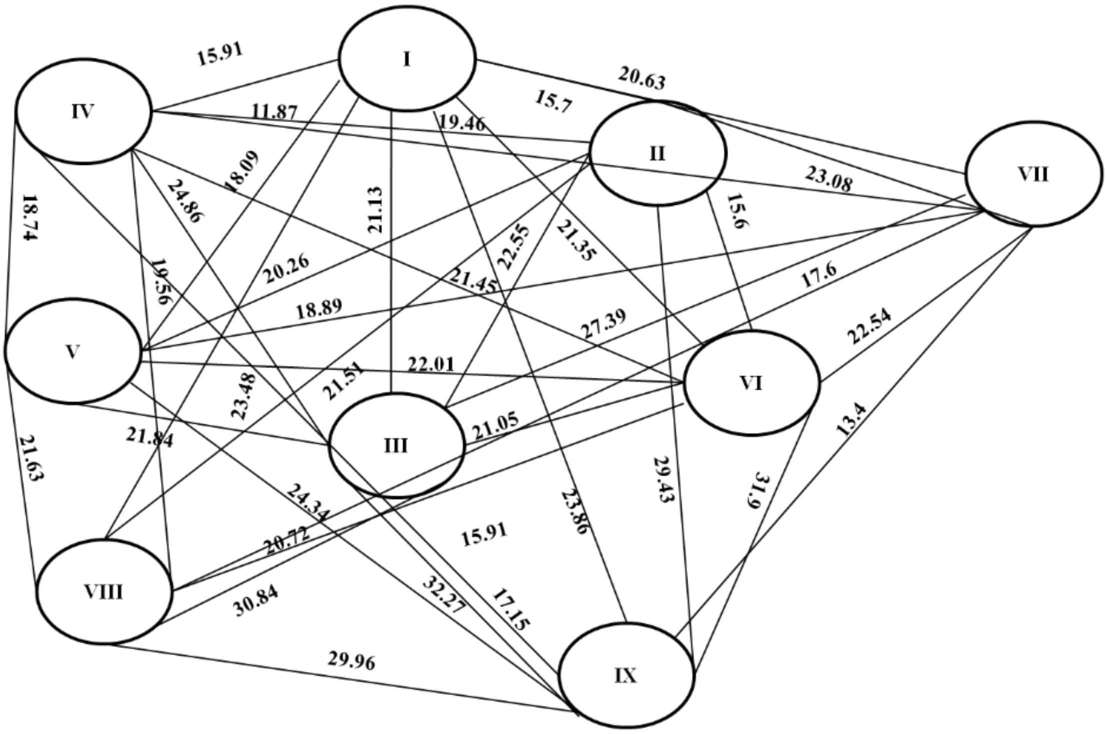
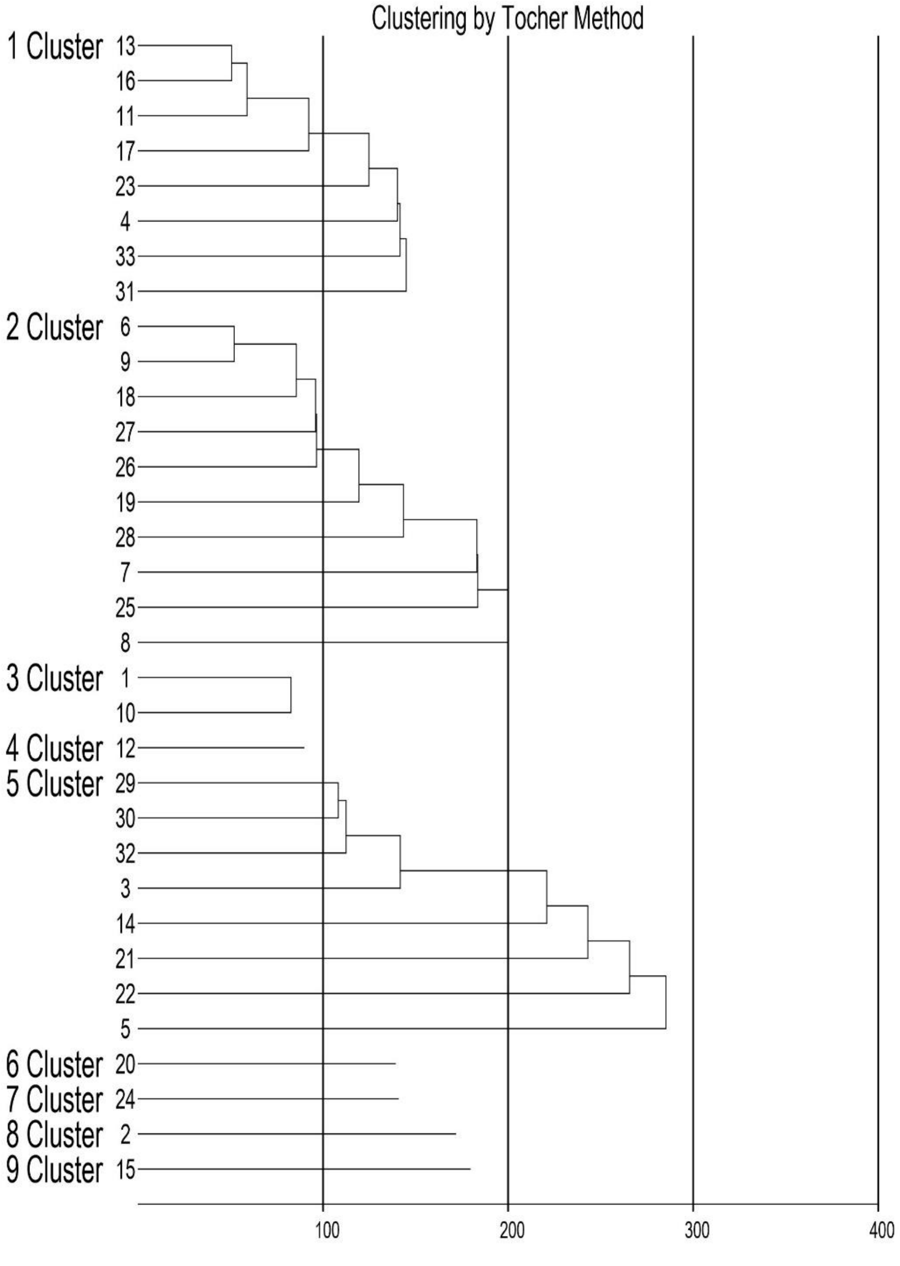


Fig 5. Dendrogram showing clustering pattern of thirty three grain cowpea genotypes



The lowest cluster mean for days to 50% flowering (37.33), number of seeds per pod (11.18), crop duration (52.67) and LAD at flowering (7.21) was shown by cluster III. Cluster I had lowest cluster means for number of pods per plant (4.43), harvest index (0.34) and seed yield per plant (4.37). 100 seed weight (10.60) and protein content (31.56) had lowest cluster mean values in cluster V whereas cluster means for number of primary branches per plant (4.82) and height of the plant 41.63) was lowest in cluster IX. Cluster IV exhibited lowest cluster mean for CGR at flowering (0.52).

4.7.2. Relative contribution of characters to divergence

The relative contribution of twelve characters to the total divergence was estimated and is depicted in table 13. The relative contribution was much higher for 100 seed weight (22.92%) followed by CGR at flowering (21.59%), protein content (20.45%) and seed yield per plant (14.58%) while crop duration (9.66%), number of seeds per pod (3.03%), number of primary branches (2.08%), LAD at flowering (2.08%), number of pods per plant (1.89%) and harvest index (1.7%) were least contributors towards diversity. Traits *viz*., days to 50% flowering and height of the plant had zero per cent contribution to genetic divergence.

