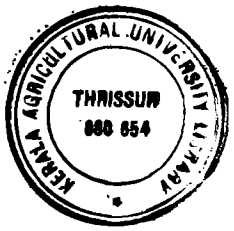
GENETIC ANALYSIS IN HORSEGRAM (*Dolichos biflorus* Linn.) WITH SPECIAL REFERENCE TO PHOTOPERIODIC RESPONSE

By

SREENIVASAN, E.



THESIS

Submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding and Genetics
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR-680 656
KERALA, INDIA

2001

DECLARATION

I hereby declare that this thesis entitled " **GENETIC ANALYSIS IN HORSEGRAM (*Dolichos biflorus* Linn.) WITH SPECIAL REFERENCE TO PHOTOPERIODIC RESPONSE** " is a bonafide record of research work done by me during the course of research and that 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.

Vellanikkara

27 . 10 . 2000

SREENIVASAN, E.

DR. K.PUSHKARAN
Professor & Head
Dept. of Plant Breeding & Genetics
College of Horticulture

CERTIFICATE

Certified that this thesis entitled " **GENETIC ANALYSIS IN HORSEGRAM (*Dolichos biflorus* Linn.) WITH SPECIAL REFERENCE TO PHOTOPERIODIC RESPONSE** " is a record of research work done independently by **Mr. Sreenivasan, E.**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Vellanikkara

Date: 27 . 10 . 2000

DR. K.PUSHKARAN

Chairman, Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr. Sreenivasan, E.**, a candidate for the degree of Doctor of Philosophy in Agriculture with major in Plant Breeding and Genetics, agree that the thesis entitled "**GENETIC ANALYSIS IN HORSEGRAM (*Dolichos biflorus* Linn.) WITH SPECIAL REFERENCE TO PHOTOPERIODIC RESPONSE** " may be submitted by Mr. **Sreenivasan, E.**, in partial fulfilment of the requirements for the degree.

27/11/01

DR. K.PUSHKARAN
(Chairman, Advisory Committee)
Professor & Head,
Dept. of Plant Breeding & Genetics
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur

Dr. ACHAMMA OOMMEN
(Member, Advisory Committee)
Professor
Dept. of Plant Breeding & Genetics
College of Horticulture,
Kerala Agricultural University
Vellanikkara, Thrissur

Dr. V.K.G. UNNITHAN
(Member, Advisory Committee)
Associate Professor
Dept. of Agricultural Statistics
College of Horticulture,
Kerala Agricultural University
Vellanikkara, Thrissur

Dr. V.V. RADHAKRISHNAN
(Member, Advisory Committee)
Associate Professor
Dept. of Plant Breeding & Genetics
College of Horticulture,
Kerala Agricultural University
Vellanikkara, Thrissur

Dr. P.V. BALACHANDRAN
(Member, Advisory Committee)
Associate Director of Research i/c
Regl. Agrl. Res. Station
Kerala Agricultural University
Pattambi ,
Palakkad Dist.

27/11/2001

EXTERNAL EXAMINER
Dr THYAGARAJAN.
Prof & HEAD
PADDY BREEDING STATION
COIMBATORE.

ACKNOWLEDGEMENTS

With all respect, I express my deep sense of gratitude and indebtedness to ***Dr. K. Pushkaran****, Professor & Head, Department of Plant Breeding and Genetics and Chairman of my advisory committee, for suggesting the problem for research and for providing valuable guidance, technical advice, keen interest and constant encouragement with unfailing patience, throughout the period.*

My thanks are due to ***Dr. Achamma Oommen****, Professor, Department of Plant Breeding and Genetics and member of my advisory committee for the kind care and encouragement rendered in various stages of this research.*

I also place my respectful gratitude to ***Dr.V.K.G. Unnithan****, Associate Professor, Department of Agricultural Statistics and member of my advisory committee, for the technical advice, critical suggestions and whole-hearted help rendered in statistical analysis of data and interpretation of the results.*

I am in dearth of words to express my deep sense of gratefulness and indebtedness to ***Dr. V.V. Radhakrishnan****, Associate Professor, Department of Plant Breeding and Genetics and member of my advisory committee, for the inspiration, patient encouragement and technical guidance in making this endeavor into reality. His timely helps and advises imparted immense mental and physical strength to make this venture a success.*

I wish to keep on record, my sincere thanks to ***Dr. P.V. Balachandran****, Associate Director i/c of Regional Agricultural Research Station, Pattambi and member of my advisory committee for the constant inspiration and for providing facilities for conduct of the field experiments.*

I am grateful to ***Dr. K.M.N. Namboodiri****, Professor (Retd.),* ***Dr. N. Krishnan Nair****, Associate Director of Research (Retd.) and* ***Dr. T.E. George****, Associate Professor, who provided valuable help and advices as members of my advisory committee.*

My sincere thanks are also due to ***Dr. K.K. Ibrahim****, Associate Professor, Department of Plant Breeding and Genetics, for the technical advices on analysis of data and interpretation of results. With all love and affection, I acknowledge the help and encouragement rendered by* ***Sri. A.V. Santhosh Kumar****, Assistant Professor, K.V.K., Pattambi and* ***Dr. Jiji Joseph,*** *Assisstant Professor, College of Agriculture, Nileshwar, in the computer processing, data analysis and interpretation of results.*

I have great pleasure to place on record, my sincere gratitude to ***Dr. P.V. Prabhakaran****, Associate Dean i/c and other* ***faculty members*** *of College of Horticulture, Vellanikkara for providing excellent teaching and other facilities during my entire study period. My sincere thanks are also due to* ***all the scientists, other staff members and labourers*** *of Regional Agricultural Research Station, Pattambi, for the co-operation and support they rendered in conduct of the field experiments.*

It is my pleasant privilege to express my respectful gratitude to ***Dr. A.I. Jose****, Director of Extension of Kerala Agricultural University and former Associate Dean of College of Horticulture, Vellanikkara, for providing all facilities for smooth conduct and completion of the research programme*

I owe a lot to ***my wife and my sons,*** *who had to sacrifice a lot of joyous occasions to be with me for making this venture fruitful. I also wish to express my sincere gratitude to my* ***parents, brother and sisters*** *for the warm blessings they showered at every stage of my study. I accord my sincere thanks to my colleagues* ***Mr. Jagdish Kumar, Mr. Purushothaman, Mrs. Anitha, Dr. Narayanan Kutty, Dr. Ahammed, Dr. Leena Kumary and others*** *who rendered timely help and advices in various stages of the work.*

I express my heartfelt thanks to ***Smt. Joicy,*** *Programmer, Department of Agricultural Statistics, College of Horticulture, Vellanikkara, for the help rendered in computer analysis of the data and to* ***Mr. Satheesan****, University photographer, who helped in preparation of the photographs and transparencies.*

I am grateful to the ***Kerala Agricultural University*** *for granting me study leave and part-time research facilities for the programme and to* ***NBPGR, Regional Stations at Vellanikkara and Akola*** *for supplying the seed material of horsegram germplasm accessions used in the study.*

Again, I thank to one and all those who helped me all the way through, for the successful completion of this endeavor. Finally I bow my head before the God Almighty for providing mental and physical strength for successful completion of the programme and submission of thesis.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

INTRODUCTION

Horsegram (*Dolichos biflorus* Linn.; Syn. *D. uniflorus* Lam., *Macrotyloma uniflorum* (Lam.) verde.) belonging to the family Fabaceae and sub-family Faboidae, is a traditional, hardy, annual, tropical grain legume extensively grown in India. Grain legumes in general play a key role in the agrarian economy. Nutritionally they serve as an inexpensive source of dietary proteins that complements cereal proteins. In agriculture, it can restore soil fertility by fixation of atmospheric nitrogen to the tune of about 35 to 40 Kg per hectare, through symbiotic bacteria living in its root nodules. The crop residues also add substantial amount of organic matter to enrich the soil. Horsegram is the poor man's pulse crop and is well known for its relatively low cost of cultivation, hardiness and adaptability to poor soils and adverse climatic conditions that are unsuitable for most of the other crops.