Table 12. Cluster means of yield and yield contributing characters in grain cowpea

	DF	**PB**	**HT**	**NPP**	**SPP**	**100SW**	**CD**	**HI**	**LAD (F)**	**CGR (F)**	**PC**	**SYP**
I	47.83	5.93	41.94	4.43	12.63	12.43	88.46	0.34	25.38	1.85	31.84	4.37
II	50.03	7.56	50.60	8.50	13.78	11.52	93.40	0.51	28.41	1.59	33.92	10.97
III	37.33	6.30	45.25	12.22	11.18	5.43	52.67	0.36	7.21	1.83	32.77	4.65
IV	47.33	8.47	47.03	13.07	12.08	16.59	76.67	0.25	33.63	0.52	31.77	4.65
V	48.04	6.63	44.29	12.03	14.08	10.60	81.92	0.49	37.87	4.09	31.56	12.13
VI	64.00	9.54	47.87	15.25	14.97	10.67	75.33	0.77	13.52	1.49	35.31	18.99
VII	49.67	8.41	47.47	13.94	12.99	16.17	78.33	0.76	9.56	3.37	32.25	17.58
VIII	49.67	5.67	45.10	14.23	14.06	14.05	99.33	0.49	18.98	2.28	32.42	25.22
IX	46.33	4.82	41.63	6.29	12.57	18.79	78.67	0.36	12.79	4.12	34.37	6.22

DF	Days to 50% flowering	SPP	No. of seeds per pod	LAD(F)	Leaf area duration at flowering
PB	No. of primary branches/ plant	100SW	100 seed weight	CGR(F)	Crop growth rate at flowering
HT	Height of plant	CD	Crop duration	PC	Protein content
NPP	No. of pods per plant	HI	Harvest index	SYP	Seed yield per plant

Table 13: Relative contribution of each character to divergence

Sl. No	**Source**	**Times Ranked 1st**	**Contribution (%)**
1	Days to 50% flowering (days)	-	-
2	Number of primary branches per plant	11	2.08
3	Height of the plant (cm)	-	-
4	Number of pods per plant	10	1.89
5	Number of seeds per pod	16	3.03
6	100 seed weight (g)	121	22.92
7	Crop duration (days)	51	9.66
8	Harvest index	9	1.70
9	LAD at flowering (days)	11	2.08
10	CGR at flowering (g m^{-2} day^{-1})	114	21.59
11	Protein content (%)	108	20.45
12	Seed yield per plant (g)	77	14.58

Discussion

5. DISCUSSION

The diminishing per capita availability of land and ever increasing labour charges are the major constraints to agricultural production in Kerala. In such a scenario, the small and marginal farmers rely upon strategies such as homestead farming where the available land area and family labour can be utilised and also it contributes to the food security of the State. Coconut is the dominant and important tree crop in the small holdings of Kerala. Cowpea is a modest but versatile crop which is capable to complement other crops and ensure higher food production and family nutrition, without competing for land and other resources (Singh, 2014). Niche performance, rising popularity, high nutritional value and moderate shade tolerance makes cowpea a promising candidate in different intensive cropping systems.

In this context, the present investigation was undertaken to select shade tolerant grain cowpea genotypes suited as intercrop in the coconut based homesteads of Kerala. The results of the study are discussed in this section under different subheads:

5.1. LIGHT INTENSITY

The experiment was laid in a coconut based homestead where coconuts are of age 30-40 years. The light intensity measured in the experimental plot was 0.719 W/m^2 resulting in shade intensity of 33.49 per cent. Das (1988) also reported that light transmission was 30 per cent and 50 per cent when age of the palms are 30 years and 40 years respectively.

5.2. CHARACTERISATION OF GENOTYPES

Characterisation of the genotypes revealed that parameters selected for the study is appropriate to categorise the genotypes in terms of distinctness, uniformity and stability. High level of morphological diversity among the genotypes revealed that these stable characters can be considered in future breeding programmes, quality seed production and also in protection in plant variety of cowpea. Stoilova and Pereira (2013) also reported that descriptors like pod length, number of seeds per pod, seed thickness and 100 seed weight were the most stable traits which can be used in characterization

5.3. EFFECT OF SHADE ON IMPORTANT BIOMETRIC CHARACTERS

Intercropping is an important cropping system extensively used for food and dietary fiber sustainability. The advantages of this system are the effective and efficient utilization of farm resources, providing additional income to the farmer and low incidences of diseases, pests and weed. The success of this approach is attributed to the efficient utilization of water and light, thereby increasing crop yield and improving the biodiversity and ecological services. Light directly affects the crop growth and yield potential. In the coconut based cropping system, tree crop absorb major part of the light, whereas shorter crops receive low amounts of light for photosynthesis and suffer shading from taller crops. However intercropping is recommended in coconut garden when the trees are below 20 years and above 40 years old. The important characteristic of a plant species which can be grown as intercrop in coconut garden is shade tolerance. Simion (2018) reported that cowpea is shade tolerant and therefore, compatible as an intercrop with maize, millet, sorghum, sugarcane, and cotton as well as with several plantation crops and thus it forms a valuable component of the traditional cropping systems. The data collected from the experiment was critically analysed for identifying the suitable genotypes which can be utilised in future breeding programme to develop a new variety.

5.3.1. Biometric characters

5.3.1.1. Days to 50% flowering and crop duration

The genotypes evaluated in this study includes early, medium and late duration types. Flowering and crop duration were delayed in most of the genotypes under shade. Similar observations were made by Danlami *et al.* (2015) in cowpea, Masaku *et al.* (2018) in green gram and Sivan (2019) in horse gram. The delay in reproductive stage under partial shade may be due to the increased vegetative growth caused by ambient environmental conditions which also resulted in prolonged crop duration.

Fig. 6. Days to 50% flowering in grain cowpea

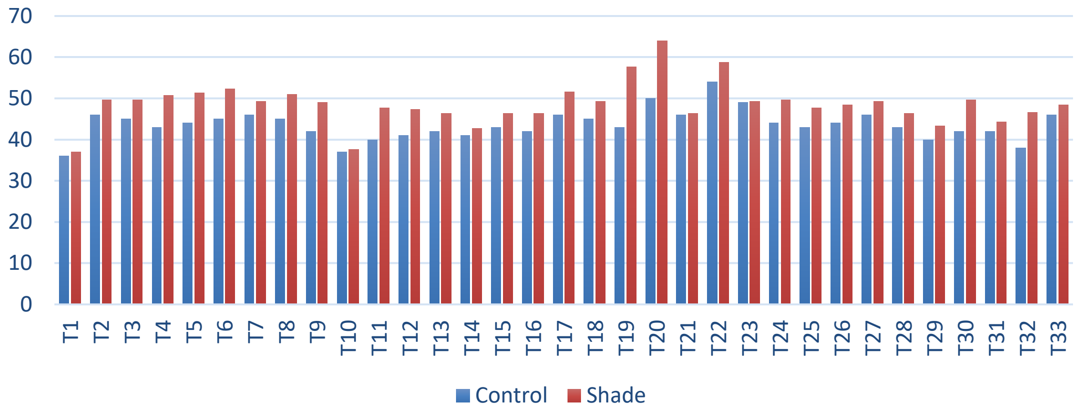
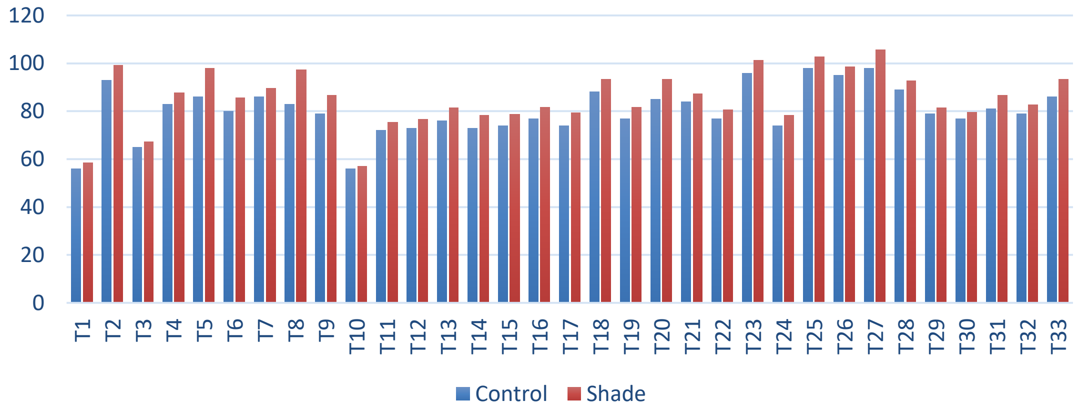


Fig. 7. Crop duration in grain cowpea



The delay in flowering and crop duration varied among the genotypes and the delay varied from a minimum of 1 day to a maximum of about 14 days.

In this study, CHESCP-03 recorded maximum days to flowering and Hridya recorded minimum days to flowering which was on par with KYLMVU-10. CHESCP-22 showed maximum crop duration which was on par with CHESCP-19 and CHESCP-13 and minimum duration was observed for Hridya and KYLMVU-10. Delay in days to 50% flowering and crop duration were found to have positive effect on seed yield as evident from the correlation studies which also contributed to the higher yield of genotypes CHESCP-03 and CHESCP-19.

5.3.1.2. Height of plant (cm)

Plant height was found to increase in almost all the genotypes under partial shade which was in conformity with the findings of Adedipe and Ormrod (1975) in cowpea and Sivan (2019) in horse gram. This is contradictory to the report of Eriksen and Whitney (1984) who reported no effect of shading on plant heights of cowpea. The increase in plant height may be due to increased vegetative growth and longer internodal length as suggested by Adelusi and Aileme (2006). The genotype KYLMVU-3 recorded maximum height and lowest height was noted for the genotype CHESCP-29.

5.3.1.3. Number of primary branches and number of pods per plant

According to Eriksen and Whitney (1984), pods per plant is the main component of yield affected by shade in cowpea and soybean. Under shade the number of leaves (source) and number of pods (sink) is limited by the reduction in number of branches (Terao *et al.*, 1997).

In this study, reduction in number of primary branches and number of pods per plant was observed under shaded condition which was in accordance with the reports of Wien (1977), Danlami *et al.* (2015) in cowpea and Kumar and Kishor (2015) in soybean. The reduction in number of pods per plant may be due to lesser number of primary branches along with delay in flowering and pod maturity.

Fig. 8. Height of plant (cm) in grain cowpea

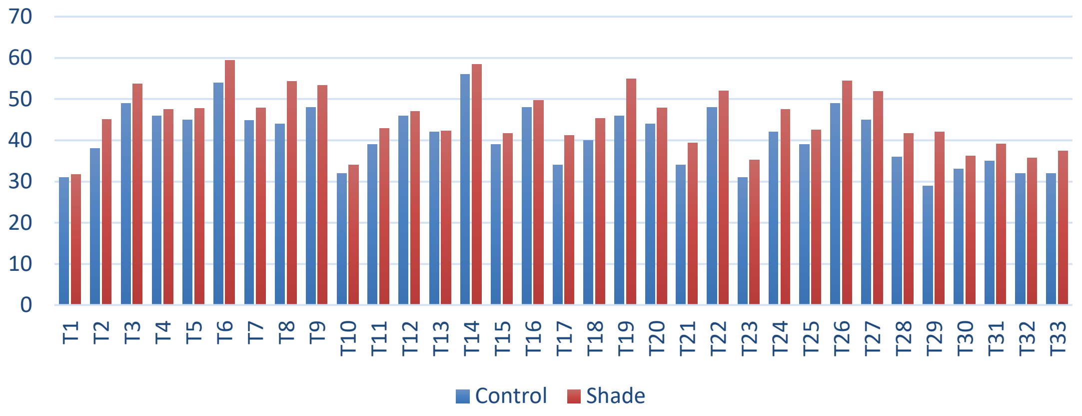


Fig. 9. No. of primary branches per plant in grain cowpea

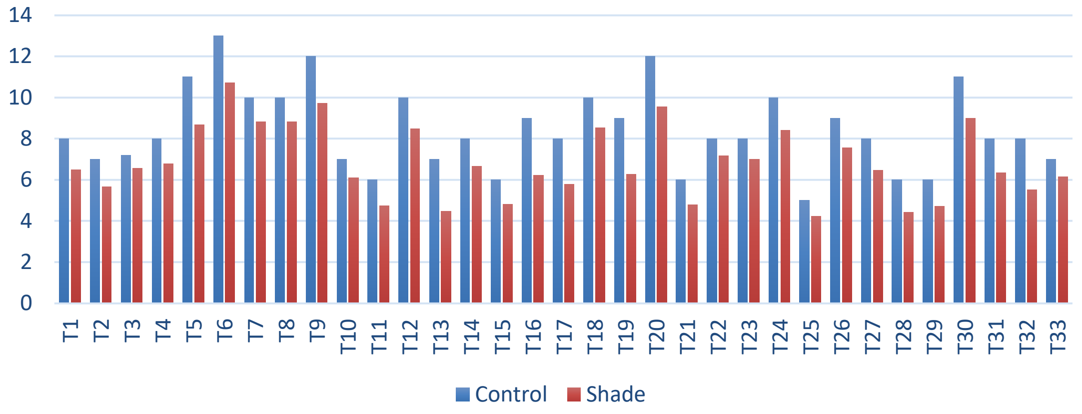
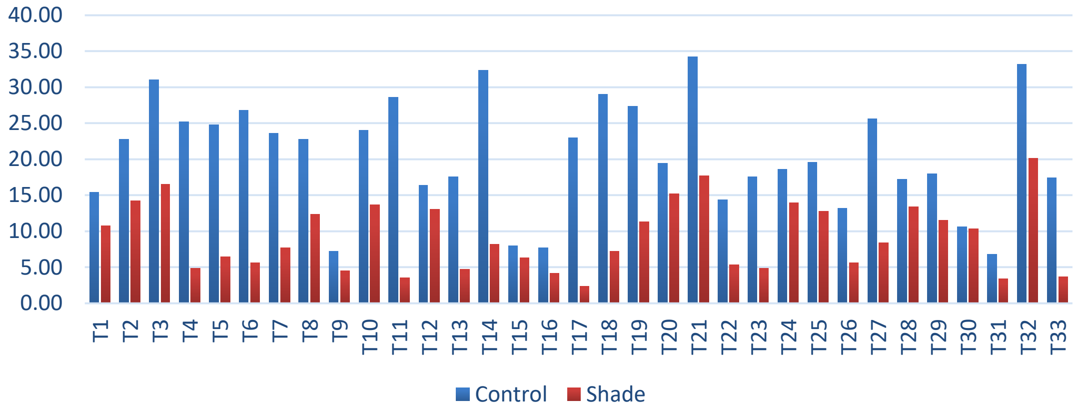


Fig. 10. No. of pods per plant



Maximum number of primary branches per plant were observed for the genotype KYLMVU-3 and lowest number of primary branches were noted for CHESCP-19. Highest number of pods per plant was observed in the genotype IC 39853 which was statistically on par with CHESCP-03 and minimum number of pods was observed in the genotype CP VBN 1. High number of pods per plant is one of the attributing characters for shade tolerance of genotype CHESCP-03 which is supported by the inference of Abilay and Lantican (1982) that greater number of pods per plant is a character associated with shade tolerance.

5.3.1.4. Number of seeds per pod and 100 seed weight

Under shade, number of seeds per pod was reduced in almost all the genotypes which was supported by the observations made by Hossain *et al.* (2017) in greengram.

Decrease in 100 seed weight was observed under shade in almost all the genotypes as reported by Hossain *et al.* (2017) in greengram. According to him, heavier grains are one of the reasons for stable performance of tolerant genotypes under shade. The genotypes CHESCP-03 and CHESCP-17 which were found to be shade tolerant showed an increase in 100 seed weight under shade compared to open condition.

Highest number of seeds per pod was recorded by CHESCP-32 and lowest number of seeds per pod was recorded for CHESCP-13. The variety PL-4 recorded highest 100 seed weight and Hridya recorded lowest.

5.3.1.5. Seed yield per plant and protein content

A reduction in seed yield per plant was observed in all genotypes under shade which is supported by the reports of Summerfield *et al.* (1976) in cowpea and Singh (1997) in green gram. Highest yield was recorded for the variety Sreya and lowest was recorded for the genotype IC 300039. The high variation recorded by the genotypes may be due to the difference in duration as early, medium and late genotypes were included in the study. The per cent of yield reduction varied among the genotypes as reported by Hossain *et al.* (2017) in green gram. Lowest reduction was observed for the genotype CHESCP-32 followed by CHESCP-17 and CHESCP-03 which reveals its adaptability under partial shade.