This legume has been under cultivation in India since pre-historic times. It is an extensively grown pulse crop of peninsular India. It ranks as the third among Indian pulses in area. Horsegram is cultivated in about 1.7 million hectares in India, which accounts for 7.6 per cent of the total cultivated area under pulses in the country. The southern states have the major horsegram growing areas in the country. The total annual production of horsegram is about 0.84 million tonnes which constitutes about 7 per cent of total annual legume production in the country. (Narayanan and Balasubramanian, 1991). The productivity of the crop is rather poor, compared to other grain legumes. At present, the national average productivity for horsegram is 494 kg/ha as against 539 kg/ha of all the grain legumes as a whole.

From the foregoing it is evident that horsegram is one of the potential pulse crops in the country that has not been fully exploited to reduce the gap between production and requirement of pulses. Systematic research efforts to evaluate the

contribution of different production factors to the improvement of grain yield in the crop are yet to be carried out. Information on these aspects needs to be generated to evolve economical production practices for popularisation among farmers. So far very little efforts have been made to have an in-depth study of this crop with a view to identify its role in the cropping system and its relevance in the socio-economic aspects of the farming community.

In Kerala horsegram was popular as a traditional rabi crop, extensively grown in terraced uplands (palliyals) and mundakan (II^{nd} crop paddy) nursery fields. Almost all the traditional varieties popular in the State are photosensitive (short day types) since they evolved under such cropping situations that are prevalent in rabi season. These cultivars generally flower only during the month of November or December, which coincides with short days. In contrast to this, many of the other states where horsegram is a kharif season crop, day-neutral genotypes have evolved and established. In southern districts of the Kerala, there was a practice of raising horsegram along with tapioca. Later on when irrigation facilities improved, the cropping sequences and systems changed and most of the farmers turned to other more remunerative crops.

At present, Kerala has to depend on other States for bulk of its consumption requirements in horsegram. Hence there is enough scope for popularising cultivation of the crop in the State in non-traditional seasons and situations. Some of the potential areas that offer scope for expansion of pulses cultivation in the State are the summer rice fallows and interspaces of perennial gardens. Possibility of mixed cropping with other annual crops also needs to be explored. At present other crops like cowpea, greengram, blackgram, sesame, groundnut, vegetables etc. are cultivated in about 12,000 ha area available as summer rice fallows. However considerable area are still left fallow, due to scarcity of adequate residual soil moisture. Horsegram can be successfully introduced to these areas. But majority of

traditional cultivars of the State are short day plants and hence do not flower or successfully set pods during summer.

As a hardy legume crop, horsegram has an array of favorable points from the point of view of farmers and consumers in Kerala. It is a short-duration crop showing appreciable ability to withstand prolonged drought and cost of irrigation can be saved to a great extent. Incidence of pests and diseases is very meager and plant protection expenses are hence minimum for the crop. It shows good adaptability to a wide range of soils. As such, not much expensive care and management is needed for its cultivation. Thus the general features of horsegram, except the photosensitive nature of local traditional cultivars, make it an apt crop for summer rice fallows.

Hence, it is worth to attempt for varietal improvement studies in the crop so as to evolve day-neutral high yielding varieties specifically suitable for such cropping situations, that also combine early maturity, high protein content and stability over seasons, through evaluation of available germplasm and adopting suitable breeding techniques. An ideal recombination of these features can extend cultivation of horsegram to non-traditional seasons and situations. Cleistogamy, minute size of flowers, excessive shedding of flowers and young pods, poor seed set on crossing etc. limits improvement of the crop through breeding procedures that involve hybridization.

For achieving genetic improvement in the desired direction as described above, the present investigation was taken up with the following objectives:

- Collection of horsegram genetic resources from diverse sources and their evaluation in rabi and summer (rice fallows) for assessing genetic variability in qualitative, quantitative and physiological characters

- Association analysis to study inter-relationship among seed yield and component traits and path coefficient analysis to assess the direct and indirect contribution of related traits on seed yield

- Study of genetic divergence in relation to geographical diversity, through D^2 analysis and clustering of genotypes based on genetic distances so that it can serve as a guideline in selection of parents for crossing.

- Evaluation of promising genotypes in rabi (traditional) and summer seasons to identify stable high-yielding genotypes suitable for both situations.

- Study of floral biology and standardisation of techniques for selfing and crossing, and undertaking hybridisation between selected genotypes belonging to day-neutral and photosensitive types, in order to study the combining ability and heterosis using diallel analysis.

- To understand the nature of gene action involved in the inheritance of traits like photoperiodic response and seed colour, by evaluation of F_1 and F_2 generations along with parents.

- Selection of desirable recombinants in F_2 for further studies and yield improvement.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Horsegram is a traditional tropical grain legume, well known for its hardiness and adaptability to poor soils and adverse climatic conditions that are unsuitable for most other crops. It is distributed throughout the tropics and is reported to be cultivated in India, Myanmar, Nepal, Malaya, Mauritius, Sierra Leone, Transval and West Indies and grows wild in the eucalyptus forests of Queensland (Sundararaj and Thulasidas, 1976). It has been under cultivation in India since pre-historic times and according to Vavilov (1951) India is its primary centre of origin. But Dana (1976) reported that out of 240 species that are related to horsegram, only 23 are found in India and the remaining ones are located in Africa. Therefore Dana claims that Africa is the primary centre of origin of this crop. According to recent classification by West Phal (1974) horsegram belongs to the sub-family Faboidae of family Fabaceae and the scientific name has been changed from *Dolichos biflorus* Linn. to *Macrotyloma uniflorum* (Lam.) verde.