Fig. 11. No. of seeds per pod in grain cowpea

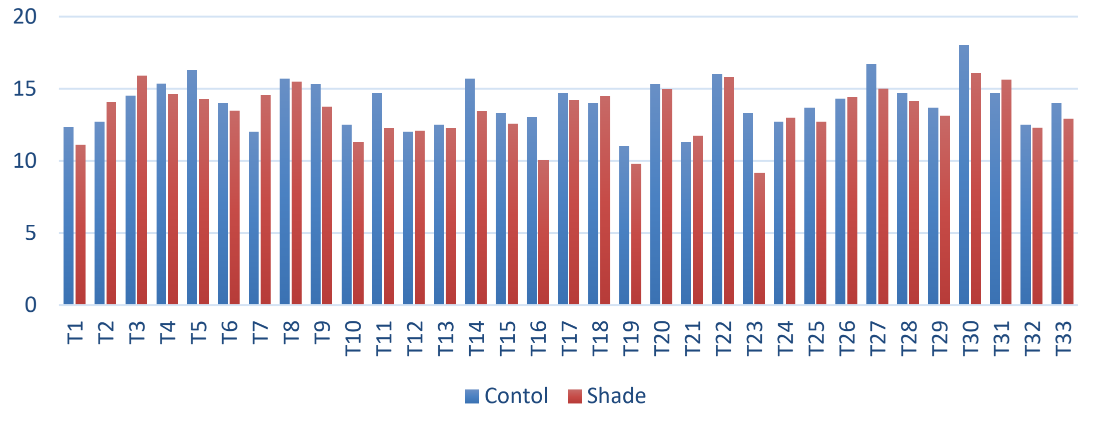


Fig. 12. 100 seed weight in grain cowpea

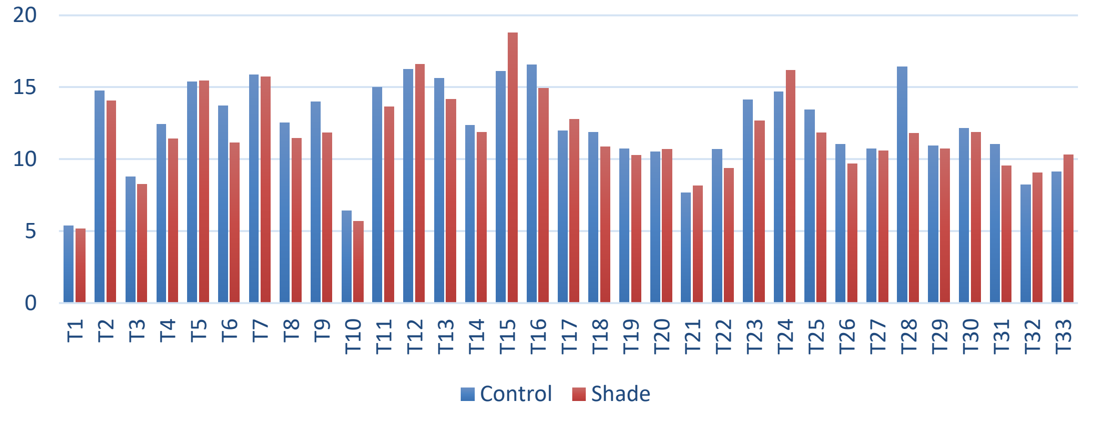
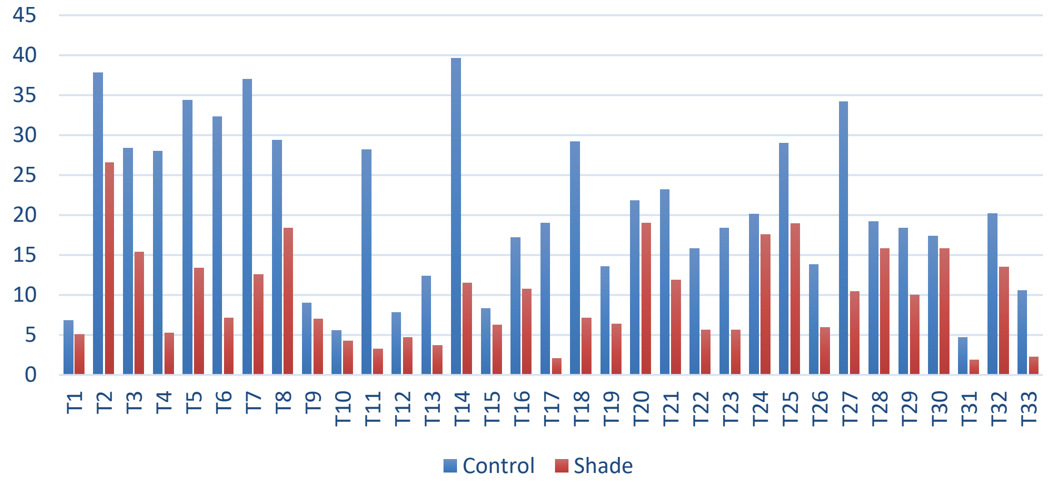


Fig. 13. Seed yield per plant in grain cowpea



Protein content is the important quality character of pulses. For most of the genotypes, an increase in seed protein content was observed which was supported by the findings of Lakshmamma and Rao (1996) in black gram and Mawarni *et al.* (2019) in soybean. In this study, among the genotypes Subhra recorded highest protein content and CHESCP-07 recorded the lowest protein content.

5.3.1.6. Harvest index (HI)

Harvest index was lowered under shade in most of the genotypes which was in accordance with the observations of Hossain *et al.* (2017) in green gram and Sivan (2019) in horsegram. It may be due to the influence of low radiation on the partitioning of assimilates from source to sink.

Maximum harvest index was observed for the genotype CHESCP-03 and minimum value for IC 300039. Higher harvest index of CHESCP-03 is a desirable trait contributing to its shade tolerance.

5.3.1.7. Leaf area and dry matter production

Leaf area was found to be decreasing under shade in most of the genotypes which was in accordance with the reports of Kubota and Hamid (1992) in black gram and Kumar and Kishor (2015) in soybean. It was contrary to the findings of Araki *et al.* (2014) and Hossain *et al.* (2017) in green gram.

Shade reduced the dry matter production in all genotypes which was in conformity with the results obtained by Dart and Mercer (1965) and Eriksen and Whitney (1984).

At flowering stage, maximum leaf area was observed for PL-3 and minimum for KYLMVU-7. At flowering stage, the genotypes IC 39853 and PL-5 recorded highest and lowest dry matter production respectively.

Fig. 14. Seed protein content in grain cowpea

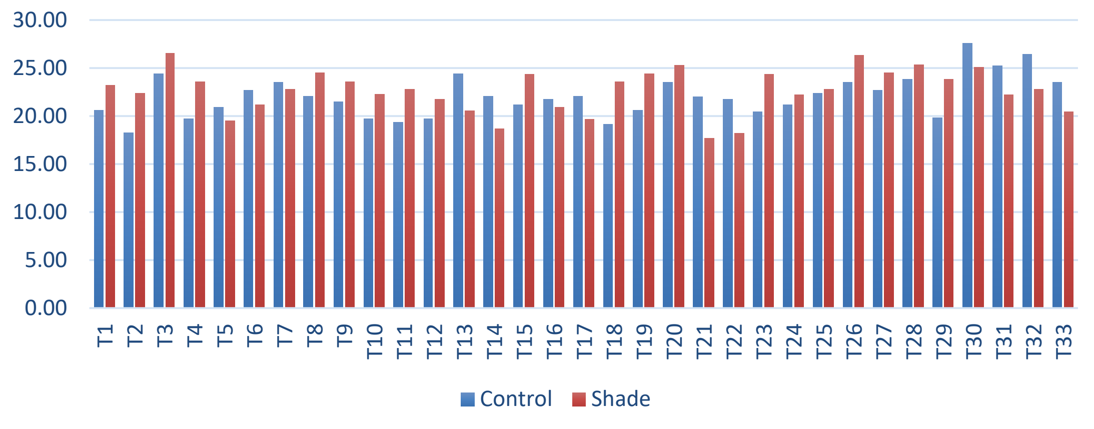
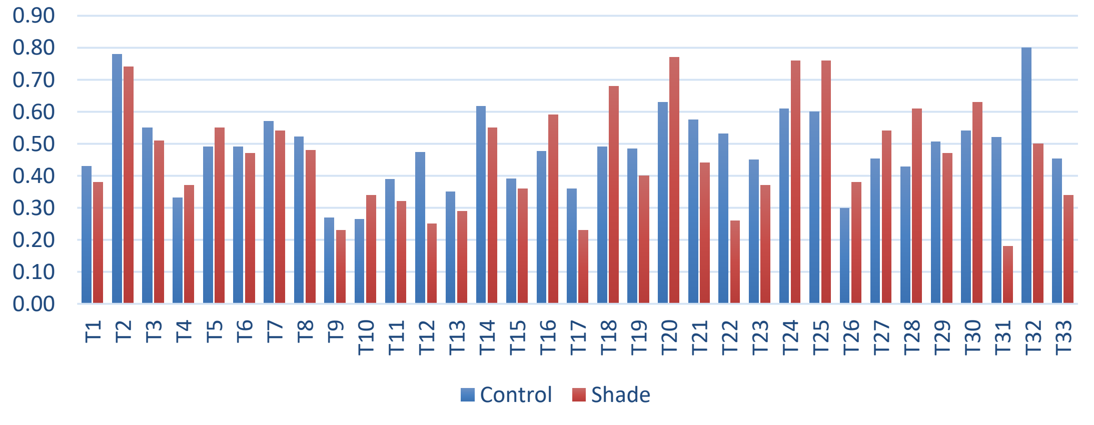


Fig. 15. Harvest index in grain cowpea



5.3.2. Physiological characters

5.3.2.1. Specific leaf area (SLA) and Specific leaf weight (SLW)

Specific leaf area was increased for most of the genotypes under shade which was supported by the findings of Kubota and Hamid (1992) and Sundari (2009) in greengram. The reduction in availability of light intensity is compensated by the production of thinner leaves with greater leaf area which enhances the light utilization efficiency, thereby enhancing productivity.

Specific leaf weight is the inverse of SLA and was found to lower under shade. Higher SLW indicates high photosynthetic potential since it is positively correlated with RuBP carboxylase activity.

In this study, at flowering stage CHESCP-23 recorded highest SLA and lowest SLW whereas CHESCP-17 recorded lowest SLA and highest SLW.

According to Abilay and Lantican (1982), higher SLW is a character associated with shade tolerance in mungbean. Sundari (2009) also confirmed that specific leaf area at four weeks after planting could be used as shading tolerant indicator of mungbean and SLA value of shading sensitive genotypes were greater than that of tolerant genotypes. In the present study, genotypes CHESCP-03 and CHESCP-17 were found to have comparatively high values for SLW and low values for SLA at vegetative stage, which may also have contributed to its shade tolerance and better performance under coconut based homesteads.

5.3.2.2. Leaf Area Index (LAI)

In the present study, reduction in LAI was observed under shade for most of the genotypes which is in conjunction with the reports of Babu and Nagarajan (1993) in soybean and Manoj (2017) in cowpea.