India is the largest pulse producing nation with 35% of world area and 27% of production. The country produces nearly 15 million tones of pulses from an estimated 22.6 million ha. The productivity of pulses in the country is 650 kg/ha, as against the world average of 772 kg/ha. The requirement of pulses is projected to be around 19 million tons (MT) by 2010 AD, 23 MT by 2020 AD and 24-36 MT by 2030 AD. (National Commission of Agriculture). It means that about 75% increase in production is required by 2030 and the present productivity has to be raised to 990 Kg/ha from the present level of 650 Kg/ha, since scope for further expansion of area under pulses is limited (Asthana, 2000). Considering the raising population and increase in demand for pulses, there is urgency for enhancing the productivity of all pulse crops. Horsegram is one of the potential pulse crops in the country that has not been fully exploited in the efforts to reduce the gap between requirement and production. It serves as a multipurpose crop providing protein rich (18 to 29%)

human food, feed and fodder for animals and green manure that enrich soil fertility (Gohokar, 1983). It is a cheap source of proteins, vitamins, calcium and iron (Katiyar, 1984). Horsegram is a rich source of urease. Seeds are well known for its medicinal (diuretic) properties. It is said to be good for patients suffering from urinary and kidney problems. (Naraynan and Balasubramanian, 1991.)

Horsegram is extensively grown in peninsular India and is cultivated up to 5000 feet elevation of Himachal Predesh and Nepal. At present, it ranks the third among Indian pulses in area, covering about 1.7 million hectares that accounts for 7.6 per cent of the total cultivated area under pulses in the country. However recent surveys indicate that its cultivation has been drastically reduced to nearly 0.6 million hectares, indicating its replacement by other crops. The Southern States are the major horsegram growing states in the country. In many parts of Tamil Nadu, horsegram is grown as a preparatory crop in newly reclaimed land to improve soil fertility by fixing nitrogen and increasing organic matter status through shed leaves (Sen and Bhowal, 1959). Usually two or three crops are raised before the land is put under ragi, sorghum or other grain crops.

About 93 per cent of the total area under horsegram in the country is in six states viz., Karnataka, Maharashtra, Orissa, Andra Pradesh, Madhya Pradesh and Tamil Nadu. In Karnataka about 34 per cent of the area under grain legumes is sown to horsegram. In Tamil Nadu the area under horsegram is about 18 per cent and in Maharashtra, Orissa, Andhra Pradesh and Madhya Pradesh, it is cultivated in about 9 per cent of the total grain legumes growing area. (Naraynan and Balasubramanian, 1991.)

Horsegram is cultivated both in kharif and rabi seasons. In Maharashtra, Madhya Pradesh, Bihar and Tamil Nadu, it is cultivated during kharif season. While in Orissa and Kerala it is traditionally grown as a rabi crop. In Karnataka and Andhra Pradesh it is grown during kharif and rabi seasons in different locations. It

thrives well in almost any type of soil, except highly alkaline soils. Light sandy soils are the best for the crop. It is also grown extensively on red loams, black cotton soils, and stony and gravely upland soils of Deccan, without much preparatory tillage

India produces about 0.84 million tones of horsegram annually, which constitutes about 7 per cent of total grain legume production in the country. However the contribution of horsegram to the total grain legume production is about 28 per cent in Karnataka, 18 per cent in Tamil Nadu and around 10 per cent in Maharashtra, Orissa, Andhra Pradesh and Madhya Pradesh (Naraynan and Balasubramanian, 1991). The productivity of the crop also is rather poor. The national average figure for productivity of horsegram is 494 kg/ha against 539 kg/ha for grain legumes as a whole. The productivity is better in Orissa, Bihar, West Bengal,Tamil Nadu and Kerala, whereas in other States, it is below the national average (Patel *et al.*, 1995).

2.1. Studies on genetic resources

In the course of crop evolution under domestication, there had been a continuous narrowing down of the spectrum of plant species. This narrowing actually occurred in three phases, starting with the ice ages when only ten percent of the 10 million species of living organisms could survive. The second phase started with the spread of Agriculture (Neolithic revolution), wherein the narrowing above species level was however compensated by an increase in varietal diversity within crops. Out of the 300,000 species of flowering plants, only 200 have been domesticated and today only eight cereal species (wheat, rice, maize, barley, oats, sorghum, millet and rye) meets about 75% of the requirements of food for human consumption. The third phase of narrowing started with scientific plant breeding, which lead to large-scale genetic erosion through displacement of traditional cultivars having broad genetic basis, by the high-yielding varieties having narrow genetic base. This trend towards uniformity increased the genetic vulnerability of

major crops to pests and diseases because of the narrow genetic base of new varieties, leading to large-scale disasters. The need for conservation of genetic diversity was thus recognized about 50 years ago. Today, over one million accessions of the major crops and their wild relatives are stored in nearly 100 seed banks.

2.1.1. Variability

A wealth of variability is the prime requirement in any crop improvement programme. Greater the diversity in a crop, better are the chances of evolving desirable plant types. Genetic variability is the real measure for diversity concealed in a population, while the expressed variability or phenotypic variability is due to genotype, environment and their interaction. Thus a detailed study on the extent of variability available for different characters associated with yield, forms the initial step in any breeding programme.

Recognizing the importance of horsegram as an under-exploited multiutility crop, the National Bureau of Plant Genetic Resources (NBPGR), has gathered and maintained sizeable collections of germplasm material at New Delhi (more than 500 accessions) Akola, Maharashtra (about 650 accessions) and Trichur (about 500 accessions). The information generated from evaluation of these materials have been documented (Patel *et al.*, 1995). The Tamil Nadu Agricultural University also maintains about 320 accessions at its Regional Research Station at Paiyur. At present the Indian Council of Agricultural Research (ICAR), New Delhi co-ordinates the scientific research in the crop as part of the All India Co-ordinated Research Project on Arid legumes.

Horsegram possesses wide range of variability that can be exploited for evolving high yielding plant types. Many reports are available about the variability, heritability, genetic advance, correlation between yield and associated characters,

path analysis and genetic divergence in the crop, mostly confined to the usual season of cultivation. However, information regarding the inheritance pattern of photoperiodic response among the crop cultivars in relation to grain yield and duration, is limited. Not much works have been reported regarding hybridization, combining ability, heterosis and gene action in the crop. The available literature on genetic resources and variability analysis in horsegram and some of the works in other related pulse crops, are reviewed below: -

Horsegram

Wide range of variability for traits like plant height, number of branches, number of nodes, number of pods, days to flowering, days to maturity, pod length, pod yield and grain yield had been reported in horsegram by various workers like Sreekantaradhya *et al.*(1975), Aggarwal and Kang (1976), Shivashankar *et al.*(1977), Ramakrishnan *et al.*(1978), Balan (1980), Ganeshaiah *et al.*(1982), Suraiya *et al.* (1988), Singh (1990), Balan *et al.* (1991), Dobhal and Rana (1994), Rao and Nanda (1994), Sood *et al.* (1994), Savithramma *et al.* (1996), Nagaraja *et al.*(1997), Samal and Senapati (1997) and Lad *et al.* (1998).

Sreekantaradhya *et al.* (1975) obtained highest GCV values for number of nodes, followed by number of branches and number of pods. The values were moderate for seed yield and plant height and low for seeds per pod and pod length. Ganeshaiah(1980) studied 100 horsegram varieties, which showed significant variation in the 18 characters analysed. Genotypic and phenotypic variation was greatest for number of secondary branches. Balan (1980) observed maximum variability for pod number, followed by plant height and node number, which offer good scope for selection in crop improvement works. He also reported that difference between phenotypic and genotypic variance was maximum for pod number and minimum for pod length. In the case of PCV and GCV, the difference was maximum for branch number and minimum for pod length.

Borole (1984) had observed low genotypic coefficient of variance for days to maturity in the crop. Kabir and Sen (1987) also reported significant genetic differences in the six yield component traits of horsegram studied by them. Genotypic and phenotypic co-efficients of variations were highest for pod yield per plant.

According to Suraiya *et al.* (1988), pods per plant, plant height, days to 50 per cent flowering and days to maturity showed the highest, while 100 seed weight showed the lowest genotypic variance in horsegram. Studies of Swapna (1993) indicated that a large proportion of the total variability of all the traits studied, is due to genetic factors except in the case of number of seeds per pod and seed yield

Sood *et al.* (1994) observed that the magnitude of phenotypic and genotypic coefficients of variation were similar for the characters like seed yield, days to flowering, days to maturity and 100 seed weight, indicating little influence of environment in the expression of these characters.

Savithramma *et al.* (1996) who evaluated 103 horsegram genotypes during Kharif, rabi and summer seasons, observed that the difference between PCV and GCV was narrow in all the three seasons in the case of days to flowering, days to maturity, seeds per pod, 100 seed weight, threshing % and protein %, indicating less influence of environment on expression of these traits and phenotypic values will be reliable for selection. Samal and Senapati (1997) also observed wide variation for plant height pods/plant, days to 50% flowering, branches/plant and yield/plant. 100 seed weight showed minimum variance. Both GCV and PCV were low, for days to flowering, indicating less scope for selection. Influence of environment as indicated by the difference between PCV and GCV, was very low in most cases, except for number of branches/plant.

Nagaraja *et al.* (1997) reported low PCV and GCV values in the case of days to flowering and days to maturity and high PCV/GCV values in the case of primary branches. Low variability was observed for pod length and number of seeds per pod by Sreekantaradhya *et al.* (1975), Balan (1980), Balan *et al.* (1991), Savithramma *et al.* (1996) and Rao and Nanda (1994). Low GCV and PCV values were also reported for days to flowering, days to maturity and 100 seed weight by Samal and Senapati (1997) Sood *et al.* 1994, Singh (1990) Rao and Nanda (1994).

Shivashankar *et al.* (1977) studied hundred genotypes of horsegram and reported that genotypic variance was high for nodes per plant and secondary branches, moderate for pods per plant and days to flowering and low for seeds per pod. They also suggested that variations were mostly due to genetic factors.

Studies of Ganeshaiah *et al.* (1982) also revealed high GCV and PCV values for number of branches, fruit nodes and grain yield. Lowest values for GCV and PCV were for seeds per pod, days to flowering, 100 seed weight and number of pods per plant.

Cowpea

In cowpea, high variability has been reported for traits like days to flowering, plant height, primary branches per plant, cluster number, pod number, pod length, seeds per pod and seed yield per plant by Rang *et al.* (1980) Pandita *et al.* (1982) and Tewari (1988). In the case of primary branches per plant, Trehan *et al.* (1970), Hanchinal *et al.* (1981) Vaid and Singh (1983) and Vijayakumar (1989) reported high variability, where as Veeraswamy *et al.* (1973.c.), Bapna and Joshi (1973) and Balakrishnan (1978) reported low variability. Veeraswamy *et al.* (1973.c.) also reported low variability for pod number and pod length in cowpea. In the case of seeds/pod , high variability has been reported by Hanchinal *et al.* (1981) and Jagadishmurthy (1984). However Singh and Mehndiratta (1969), Bapna and Joshi

(1973) Angadi (1976) and Dumbre *et al.* (1983) reported low values. For 100 seed weight, Gowda (1984) observed low variability, while Balakrishnan (1978), Jagadishmurthy (1984) and Tewari *et al.* (1988) reported high variability.

In the case of seed yield per plant, Singh and Mehndiratta (1969) and Bapna and Joshi (1973) reported low variability. Thiyagarajan and Rajasekharan (1989) reported higher degree of environmental fluctuation for plant height, number of clusters per plant and number of branches per plant in cowpea.

Greengram

In greengram various workers like Natarajan *et al.* (1988), Reddy *et al.* (1994), Ranganayaki and Sree Rangaswamy (1993), Borah and Hazarika (1995), and Patil and Shinde (1995) reported low GCV and PCV (of around 10-15%) for days to flowering, seeds per pod 100 seed weight

Moderate to high GCV and PCV values (of around 35-65%) were reported for plant height, number of branches per plant, number of clusters per plant, pods per cluster and seed yield per plant by Gupta and Singh (1970), Srikanthan (1976), Sulaiman (1976), Natarajan *et al.* 1988, Reddy *et al.* 1991, Ranganayaki and Sree Rangaswamy (1993), Borah and Hazarika (1995), Patil and Shinde (1995) and Jiji Joseph (1998).

Blackgram

Moderate to high variability was reported for plant height, number of primary branches, number of pods, pod yield and seed yield by Singh *et al.* (1972), Veeraswamy *et al.* (1973.b.) and Soundarapandian *et al.* (1975) .

Veeraswamy *et al.* (1973.b.) and Soundrapadian *et al.* (1975) have reported low GCV and PCV values for number of clusters, pod length and number of seeds per pod. According to Singh *et al.* (1975), 100 seed weight recorded the lowest GCV and PCV of 3.08 and 3.62, respectively.

2.1.2. Heritability and Genetic Advance

The degree to which the variability expressed in a quantitative trait is transmitted to the progeny or offspring is referred to as heritability. It is an effective tool in estimating the relative importance of heredity and environment on the variability expressed in a trait. Heritability in a narrow sense (h^2) is that fraction of the observed variance, which is due to additive genetic effects. Genetic advance for a trait (normally expressed as % of mean), denotes a measure of genetic gain that could be achieved by further selection. This will serve as an effective tool in formulating selection programmes. The following is a brief review of the reports on these aspects by various workers, in horsegram and other related pulse crops.

Horsegram

In horsegram high heritability values were reported for all characters studied such as plant height, number of pods, number of nodes, number of branches, seeds per pod and seed yield by Sreekantaradhya *et al.* (1975), Aggarwal and Kang (1976), Shivashankar *et al.* (1977) and Ramakrishnan *et al.* (1978). Low values for heritability was recorded for number of branches by Aggarwal and Kang (1976). Other reports on low heritability estimates include that for plant height, seeds/pod, number of pods and seed yield (Shivashankar *et al.* 1977) and number of seeds per pod (Ramakrishnan *et al.* 1978). Aggarwal and Kang (1976) recorded highest estimate of heritability for 100 seed weight in the crop.

Shivashankar *et al.*(1977) evaluated 100 horsegram genotypes and reported that primary branches, secondary branches, days to flowering, number of nodes and 100 seed weight were highly heritable, whereas plant height, number of seeds per pod, number of pods and seed yield showed low heritability.

Ganeshaiah (1980) observed that number of secondary branches, number of leaves at flowering, plant height, days to maturity and seed yield showed good response to selection. Days to flowering and maturity had the highest heritability.