At flowering stage, highest LAI was recorded for KYLMVU-10 while lowest was for IC 39853. According to Abraham (1988), an ideal plant type of black gram under partial shade should have high LAI at 50 per cent flowering, with high dry matter accumulation, resulting in high harvest index. The relatively higher LAI at flowering stage exhibited by the genotype CHESCP-32 may also have contributed to its shade tolerance.

5.3.2.3. Leaf area ratio (LAR)

For most of the genotypes LAR exhibited an increasing trend under shade compared to open conditions which was in conformity with the results of Nomoto *et al.* (1961). According to Kumar and Kishor (2015), in soybean greater survival potential under shade was attained with higher LAR.

In this study, maximum LAR at flowering stage observed for the genotype DC15 lowest LAR was observed for the genotype CHESCP-17.

5.3.2.4. Leaf area duration (LAD)

In this study, LAD was reduced by shade which was contrary to the reports of Abilay and Lantican (1982) in greengram in which greengram varieties with lower leaf area duration at six weeks after emergence (or early maturity) were considered as shade tolerant. The present study revealed positive significant correlation between LAD at flowering stage with seed yield which is supported by the findings of *Estrada et al.* in *Phaseolus* cultivars that greater LAD can contribute to greater seed yield.

In this study, highest LAD at flowering was recorded for IC 39853 and lowest for KYLMVU-10. The shade tolerant genotype CHESCP-32 exhibited relatively higher LAD values at flowering stage which contributed to its better performance under coconut based homesteads.

5.3.2.5. Crop Growth Rate (CGR)

CGR was found to be decreased by shade in most of the genotypes at flowering stage and it was in confirmation with the results of Babu and Nagarajan (1993) in soybean and Islam *et al.* (1993) in greengram.

Maximum CGR at flowering was noted for IC 39853 while the lowest value for CGR was recorded for PL-1. Relatively higher CGR values were noted for the genotypes CHESCP-17 and CHESCP-32 which may have contributed to its higher yield under shade condition.

5.4. STATISTICAL ANALYSIS

5.4.1. Variability

The prerequisite of any breeding programme is the evaluation of variability present in the population. In this study, significant differences were observed among the genotypes for all characters studied which indicated the presence of substantial amount of variability.

The genotypes differed significantly for biometric characters *viz.,* days to 50% flowering, number of primary branches per plant, height of plant (cm), number of pods per plant, number of seeds per pod, 100 seed weight (g), seed yield per plant (g), seed yield per unit area (kg/ha), crop duration (days), harvest index, leaf area and dry matter production at vegetative, flowering and harvesting stages indicating that the genotypes genetically differ in maturity period, yield and yield components. Similar results were observed by Manggoel *et al.* (2012), Kamara *et al.* (2017), Thouseem (2017) and Nkoana *et al.*(2019).

Earlier, high variability among cowpea genotypes for the characters days to 50% flowering, number of pods per plant, number of seeds per pod, 100 seed weight (g), seed yield per plant (g) were reported by Pandey (2007), Adewale *et al.* (2010), Manggoel *et al.* (2012), Aliyu and Makinde (2016), Khan and Viswanatha (2016), Thouseem (2017) and Aramendiz *et al.* (2018). In addition to above traits, significant difference among the cowpea genotypes for plant height (cm), number of primary branches per plant and harvest index was observed by Nwofia *et al.* (2012), Shanko *et al.* (2014a), Kamara *et al*. (2017), Sharma *et al*. (2017) and Viswanatha and Yogeesh (2017).

In the present study, high variability was observed for dry matter production in cowpea which was in agreement with the observations of Uprety *et al*. (1979), Bhardu and Navale (2011), Kamara *et al*. (2017) and Nkoana *et al*. (2019). Considerable variation for leaf area in cowpea was supported by Uprety *et al*. (1979), Dhanasekhar and Pandey (2005), Araki *et al*. (2014) and Gerrano *et al*. (2017).

Under partially shaded conditions, Philip (1987) and Abraham (1988) reported significant differences for days to flowering, crop duration, LAI and dry matter at blooming and harvesting stages in blackgram whereas significant differences for days to flowering, height of the plant, number of primary branches, number of pods per plant, number of grains per pod, grain yield per plant, harvest index, LAI and dry matter accumulation at flowering and pod formation stages were reported in greengram by Rajeswari (1998). Similar results were obtained by Sivan (2019) in horsegram under partial shade.

Significant variation was observed for physiological characters associated with shade tolerance *viz.,* SLA, SLW, LAI, LAR, LAD, CGR, RGR at vegetative, flowering and harvesting stages. It was in conformity with the findings of Abhilay and Lantican (1982) in green gram which reported significant variation among the entries for LAI, SLW, HI, LAR and LAD under partial shade. Sundari (2009) reported significant difference between shade tolerant and sensitive genotypes in green gram for leaf characters which includes leaf area and SLA.

The variation for seed protein content among genotypes was in consonance with the findings of Richard (2016) in cowpea.

5.4.2. Genetic parameters

Another means of expressing the amount of variability is coefficient of variation which gives information on nature and magnitude of variation. It gives knowledge on whether the variations are due to genetic factors or environmental influence. In the present study, PCV was higher than GCV for all characters considered. Similar trend was reported by Tigga (2009), Manggoel *et al*. (2012), Nwofia *et al*. (2012), Annasaheb (2013) and Thouseem (2017). The difference between PCV and GCV was low for all characters indicating higher genetic variability. This suggests low environmental effect and scope for improvement of these characters through hybridization followed by selection.

PCV and GCV were highest for seed yield per plant (g). High GCV with correspondingly high values of PCV was observed for number of primary branches, number of pods per plant, 100 seed weight, harvest index, LAD at flowering and CGR at flowering. The results were consistent with the findings of Girish (2000) for number of primary branches, number of pods per plant and seed yield per plant; Tigga (2009), Aliyu and Makinde (2016) for seed yield per plant, Adewale *et al*. (2010), Aramendiz *et al*. (2018) for 100 seed weight and number of pods per plant; Manggoel *et al*. (2012) for seed yield per plant, 100 seed weight and number of pods per plant; Annasaheb (2013) for days to 50% flowering, harvest index and seed yield per plant and Vu (2017) for number of pods per plant, 100 seed weight, seed yield per plant and harvest index.

PCV and GCV values were moderate for days to 50% flowering, height of the plant, number of seeds per pod and crop duration and low for seed protein content which was in agreement with the results obtained by Girish (2000), Annasaheb (2013) and Vu (2017) for number of seeds per pod; Kakde (2015) for protein content, Thouseem (2017) for days to 50% flowering, height of plant, number of seeds per pod and crop duration and Nkoana *et al*. (2019) for days to 50% flowering and number of seeds per pod.

In agreement to the present findings, moderate GCV was reported in blackgram under partially shaded conditions for height of the plant and high GCV for number of primary branches by Philip (1987) and Abraham (1988) respectively. High PCV and GCV were recorded for number of pods per plant, grains per pod, grain yield per plant and harvest index in greengram under partial shade by Rajeswari (1998) whereas low GCV was observed for protein content in blackgram under shade by Gambhire (2015).

Heritability denotes the heritable portion of total phenotypic variance present in the population which gives an exact information about the influence of environment on characters and also the gene action involved in the expression of polygenic traits. Genetic advance is the measure of genetic gain under selection. Selection based on heritability estimates along with genetic gain is more effective than heritability estimates alone (Johnson *et al*., 1955).

For all the characters high heritability was estimated which indicates the highly heritable nature of these characters and the minimum influence of environment in its expression.The high heritability estimates recorded for days to 50% flowering, height of the plant, number of primary branches, number of pods per plant, number of seeds per pod, seed yield per plant and 100 seed weight was in consonance with the reports of Girish (2000) and Manggoel *et al*. (2012). In addition to the above characters, high heritability was reported for harvest index and protein content by Annasaheb (2013).The findings were also supported by the observations of Ajayi *et al*. (2014) for number of primary branches, number of pods per plant, number of seeds per plant and 100 seed weight; Sharma *et al*. (2017) for height of the plant, number of primary branches, number of pods per plant, 100 seed weight, seed yield per plant and harvest index; Surpura and Sharma (2017) and Yadav and Rajasekhar (2019) for days to 50% flowering, grain yield per plant, 100 seed weight and number of pods per plant in cowpea.

High heritability was observed for the characters days to 50% flowering and 100 seed weight by Philip (1987) in blackgram; for number of pods per plant by Rajeswari (1998) in greengram and for days to 50% flowering, height of the plant, number of pods per plant, number of seeds per pod, 100 seed weight, seed yield per plant and protein content by Gambhire (2015) in black gram under partial shade.

In contrary, Abraham (1988) reported heritability values moderate for height of the plant and low for number of pods per plant, number of seeds per plant, grain yield per plant and harvest index in blackgram under partial shade.