Patil and Deshmukh (1982) reported that seed yield, number of primary and secondary branches and pods per plant showed high heritability and genetic advance.

According to Birari *et al.* (1987) yield per hectare, days to first pod maturity and 100 seed weight showed high heritability, and low heritability was observed for pods per plant and seeds per pod. Borole (1984) reported high heritability for flowering, days to maturity, plant height and seed yield per plant. Suraiya *et al.*(1988) observed that number of pods, plant height, days to 50 per cent flowering and days to maturity showed high heritability and genetic advance, in horsegram. Studies of Swapna (1993) indicated that length of pods and number of pods exhibited high heritability and genetic advance.

High values of genetic advance have been reported in horsegram for number of nodes, number of branches and number of pods, plant height and seed yield by Sreekantaradhya *et al.* (1975). In the same crop, Aggarwal and Kang (1976) observed high genetic advance for number of pods, 100 seed weight and seed yield. High estimates for genetic advance have also been reported in the crop, for number of secondary branches by Shivashankar *et al.* (1977) and for number of pods and number of branches, plant height and seed yield by Ramakrishnan *et al.* (1978).

Low values for genetic advance was reported for pod length and seeds per pod (Sreekantaradhya *et al.*, 1975 and Ramakrishnan *et al.* 1978) and for plant height

and seed yield (Shivashankar *et al.* 1977). Aggarval and Kang (1976) recorded lowest estimate of genetic advance for seeds per pod in horsegram.

The heritability and genetic advance values of important biometric traits of horsegram, as reported by various workers are summarized below: -

Days to flowering	***H^2***	***G.A (as % of Mean)***
Singh (1990)	(low)	---
Rao and Nanda (1994)	8.9	0.56
Sood *et al.* (1994)	94.0	9.01
Savithramma *et al.* (1996)	89.0 (Kharif)	30.4
-do-	32.7 (Rabi)	3.7
-do-	29.3 (Summer)	6.7
Nagaraja *et al.* (1997)	30.8	8.5
Samal and Senapathy (1997)	69.0	5.0

Plant height	***H^2***	***G.A (as % of Mean)***
Balan *et al.* (1991)	81.0	28.1
Rao and Nanda (1994)	33.9	10.6
Savithramma *et al.* (1996)	40.0 (Kharif)	37.5
-do-	61.1 (Rabi)	34.6
-do-	59.0 (Summer)	54.9
Nagaraja *et al.* (1997)	33.5	12.1
Samal and Senapati (1997)	69.0	16.2

Number of branches	***H^2***	***G.A (as % of Mean)***
Aggarval and Kang (1976)	low	--
Balan *et al.* (1991)	61.4	2.8
Savithramma *et al.* (1996)	25.4 (Kharif)	28.1
-do-	46.9 (Rabi)	45.8
-do-	27.7 (Summer)	27.3

Nagaraja *et al.* (1997)	46.9	45.6
Samal and Senapati (1997)	51.6	1.00

Number of Pods	H^2	***G.A (as % of Mean)***
Balan *et al.* (1991)	86.5	34.3
Rao and Nanda (1994)	24.5	12.4
Savithramma *et al.* (1996)	13.0 (Kharif)	12.2
-do-	41.0 (Rabi)	31.3
-do-	28.3 (Summer)	43.9
Samal and Senapati (1997)	90.9	17.6

Seeds per pod	H^2	***G.A (as % of Mean)***
Balan *et al.* (1991)	50.1	0.08
Savithramma *et al.* (1994)	14.2 (Kharif)	3.1
-do-	13.6 (Rabi)	3.9
-do-	40.8 (Summer)	17.3
Samal and Senapati (1997)	80.0	0.5
Nagaraja *et al.* (1997)	83.1	25.6

Days to maturity	H^2	***G.A (as % of Mean)***
Rao and Nanda(1994)	5.8	5.5
Sood *et al.*(1994)	6.0	6.7
Savithramma *et al.*(1996)	81.0 (Kharif)	39.1
"	55.5 (Rabi)	6.1
"	23.1 (Summer)	4.4
Nagaraja *et al.* (1997)	65.4	10.7

Pod length	H^2	***G.A (as % of Mean)***
Balan *et al.*(1991)	46.7	0.23
Savithramma *et al.*(1996)	2.6 (Kharif)	1.9

"	2.1 (Rabi)	0.2
"	28.5 (Summer)	8.5

Pod yield	***H2***	***G.A (as % of Mean)***
Balan *et al.*(1991)	82.8	7.6
Savithramma *et al.* (1996)	37.7 (Kharif)	46.9
"	21.8 (Rabi)	23.9
"	36.0 (Summer)	47.8

100 seed weight	***H2***	***G.A (as % of Mean)***
Balan *et al.*(1991)	59.3	0.6
Sood *et al.* (1994)	73.8	0.5
Savithramma *et al.*(1996)	75.5 (Kharif)	24.3
"	83.8 (Rabi)	30.5
"	50.3 (Summer)	14.2

Harvest index	***H^2***	***G.A (as % of Mean)***
Rao and Nanda(1994)	33.3	12.7
Savithramma *et al.*(1996)	34.6 Kharif	28.5
"	39.1	16.5
"	35.1 Summer	39.9

Crude Protein percentage	***H2***	***G.A (as % of Mean)***
Savithramma *et al.* (1996)	78.6 (Kharif)	19.4
"	80.2 (Rabi)	19.8
	57.6 (Summer)	16.1

Seed yield	***H2***	***G.A (as % of Mean)***
Balan *et al.*(1991)	79.5	5.2
Sood *et al.*(1994)	73.6	233.7

Savithramma *et al.*(1996)	45.7 (Kharif)	62.8
	19.9 (Rabi)	20.2
	28.7 (Summer)	36.6
Nagaraja *et al.* (1997)	41.5	23.0
Samal andSenapati (1997)	73.3	1.8

Cowpea

In cowpea, the genetic advance was high in the case of pod yield per plant, pod length, number of pods per plant and seed yield per plant (Veeraswamy *et al.* 1973.c.) plant height, 100 seed weight and pod length (Lakshmi and Goud, 1977) and number of seeds per pod (Gopalsingh *et al.,* 1977). Gopalsingh *et al.* (1977) also reported low genetic advance for number of seeds per pod, 100 seed weight and number of pods and seed yield per plant.

Greengram

Estimates of genetic advance were high in greengram for plant height and pod length (Gupta and Singh, 1969), plant height alone (Singh and Malhotra, 1970 and Chowdhury *et al.*, 1971), plant height and number of branches per plant (Veeraswamy *et al.*, 1973.a.), number of pods per plant (Joshi and Kabaria, 1973), number of pods and seed yield per plant (Rangareddy and Krishnaiah, 1977) and pod length, plant height, pod weight, cluster number per plant and seed yield per plant (Paramasivan, 1979). At the same time the values of genetic advance were found to be moderate for number of branches (Singh and Malhotra, 1970) and number of pods and pod yield (Veeraswamy *et al.* 1973.a.) in greengram. Low estimates of genetic advance was observed in the crop, for number of pods and seed yield (Gupta and Singh, 1969) number of pods (Singh and Malhotra, 1970) and seeds per pod and seed yield (Veeraswamy *et al.*, 1973.a..).

Blackgram

In blackgram, high values of genetic advance was reported for plant height, pod yield and seed yield per plant and moderate values for number of branches per plant and pod length by Veeraswamy *et al.* (1973.b.). Soundarapandian *et al.* (1975) observed high genetic advance for plant height and seed yield and moderate genetic advance for number of pods and pod length in blackgram. In the same crop, Rasupandi (1979) recorded high values of genetic advance for the characters like seed yield and number of pods and plant height. Low genetic advance was reported in blackgram for number of branches and number of seeds per pod by Soundarapandian *et al.*(1975).

2.1.3. Correlation Studies

Metric characters of economic importance are often observed to be associated with one another. Yield is considered to be dependent on several other component characters. Correlation study is therefore of much importance in selection programme when highly heritable traits are associated with the most important character, the yield.

2.1.3.1. Association between seed yield and its components

Horsegram

Aggarwal and Kang (1976), Shivashankar *et al.*(1977) and Ganeshaiah *et al.* (1980) reported significant positive correlation of number of pods, 100 grain weight, length of pod, height of plant and number of seeds per pod, with seed yield.

Shivashankar *et al.* (1977) also reported high positive correlation between seed yield with traits like plant height, number of secondary branches, number of

nodes, seeds per pod and number of pods. Correlation coefficients were low for traits like number of primary branches, 100 seed weight and days to flowering.

Patil and Deshmukh (1982) observed positive correlation of grain yield in Horsegram with number of pods, secondary branches and 100 seed weight. Based on his studies involving 216 Horsegram varieties, Ghorpade (1985) reported positive correlation of yield with days to 50 per cent flowering. Birari *et al.*(1987) noted a strong positive correlation of seed yield with number of days to first pod maturity, number of pods and seeds per pod. According to them 100 seed weight and seed yield were negatively correlated. Singh (1990) also reported about correlations existing between seed yield and nine biometric traits, in horsegram.

Swapna (1993) reported significant positive genotypic correlation for seed yield with traits like primary branches, number of pods per plant, pod length and seeds per pod. According to her, seeds per pod and number of pods had maximum correlation with seed yield. Dobhal and Rana (1994) observed that genotypic correlation was generally higher in magnitude that phenotypic correlations for the nine traits they studied in Horsegram. Grain yield showed significant positive correlations with number of branches, number of clusters, number of pods, pod length and days to flowering. Plant height had significant positive association with number of internodes, number of branches, number of clusters and seeds per pod. Number of internodes had significant positive association with number of clusters, branches and pods per plant. Pod length had positive association with days to flower.

Rao and Nanda (1994) studied association between eight biometric traits with seed yield in horsegram. Only harvest index had significant positive correlation with seed yield. Plant height, number of nodes and number of pods also showed positive correlations with grain yield. However, days to flowering was negatively correlated. They concluded that harvest index and number of pods are the most important and

reliable selection indices for grain yield in horsegram. Inter-correlation between the traits were significant and positive for plant height with pod bearing nodes and number of pods with number of nodes. Inter-correlations of days to flowering with plant height and number of pods and harvest index with days to maturity, were negative.

Sood *et al.* (1994) evaluated ten horsegram genotypes and reported significant negative correlation for seed yield with days to flowering and maturity, which offer scope for selecting early maturing high yielding genotypes. They also reported strong and positive inter-correlations for days to flowering with days to maturity. However, 100 seed weight had weak negative association with these two traits. According to Nagaraja *et al.* (1997) grain yield showed strong and significant positive correlation with pod yield per plant, per day productivity, both at genotypic and phenotypic levels correlation was positive and significant for their traits like plant height, number of primary branches, number of nodes and seeds per plant, only at genotypic levels Negative inter correlation was observed between plant height and primary branches. Significant positive inter-correlation was observed for plant height with pod yield and number of primary branches with pod bearing nodes and per day productivity.

Samal and Senapathy (1997) observed that seed yield showed significant positive correlation with pods per plant, seeds per pod and branches per plant and negative correlation with 100 seed weight and days to flowering, both at phenotypic and genotypic levels. Inter-correlations were positive for branches per plant with pods per plant; days to flowering and plant height and negative with 100 seed weight. Pods per plant was positively correlated with seeds per pod and plant height; and negatively correlated with 100 seed weight and days to flowering. 100 seed weight showed negative correlation with all the traits. Days to flowering also had negative association with all traits except branches per plant and plant height.

Lad *et al.*(1998) reported strong positive correlation of seed yield with number of pods, pod length, seeds per pod, pod yield and days to maturity. Strong and negative correlation were observed in the case of seed yield and 100 seed weight. Plant height also had negative but non-significant correlation with grain yield. Among inter-correlations, positive and significant association was observed for days to flower with plant height and dry weight of plant. Days to flower had weak, but negative association with number of pods and seeds per pod. Plant height had significant positive correlation with number of branches, 100 seed weight, number of compound leaves, leaf area per plant, days to maturity and dry weight of plant. Number of pods had significant positive association with pod length, seeds per pod, leaf area, days to maturity, dry weight of plant and pod yield. 100 seed weight had negative association with all the traits studied except days to flower, plant height and number of branches.

Cowpea

In cowpea, seed yield showed significant positive association with number of branches and seeds per pod (Singh and Mehndiratta, 1969; Trehan *et al.*, 1970 and Doku, 1970). All the yield components except pod length showed significant positive relationship with yield in this crop. Janoria and Ali (1970) observed positive association of yield with seeds per pod and 100 seed weight. Kheradnam and Niknejad (1973) found that all the traits except number of branches per plant were positively correlated with seed yield. Gopalsingh *et al.* (1977) also reported that yield was positively associated with number of pods per plant and number of seeds per pod in cowpea.

Negative association for seed yield has been reported in Cowpea with pod length Aryeetey and Laing (1973), number of branches (Kheradnam and Niknejad, 1973) and 100 seed weight (Gopalsingh *et al.*, 1977).

Greengram

There was positive association of yield with plant height, number of branches per plant, number of pods per plant, number of clusters per plant, pod length, 100 seed weight and number of seeds per pod in greengram (Gupta and Singh 1969; Singh and Malhotra, 1970; Joshi and Kabaria, 1973; Singh and Singh, 1973; Giriraj and Vijayakumar, 1974 and Paramasivan, 1979). Malhotra *et al.* (1974) reported that days to flowering was also positively associated with yield in greengram. Positive association of seed yield with plant height has been reported by Naidu and Rosaiah(1993), Reddy *et al.*(1994), Kumar *et al.*(1995), Panwar *et al.*(1995), Mishra *et al.*(1995) and Byregowda *et al.*(1997). However Malik *et al.*(1987), Khan (1985) and Pundir *et al.*(1992) reported negative associations. For branch number, Khan and Ahamed (1989), Mishra and Yadav(1992), Pundir *et al.*(1992), Mishra *et al.*(1995) and Byregowda *et al.*(1997) reported positive correlation whereas Malik *et al.*(1987) and Khan (1985) reported negative correlations. Pundir *et al.*(1992), Singh and Pathak (1993), Reddy *et al.*(1994), Khorgade (1995), Kumar *et al.*(1995), Panwar *et al.*(1995) and Byregowda *et al.*(1997) reported positive association of seed yield with pods per plant. Rathinaswamy *et al.*(1978) and Khan (1985)reported negative associations. In the case of seeds per pod, Singh and Pathak (1993), Khorgade (1995), Mishra *et al.*(1995) and Byregowda *et al.*(1997) reported positive correlation and Khan (1985), Malik *et al.*(1987) and Khan (1985) reported negative correlations. According to Naidu *et al.*(1994),Gill *et al.* (1995), Khorgade (1995), Mishra *et al.*(1995) and Byregowda *et al.*(1997), hundred seed weight had positive correlation with grain yield in greengram, whereas Nadarajan *et al.*(1988) and Panwar *et al.*(1995) reported negative associations.