In the study, high genetic advance (as per cent of mean) was exhibited by all the characters except days to 50% flowering and protein content which exhibited moderate genetic advance. The genetic gain was high for number of primary branches per plant, height of the plant, number of pods per plant, number of seeds per pod, 100 seed weight, crop duration, harvest index, LAD at flowering, CGR at flowering and seed yield per plant. The moderate GAM was observed for protein content (13.72%)

followed by days to 50% flowering (17.93%). This indicates that by selecting five per cent superior individuals the genetic improvement possible for protein content will be 13.72 per cent. Corroborative results were reported by Girish (2000) for height of the plant, number of primary branches per plant, number of pods per plant, number of seeds per pod, 100 seed weight and seed yield per plant; Tigga (2009) for seed yield per plant; Kakde (2015) for height of the plant, number of pods per plant and seed yield per plant, Sharma *et al*. (2017) for number of pods per plant, 100 seed weight, seed yield per plant and harvest index; Purohit *et al*. (2020) for days to 50% flowering and protein content in cowpea.

The results were in conjunction with the observations of Rajeswari (1998) for number of seeds per pod, grain yield per plant, and harvest index in greengram and Gambhire (2015) for height of the plant and protein content in blackgram under partial shade.

The reports of Philip (1987) and Abraham (1988) in blackgram under partial shade were contrary to the findings of the present study for days to 50% flowering, number of pods per plant, number of seeds per pod and 100 seed weight and harvest index.

High heritability coupled with high genetic advance was observed for number of primary branches per plant, height of the plant, number of pods per plant, number of seeds per pod, 100 seed weight, crop duration, harvest index, LAD at flowering, CGR at flowering and seed yield per plant. It was in agreement with the findings of Ajayi *et al*. (2014) for number of primary branches per plant, number of pods per plant, number of seeds per plant and 100 seed weight; Sharma *et al*. (2017) for height of the plant, number of primary branches per plant, 100 seed weight, seed yield per plant and harvest index; Thouseem (2017) for length of the stem, number of seeds per pod and 100 seed weight; Rukhsar *et al*. (2020) for height of the plant, number of primary branches per plant, number of pods per plant, number of seeds per plant, 100 seed weight and seed yield per plant. Characters exhibiting high heritability along with high GAM are most likely governed by additive gene action and hence direct phenotypic selection may be effective for their improvement whereas characters showing moderate GAM may be governed by non - additive gene action. Hence can be improved by heterosis breeding.

In this study, high heritability coupled with moderate genetic advance was exhibited by the traits days to 50% flowering and protein content which were supported by the reports of Nwosu *et al*. (2013), Kouam *et al*. (2018), Verma *et al*. (2019), Purohit *et al*. (2020).

5.4.3. Correlation studies

When a breeder does selection for a character from a population, the population is not only improved for that character but also improved for other characters associated with it. Correlation study gives information on the degree and direction of relationship between characters in a population, thus aids in selection to be effective and in simultaneous improvement of two or more characters. Since yield improvement is the prime objective of any breeding programme, knowledge on the association of other traits on yield helps to identify the characters that can form the basis of selection. In this study genotypic and phenotypic correlation of eleven characters with seed yield per plant and their association among themselves were estimated.

The association analysis revealed significant positive correlation of seed yield per plant with days to 50% flowering, number of pods per plant, number of seeds per pod, crop duration, harvest index, LAD at flowering, CGR at flowering and protein content. It indicates that selection for genotypes which are late flowering and having longer crop duration can simultaneously improve yield in cowpea under partial shade. Number of primary branches per plant, height of the plant and 100 seed weight showed non-significant positive correlation with seed yield. Earlier concurrent results on positive genotypic correlation of seed yield with number of seeds per pod (Nakawuka and Adipala, 1999; Annasaheb, 2013; Kakde, 2015; Dinesh *et al*.,2017; Thouseem, 2017 and Kouam *et al*.,2018), CGR at flowering (Sarvamangala, 2005), number of pods per plant (Bhardu and Navale, 2011; Manggoel *et al*., 2012; Thorat and Gadewar, 2013; Shanko *et al*., 2014b; Nkoana *et al*., 2019; Nwofia *et al*., 2019 and Sharma *et al*., 2019), harvest index (Uprety *et al*., 1979; Annasaheb, 2013;

Gerrano *et al*., 2015; Kamara *et al*., 2017; Sharma *et al*., 2017 and Yadav and Rajasekhar, 2019), protein content (Thorat and Gadewar, 2013), days to 50% flowering (Thouseem, 2017; Owusu *et al*., 2018; Kouam *et al*., 2018 and Yadav and Rajasekhar, 2019) and crop duration (Thouseem, 2017) supported the findings of present study.

Similarly, under partial shade significant positive genotypic correlation of seed yield per plant was reported with days to 50% flowering, number of pods per plant and number of seeds per pod by Philip (1987), number of pods per plant, number of seeds per pod and harvest index by Abraham (1988) in black gram and with number of pods per plant and harvest index by Rajeswari (1998) in green gram. Sivan (2019) also reported similar findings for days to 50% flowering, plant height, number of pods per plant, number of seeds per plant and crop duration in horsegram under partially shaded conditions.

The interrelationships among yield components is essential as it helps in efficient indirect selection for seed yield.

Number of pods per plant was noticed with significant positive genotypic correlation with harvest index, CGR at flowering and protein content and negative correlation with crop duration and 100 seed weight. Similar results were obtained by Uprety *et al*. (1979) and Annasaheb (2013) for harvest index; Shanko *et al*. (2014b) and Thouseem (2017) for crop duration and 100 seed weight. Days to 50% flowering showed significant positive correlation with number of primary branches per plant, height of the plant, number of seeds per pod, crop duration and harvest index. Similar reports on plant height and number of main branches (Thorat and Gadewar, 2013 and Ajayi *et al*., 2014), plant height and number of seeds per pod (Annasaheb, 2013), height of the plant (Umar *et al*., 2010; Gerrano *et al*., 2015 and Nkoana *et al*., 2019) andnumber of primary branches, length of main stem, number of seeds per pod and crop duration (Thouseem, 2017) supported the results of this study. Number of primary branches per plant exhibited significant positive correlation with height of the plant and number of seeds per pod which was in agreement with the findings of Thorat and Gadewar (2013) and Ajayi *et al*. (2014) for height of the plant. Significant positive correlation was observed between height of the plant and number of seeds per pod supported by the results of Annasaheb, 2013 and Thouseem, 2017. The result was in contradiction to the reports of Ajayi *et al*. (2014). Crop duration exhibited significant positive correlation with 100 seed weight which was supported by the findings of Thouseem, 2017.

The significant positive genotypic correlation of number of primary branches and height of the plant with days to 50% flowering and number of seeds per pod indicate that genotypes with higher height and primary branches flowers late and produce more number of seeds per pod thereby contributing to seed yield. Hence these traits can be considered in indirect selection for seed yield. The negative significant genotypic correlation between crop duration, 100 seed weight and number of pods per plant imply that genotypes with longer duration and greater seed weight produces lesser number of pods per plant.

Screening for shade tolerance can be done by utilizing the parameters which largely contribute to yield variation. Greater pod number per plant, higher specific leaf weight, higher leaf area ratio and lower leaf area duration was found to be contributing to yield and hence can be used as desirable characters for screening genotypes for higher yield under partial shade in mungbean (Abilay and Lantican, 1982). According to Hossain *et al*. (2017), characters contributed to better tolerance of shade tolerant genotypes under low light stress were higher pods per plant, higher seeds per pod, greater seed size and better seed yield per plant.

In the present study, the parameters *viz*., higher number of pods per plant, higher number of seeds per pod, greater harvest index, higher LAD at flowering and higher CGR at flowering were found to be positively contributing to seed yield, hence can be used as desirable characters for identifying shade tolerant genotypes in cowpea. Highest seed yield per plant was observed for the vaiety Sreya (T2) followed by the genotypes CHESCP-03, CHESCP-19, KYLMVU-6, CHESCP-17 and CHESCP-32 which were on par. It was revealed that the genotypes CHESCP-03 (late), CHESCP-17 (medium) and CHESCP-32 (medium) had shade tolerance parameters coupled with higher yield under partial shade. The genotype CHESCP-03 had higher harvest index, greater number of pods per plant and seeds per pod and CHESCP-17 possessed higher CGR at flowering coupled with higher harvest index and greater number of pods per plant which contributed to shade tolerance. Genotype CHESCP-32 exhibited comparatively higher LAD at flowering, higher CGR at flowering, higher harvest index and greater number of seeds per pod. Under partial shade, the variety Sreya recorded highest seed yield and CHESCP-19 and KYLMVU-6 recorded yield on par with the shade tolerant genotypes identified, despite low values for parameters associated with shade tolerance. This shows that there is scope for improving the yield of Sreya under shaded condition by incorporating shade tolerance characters by hybridization.