Blackgram

In blackgram, positive association of seed yield with plant height, number of branches, number of pods, number of clusters, pod length, 100 seed weight and seeds

per pod, had been reported by Verma and Dubey, 1970 and Singh *et al.*, 1972, 1975). According to Rasupandi (1979) seed yield was found to exhibit significant positive correlation with all the characters studied like plant height, branch number, number of pods, pod yield, seeds per pod, pod length, days to flowering and days to maturity except 100 seed weight in the crop.

2.1.3. 2. Inter-correlations among yield components

Horsegram

Aggarwal and Kang (1976) reported significant positive correlations between number of branches and number of pods; number of pods and seed size; pod length and seeds per pod as well as pod length and seed size. They also observed that days to flowering and days to maturity were negatively associated with grain size and number of pods in horsegram. Swapna (1993) reported significant and positive inter-correlations between plant height and length of pods; number of primary branches and number of pods; days to 50 per cent flowering and days to maturity; length of pods and seeds per pod; and 100 seed weight and days to maturity. According to her, simultaneous improvement of these traits is possible in horsegram, since the yield-correlated traits also showed inter-correlations.

Cowpea

In cowpea, Singh and Mehndiratta (1969) reported positive association between pod length and 100 seed weight, seeds per pod and 100 seed weight and number of pods and number of branches. They also reported negative association between number of branches and 100 seed weight, pod length and number of pods and number of branches and pod length.

Greengram

In greengram, Gupta and Singh (1969) studied inter-correlations among yield components and reported that pod length had positive association with 100 seed weight. Positive association of pod length with 100 seed weight and seeds per pod was also reported by Giriraj and Vijayakumar (1974). Joshi and Kabaria (1973) reported that number of pods and seeds per pod showed positive association among themselves. Rangareddy and Krishnaiah (1977) observed positive association of number of branches with number of pods and number of pods with seeds per pod. Rathinaswamy *et al.* (1978) reported that pod length was positively associated with 100 seed weight. According to Paramasivan (1979), plant height, number of branches, number clusters and number of pods, pod weight, number of seeds per pod and days to 50 per cent flowering were positively associated among themselves. Plant height is reported to have positive correlations with branch number according to(Mahalingam ,1991; Singh and Pathak, 1993; Manivannan and Nadarajan, 1996 and Byregowda *et al.*,1997), number of pods (Manivannan and Nadarajan, 1996), Seeds per pod (Mahalingam ,1991; Mishra *et al.*,1995; Manivannan and Nadarajan,1996 and Byregowda *et al.*,1997) and hundred seed weight (Mahalingam, 1991).

Gupta and Singh (1969) observed negative association between pod length and number of pods, in greengram. Singh and Malhotra (1970), Joshi and Kabaria (1973) and Paramisavan (1979) reported negative correlation between 100 seed weight and almost all the components of yield. Rangareddy and Krishnaiah (1977) reported that number of pods and seeds per pod were negatively associated with 100 seed weight. Rathnaswamy *et al.* (1978) reported negative association between number of pods per plant and 100 seed weight in the crop. Negative associations for plant height had been reported with branch number (Khan and Ahamed, 1989), number of pods per plant (Khan and Ahamed, 1989, Mahalingam ,1991), seeds per pod (Khan, 1985) and hundred seed weight (Byregowda *et al.*,1997).

Blackgram

According to Soundarapandian *et al.* (1976) and Goud *et al.* (1977) in blackgram, inter-correlations among cluster number, pod number and pod yield and pod length with seed number were very high in magnitude. Rasupandi (1979) recorded that 100 seed weight exhibited significant positive association with pod length. Singh *et al.* (1975) recorded negative association between 100 seed weight and plant height in blackgram. In the same crop Rasupandi (1979) recorded negative correlation of 100 seed weight with plant height, number of branches, number of clusters and number of pods, days to flowering, days to maturity and seeds per pod.

2.1.4. Path Coefficient Studies

Path coefficients are standardized regression coefficients. In path coefficient analysis, the correlations among cause and effect are partitioned into direct and indirect effects of causal factors on an effect factor. This technique is an effective tool for partitioning the direct influence of each trait, and their indirect influence through other traits, on yield. A review of available literature on path analysis studies in horsegram and other important pulses, is presented:

Horsegram

In horsegram, Aggarwal and Kang (1976) reported that number of pods and seed size were the main components that had direct influence on seed yield. The effect was intensified further with marginal indirect effects through seed size, number of branches, number of seeds per pod and days to maturity. In the case of number of branches, the yield was greatly influenced by the direct effect via number of pods. In the case of pod length and plant height the direct effects were negative. Compared to other characters, pods per plant showed maximum direct as well as indirect effects on yield.

Path analysis studies by Ganeshaiah (1980) and Singh (1990) revealed that number of pods, pod yield and 100 seed weight contributed the maximum to the seed yield. Dobhal and Rana (1994) reported that number of clusters per plant had the highest positive direct effect on grain yield in horsegram, followed by days to flowering, number of pods and plant height. Number of internodes which showed positive correlation with seed yield however showed negative direct effects, indicating that the positive correlation was due to indirect effects via plant height, cluster per plant and number of pods. He also reported that indirect effects via number of clusters, number of inter nodes, number of pods, seeds per pod and days to flowering were negative, whereas direct effects were positive, indicating importance of these traits in direct selection.

According to Sood *et al.* (1994) days to flowering, days to maturity and 100 seed weight had negative direct effect on seed yield. However the negative direct effect of 100 seed weight was masked by its indirect positive effects through the other two traits. Their work also indicated that simultaneous selection is possible for high seed yield and earliness. However separate breeding programme will have to be taken up for improvement of seed size

Cowpea

Singh and Mehindiratta (1970) employed path coefficient analysis to partition the direct and indirect effects of different yield components of cowpea. They were of the view that number of pods, seeds per pod and 100 seed weight were the important yield components and they showed significant direct effect on yield.