5.4.4. Path analysis

Correlation of yield and its component characters alone does not provide precise information on the contribution of these characters on yield and is inadequate to interpret the cause and effect. Path coefficient analysis splits the correlation coefficient into measures of direct and indirect effects of independent characters on yield. Thus it aids in conforming whether the correlation of component characters on yield is due to their direct effect or indirect effect *via* other characters. There exists true relationship between the component character and yield, if the correlation of that character on yield is due to direct effect and direct selection can be done for that trait. If the correlation is due to indirect effect of the character through another component character, indirect selection through that trait will be rewarding.

In the present investigation, eight characters significantly correlated with seed yield were taken for path analysis. Among them maximum positive direct effect on seed yield per plant was observed for number of pods per plant followed by harvest index and crop duration. Positive but low direct effect was recorded for number of seeds per pod whereas negligible positive direct effect was recorded for CGR at flowering and days to 50% flowering. LAD at flowering and protein content exhibited negative negligible direct effect. The findings are supported by concurrent reports on number of pods per plant (Nakawuka and Adipala, 1999; Lesly, 2005; Nagalakshmi, 2009; Kumari *et al.*, 2010; Bhardu and Navale, 2011; Nwofia *et al.*, 2012; Dinesh *et al.*, 2017; Thouseem, 2017; Vu, 2017 and Yadav and Rajasekhar, 2019), number of seeds per pod (Nakawuka and Adipala, 1999; Lesly, 2005; Nagalakshmi, 2009; Manggoel *et* *al*., 2012; Dinesh *et al*., 2017; Thouseem, 2017 and Vu, 2017), days to 50% flowering (Nagalakshmi, 2009; Kumari *et al*., 2010; Santos *et al*., 2014; Sharma *et al*., 2017; Walle *et al*., 2018 and Yadav and Rajasekhar, 2019) and protein content (Sharma *et al*.,2017).

Harvest index had high positive direct effect on seed yield per plant. However it also exerted highest indirect effect *via* number of pods per plant. It was in agreement with the findings of Lesly (2005), Sharma *et al*. (2017), Vu (2017), Walle *et al*. (2018) and Yadav and Rajasekhar (2019), who also reported positive direct effect of harvest index on seed yield.

CGR at flowering also showed positive direct effect on seed yield which was in conformity with the results obtained by Sarvamangala (2005) and it also exerted high indirect effect *via* number of pods per plant.

In this study, positive direct effect of crop duration on seed yield was observed which was supported by the findings of Thouseem, 2017. It was interesting to note that the direct effect of this character on seed yield was even more than its genotypic correlation coefficient. The correlation value was reduced probably due to its negative indirect effect *via* number of pods per plant.

Therefore, the present study revealed that direct selection for the characters number of pods per plant, number of seeds per pod, crop duration and harvest index can bring about improvement in seed yield in cowpea under partial shade.

CHESCP-03

CHESCP-17

CHESCP-32

Plate 9. Shade tolerant genotypes

5.4.5. Genetic divergence analysis

The genetic divergent studies by Mahanalobis D^2 statistics following Tocher's method was done. The genotypes were grouped into nine distinct non-overlapping clusters based on the characters *viz*., days to 50% flowering, number of primary branches, height of the plant, number of pods per plant, number of seeds per plant, 100 seed weight, crop duration, harvest index, LAD at flowering, CGR at flowering, protein content and seed yield per plant. This suggests that the material of study can be used as a good source for selecting diverse parents for hybridization programme as ample genetic variability is present among the genotypes. The existence of high genetic diversity in cowpea was also supported by the findings of Pandey, 2007; Annasaheb, 2013; Animasaun *et al*., 2015; Khan and Viswanatha, 2016 and Vu, 2017.

The experimental material used in the study comprised of thirty three grain cowpea genotypes from seven different eco-geographical regions (Table 1). It is evident from the clustering pattern that genotypes from different geographical regions were grouped into same cluster and those from same source were grouped into different clusters, indicating non-existence of any relationship between genetic diversity and geographical distribution. According to Murthy and Arunachalam (1966), greater genetic diversity could be caused by genetic drift and selection in different environment than geographical distance. Similar observation was also reported by Nagalakshmi (2009), indicating that the best criteria for selecting parents for hybridization programme is genetic divergent values rather than geographical isolation as stated by Annasaheb (2013). In contrary, because of the close genetic backgrounds of genotypes, Viswanatha and Yogeesh (2017) suggested not to consider the genotypes from same regions for hybridization.

In the current study, the clustering pattern revealed that Cluster II was the largest with 10 genotypes followed by cluster I and cluster V (8 genotypes each), cluster III (2 genotypes) and clusters IV, VI, VII, VIII, IX which were solitary. The maximum intra cluster distance was recorded among the genotypes of cluster V (16.6) and lowest in cluster III (9.09). Maximum inter cluster distance was observed between the genotypes of the clusters III and IX (32.27) followed by clusters VI and IX (31.9).

Therefore selecting parents for hybridization programme from most divergent clusters i.e., cluster III (Hridya and KYLMVU-10) and cluster IX (Pant Lobia-4) could produce transgressive segregants having high seed yield under partial shade.

The cluster means for the twelve characters were estimated and significant differences were observed among the clusters. From the data it was evident that cluster I had the lowest values for number of pods per plant (4.43) and seed yield per plant (4.37). Cluster II exhibited highest mean value for height of the plant (50.6) whereas cluster III had lowest values for days to 50% flowering (37.33), number of pods per plant (11.18), 100 seed weight (5.43), crop duration (52.67) and LAD at flowering (7.21). Cluster IV had lowest values for harvest index (0.25) and CGR at flowering (0.52). Cluster V exhibited highest mean values for LAD at flowering (37.87) whereas lowest values for protein content (31.56). Cluster VI was characterized with highest mean values for most of the characters *viz*., days to 50% flowering (64.00), number of primary branches (9.54), number of pods per plant (15.25), number of seeds per pod (14.97), harvest index (0.77) and protein content (35.31). Cluster VIII showed highest values for crop duration (99.33) and seed yield per plant (25.22). However cluster IX exhibited higher values for 100 seed weight (18.79) and CGR at flowering (4.12) and lowest values for number of primary branches per plant (4.82) and height of the plant (41.63).

Considering the cluster means in table 12, the various clusters which can provide desirable parents for the improvement of characters under partial shade are listed below:

Table 14: Source clusters of desirable parents

Sl. No.	**Characters**	**Source Clusters**
1.	Days to 50% flowering (Early)	III, IX
2.	Number of pods per plant (Maximum)	VI, VIII
3.	Number of seeds per pod (Maximum)	VI, V, VIII
4.	Crop duration (Early)	III, VI, IV

5.	Harvest index (Maximum)	VI, VII
6.	Seed protein content (Maximum)	VI, IX, II
7.	Seed yield per plant (Maximum)	VIII, VI,VII
8.	LAD (Minimum)	III , VII
9.	CGR (Maximum)	IX , V

From the analysis, it was clear that the trait 100 seed weight (22.92%) had maximum relative contribution to genetic divergence followed by CGR at flowering (21.59%), protein content (20.45%) and seed yield per plant (14.58%) and traits *viz*., days to 50% flowering and height of the plant have given nearly no contribution to genetic divergence. The findings were supported by the results obtained by Annasaheb (2013); Khan and Viswanatha (2016); Kamara *et al*. (2017); Vu (2017); Aramendiz *et al*. (2018) and Purohit *et al*. (2020).

The present study revealed that, the long duration variety Sreya recorded highest seed yield under partially shaded condition. The medium duration genotypes CHESCP-03, CHESCP-17 and CHESCP-32 recorded higher yield which are on par and also have high shade tolerance characters, hence suited to the coconut based homesteads. Genotypes CHESCP-19 and KYLMVU-6 are late in duration and recorded yield on par with the shade tolerant genotypes CHESCP-03, CHESCP-17 and CHESCP-32. Among the early duration types, Subhra recorded the highest yield making it suitable to areas where short duration varieties are preferred. Sreya, Subhra, CHESCP-19 and KYLMVU-6 expressed low values for parameters associated with shade tolerance. So there is scope for improving the yield of these genotypes by hybridization with those having shade tolerance. Subhra and CHESCP-21 were found to be superior for protein content. As quality of a pulse variety is determined by the protein content, these varieties can be used as parents in quality improvement programmes. The superior genotypes identified in the study can be recommended for future breeding programs.

Summary

6. SUMMARY

The present study on genetic variability studies in grain cowpea (*Vigna unguiculata* (L.) Walp.) was carried out at Farming Systems Research Station, Sadanandapuram, Kottarakara during 2019 – 2020 with the objective to evaluate and select shade tolerant grain cowpea genotypes suited to the coconut based homesteads.

The 33 grain cowpea genotypes were collected from research stations under KAU, AICRP centre and agricultural universities of different states. The genotypes denoted by treatment numbers T1 to T33 included thirteen released varieties and twenty accessions from different geographical locations. These were evaluated in coconut based homestead garden where coconuts are of age 30 – 40 years, in randomized block design replicated thrice. The seeds were sown on raised beds of (3 x 1.5) m^2 size at a spacing of 30 cm x 15 cm and cultural operations and plant protection measures were adopted as per the "Package of Practices" of Kerala Agricultural University.

The average light intensity in the experimental field was recorded to be 0.719 W/m^2 resulting in shade intensity of 33.49 per cent. The genotypes were evaluated for 35 characters including biometric characters, physiological characters associated with shade tolerance and quality character of seed. The genotypes showed significant differences for all the characters studied as revealed by analysis of variance. The variety Sreya (26.55g) recorded the highest seed yield per plant which is significantly higher than all other genotypes. It was followed by the genotypes *viz.*, CHESCP-03 (18.99g), CHESCP-19 (18.95g), KYLMVU-6 (18.37g), CHESCP-17 (17.58g) and CHESCP-32 (15.82g) which were on par and the genotype IC 300039 (1.87g) recorded the lowest seed yield per plant. Highest protein content was noted for the variety Subhra (26.57%) which was on par with CHESCP-21 (26.33%) and lowest protein content was observed for CHESCP-07 (17.68%).

Genetic parameter analysis was performed for twelve characters and for all the characters PCV values were higher than GCV values indicating the influence of environment. PCV and GCV were highest for seed yield per plant (g) and minimum for seed protein content. High GCV with correspondingly high values of PCV was observed for number of primary branches, number of pods per plant, 100 seed weight, harvest index, LAD at flowering and CGR at flowering. Moderate PCV and GCV values were observed for days to 50% flowering, height of the plant, number of seeds per pod and crop duration. Heritability was high for all the twelve characters and genetic gain was high for all the characters except days to 50% flowering and protein content. High heritability coupled with high genetic advance was observed for number of primary branches per plant, height of the plant, number of pods per plant, number of seeds per pod, 100 seed weight, crop duration, harvest index, LAD at flowering, CGR at flowering and seed yield per plant.

The correlation studies revealed positive correlation of the characters days to 50% flowering, number of pods per plant, number of seeds per pod, crop duration, harvest index, LAD at flowering, CGR at flowering and protein content with seed yield. It indicates that selection for genotypes which are late flowering and having longer crop duration can simultaneously improve yield in cowpea under partial shade. There existed significant positive genotypic correlation of number of primary branches and height of the plant with days to 50% flowering and number of seeds per pod indicating that genotypes with higher height and primary branches flowers late and produce more number of seeds per pod thereby contributing to seed yield. Hence these traits can be considered in indirect selection for seed yield. There was negative significant genotypic correlation between crop duration, 100 seed weight and number of pods per plant which implies that genotypes with longer duration and greater seed weight produces lesser number of pods per plant.

The path analysis provides information on contribution of traits by partitioning the total correlation into direct and indirect effects. Path analysis of the eight characters showing significant correlation with seed yield revealed high positive direct effect of the characters number of pods per plant and harvest index on seed yield. High indirect effect on seed yield was observed for CGR at flowering through number of pods per plant. Therefore, the present study revealed that direct selection for the characters number of pods per plant, number of seeds per pod, crop duration and harvest index can bring about improvement in seed yield in cowpea under partial shade.

Cluster analysis aids in the selection of genetically divergent parents for hybridization programme which results in greater heterosis. Cluster analysis using Mahanalobis D^2 statistic following Tochers' method grouped the 33 genotypes into nine clusters. From the clustering pattern it was evident that genotypes from different geographical regions were grouped into same cluster and those from same source were grouped into different clusters, indicating non-existence of any relationship between genetic diversity and geographical distribution.

Cluster II was the largest with 10 genotypes followed by cluster I and cluster V (8 genotypes each), cluster III (2 genotypes) and clusters IV, VI, VII, VIII, IX which were solitary clusters. Highest intra cluster distance was recorded among the genotypes of cluster V and lowest in cluster III whereas highest inter cluster distance was observed between the genotypes of the clusters III and IX followed by clusters VI and IX. Considering the relative contribution of different traits to divergence indicated that the trait 100 seed weight (22.92%) had maximum relative contribution followed by CGR at flowering (21.59%), protein content (20.45%) and seed yield per plant (14.58%) and traits *viz*., days to 50% flowering and height of the plant have given nearly no contribution to genetic divergence.

Screening for shade tolerance can be done utilizing the parameters which largely contribute to yield variation. Based on the results, parameters *viz*., number of pods per plant, number of seeds per pod, harvest index, LAD at flowering and CGR at flowering were found to be contributing to seed yield, hence can be used as desirable characters for identifying shade tolerant genotypes in cowpea.

The present study revealed that, the long duration variety Sreya recorded highest seed yield under partially shaded condition. The genotypes CHESCP-03, CHESCP-17 and CHESCP-32 are medium in duration with shade tolerance and higher yield, hence suited to the coconut based homesteads. Genotypes CHESCP-19 and KYLMVU-6 are late in duration and recorded yield on par with the shade tolerant genotypes CHESCP-03, CHESCP-17 and CHESCP-32. Among the early duration types, Subhra recorded the highest yield making it suitable to areas where short duration varieties are preferred. Sreya, Subhra, CHESCP-19 and KYLMVU-6 expressed low values for parameters associated with shade tolerance. So there is scope for improving the yield of these genotypes by hybridization with those having shade tolerant characters. Subhra and CHESCP-21 were found to be superior for protein content. As quality of a pulse variety is determined by the protein content, these genotypes can be used as parents in quality improvement programmes. The superior genotypes identified in the study can be recommended for future breeding programs.

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GENETIC VARIABILITY STUDIES IN GRAIN COWPEA (*Vigna unguiculata* (L.) Walp.)

by

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ABSTRACT

The study entitled “Genetic variability studies in grain cowpea (*Vigna unguiculata* (L.) Walp.) was carried out at Farming Systems Research station, Sadanandapuram during December, 2019 – March, 2020 with the objective to evaluate and select shade tolerant grain cowpea genotypes suited to the coconut based homesteads.

The 33 grain cowpea genotypes collected from research stations under KAU, AICRP centre and agricultural universities of different states were evaluated in coconut based homestead garden where coconuts are of age 30 – 40 years, in randomized block design replicated thrice. The seeds were sown on raised beds of (3 x 1.5) m^2 size at a spacing of 30 cm x 15 cm and cultural operations and plant protection measures were adopted as per the “Package of Practices Recommendations: Crops 2016” of Kerala Agricultural University.

The average light intensity in the experimental field recorded was 0.719 W/m^2 resulting in shade of 33.49 per cent. The genotypes were evaluated for biometric and physiological characters associated with shade tolerance and quality character of seed. The genotypes showed significant differences for all the characters studied. Genetic parameter analysis was performed for twelve characters and for all the characters PCV values were higher than GCV values indicating the influence of environment. The phenotypic and genotypic coefficients of variation were maximum for seed yield per plant and minimum for protein content. Heritability was high for all the twelve characters and genetic gain was high for all the characters except days to 50% flowering and protein content.

The correlation studies revealed positive correlation of the characters days to 50% flowering, number of pods per plant, number of seeds per pod, crop duration, harvest index, LAD at flowering, CGR at flowering and protein content with seed yield. The path analysis provides information on contribution of traits by partitioning the total correlation into direct and indirect effects. Path analysis of the eight characters showing significant correlation with seed yield revealed high positive direct effect of the characters number of pods per plant and harvest index on seed yield.

High indirect effect on seed yield was observed for CGR at flowering through number of pods per plant.

Cluster analysis aids in the selection of genetically divergent parents for hybridization programme which results in greater heterosis. Cluster analysis using Mahanalobis D^2 statistic following Tocher’s method grouped the 33 genotypes into nine clusters. Cluster II with 10 genotypes was the largest followed by cluster I and cluster V (8 genotypes each), cluster III (2 genotypes) and clusters IV, VI, VII, VIII, IX which were solitary clusters. Highest intra cluster distance was recorded among the genotypes of cluster V and lowest in cluster III whereas highest inter cluster distance was observed between the genotypes of the clusters III and IX followed by clusters VI and IX.

The present study revealed that the variety Sreya recorded highest seed yield under partially shaded condition. The genotypes CHESCP-03, CHESCP-17 and CHESCP-32 are medium in duration with shade tolerance and higher yield, hence suited to the coconut based homesteads. Among the early duration types, Subhra recorded the highest yield. Genotypes CHESCP-19 and KYLMVU-6 recorded yield on par with the shade tolerant genotypes CHESCP-03, CHESCP-17 and CHESCP-32. Subhra and the late duration varieties Sreya, CHESCP-19 and KYLMVU-6 recorded low values for shade tolerant parameters and there is scope for improving the yield by hybridization with shade tolerant varieties. Subhra and CHESCP-21 were found to be superior for protein content. As quality of a pulse variety is determined by the protein content, these genotypes can be used as parents in quality improvement programmes. The superior genotypes identified in the study can be recommended for cultivation and future breeding programs.