Greengram

In greengram, Chandel *et al.* (1973) reported that days to flowering, number of pods and 100 seed weight had direct positive effect on yield while pod length had

negative direct effect. They further stated that days to flowering and seeds per pod had indirect positive effect via number of pods. Giriraj and Vijayakumar (1974) reported that plant height and pod length exerted maximum direct effect on the yield and number of pods showed little direct effect. However, seeds per pod showed significant negative direct effect on seed yield followed by 100 seed weight. Tomar *et al.* (1977) in greengram, observed that number of branches, number of pods, pod length and seeds per pod had direct positive effect upon seed yield while, plant height showed negative direct effect. Plant height and number of pods had indirect positive effect through number of branches. Rangareddy and Krishnaiah (1977) reported that number of branches and seeds per pod had higher direct effects. Rathinaswamy *et al.* (1978) found that 100 seed weight, seeds per pod and pods per plant had marked direct positive influence on seed yield.

In greengram, Khan (1980), Khan and Ahamed (1989), Patil and Narkhede(1989) and Mahalingam(1991) reported positive direct effect of plant height and number of branches on seed yield. However most of the other reports indicated that number of pods is the trait having maximum direct positive effect on seed yield. (Malhotra *et al.,* 1974; Rathinaswamy *et al.,* 1978; Natarajan, 1988; Wani *et al.,* 1992; Naidu, 1993; Kumar, *et al.,* 1995; Panwar *et al.,* 1995; Singh *et al.,* 1995; Manivannan and Natarajan, 1996 and Byregowda *et al.,* 1997). Negative direct effects on seed yield have been reported for seeds per pod (Khan, 1988) and days to flowering (Veerabadhiran and Jehangir (1995).

Blackgram

In blackgram, Singh *et al.* (1975) reported that number of pods had a significant direct effect on seed yield followed by pod length and 100 seed weight. According to Soundarapandian *et al.* (1975) plant height showed high positive direct effect on seed yield while number of branches, number of pods and seeds per pod showed weak negative direct influence on yield. In blackgram, Banerjee *et al.*

(1976) observed that the number of pods had the greatest positive direct effect on the yield. However, this direct effect was to some extent nullified by the negative indirect effects through plant height, number of branches and pod length.

2.1.5. Genetic divergence

It is generally assumed that cultivars originating from different geographic regions are more likely to be genetically different. On this basis, such cultivars are included in hybridization programmes in the hope that their presumed genetic diversity will provide a greater chance to get promising genetic recombination. In very few cases, however there had been attempts to provide a quantitative measure of the presumed association between geographic and genetic diversity and also characters that contribute towards divergence (Lee and Kaltsikes, 1973).

Methods utilizing multiple measurements, which are subjected to multivariable analysis, can provide such a measure based on generalized distance as indicated by the D^2 statistics (Mahalanobis, 1936). D^2 statistics was found to be an effective tool among the various techniques available for genetic differentiation among populations (Rao 1960; Cassie, 1963; and Sokal, 1965). The utility of multivariate analysis in tracing the pattern of evolutionary process in crop plants was suggested by Murty *et al.* (1965) and Chandrasekhariah *et al.* (1969).

Horsegram

In horsegram, Ramakrishnan *et al.* (1979) analysed eight yield components among eleven varieties using Mahalanobis D^2 statistic. The varieties were collected from different geographic regions. It was shown that 100 seed weight was the chief contributor towards the total divergence. The clustering pattern of varieties did not reveal any association between geographic diversity and genetic diversity. Ganeshaiah *et al.*(1984) studied genetic divergence in 100 horsegram genotypes

collected from six countries and grouped them into 3 to 5 clusters depending on the variability of each trait. Swapna (1993) grouped fifty horsegram genotypes into eleven clusters based on variability for nine biometric traits and reported that the maximum contribution towards genetic divergence was made by the character hundred seed weight. In all the above three studies, the genetic divergence was found to be independent of geographic origin.

Cowpea

In cowpea, Mehndiratta and Singh (1971) studied 40 varieties using D^2 statistics. The results revealed that seed size (100 seed weight) contributed the maximum towards divergence, while other characters contributed little. It was observed that the same geographical origin need not represent homogeneity in the population structure, because wide diversity was observed in the material selected from the same geographical location.

Greengram

Malhotra *et al.* (1974) reported wide diversity among 60 indigenous and exotic types of greengram. These types fell into as many as 14 different clusters. They reported that days to flower, seed size and primary branches contributed the maximum towards genetic divergence and geographic diversity did not seem to have direct association with genetic diversity.

Blackgram

The multivariate analysis in blackgram by Sagar *et al.* (1976) showed that days to flower contributed much towards the genotypic diversity followed by plant height, protein content, 100 seed weight and pod length. Malhotra and Singh (1971) observed that the clustering pattern of strains clearly indicated that the geographic

diversity did not appear to be associated with genetic diversity and divergence was more influenced by seed yield, pod length, seed size and number of pods per plant.

2.1.6. Studies on Photoperiodism

A number of isolated observations during later part of nineteenth century suggested that photoperiod might be an important factor in determining the rate of growth and course of development of various plants (Stiles, 1969). Garner and Allard (1920) conducted experiments on various species and varieties of horticultural crops under conditions in which length of day was artificially shortened by keeping plants in dark for part of day time, or lengthened by exposure of plants to artificial light in part of the night. They found that rate of vegetative growth and duration of flowering could be profoundly affected by photoperiod. The height of his experimental plants (Soyabean, Var. Peking) for the same variety varied from 5" to 48" and days to flowering varied from 35 days to 74 days, depending on the photoperiod. According to Stiles (1969), the time of flowering was influenced by temperature, length of day and intensity of illumination to which the plants were exposed during their development. In short day plants, effective photoinduction results only if the long dark period is preceded by a high intensity light period. Long light periods are deleterious to photoinduction of flowering in short day plants.

Jayaprakash *et al.* (1992) studied photoperiodic response in finger millet (which is a short day plant) by growing the plants at different day lengths, through altering the sowing dates. Moderate to high quantitative photoperiod response was observed among the lines. Weakly sensitive lines took 65 days, moderately sensitive types 68 days and highly photosensitive types took 80 days. There were photo-insensitive types also, which always flowered after a fixed number of days. He also suggested a strong link between partitioning efficiency in dry matter accumulation and photoperiodic response. Highly photosensitive groups produced almost double

dry matter than photo-insensitive groups. But harvest index was 0.18 in photo-insensitive group compared to 0.13 in photosensitive group.

Sreekantaradhya et al. (1975) and Yellappa (1983) have reported that in horsegram, most of the local types as well as the few recommended varieties are photosensitive and flower only in October – November periods. According to them, such genotypes are late with a duration of up to 140 days and grow into a thick bush being prominently tendrilate and highly indeterminate in their growth habit and gives poor yields. Balasubramanian(1985) also reported that the horsegram cultivars that evolved in various States of India, are adapted to specific day lengths according to different seasons in which the crop is being grown in these States. Cultivars grown in monsoon season are day-neutral, whereas those raised during post-monsoon (rabi) season are short-day plants. Narayanan and Balasubramanian (1991) also have reported that photosensitivity appears to limit production of the crop all round the year. The ideal time for sowing photosensitive cultivars is September or October months. Crop raised prior to September is prolonged in duration and that beyond December is poor in seed set. However photosensitive varieties can be grown in early kharif to provide green manure or nutritious fodder when grown as inter / mixed crop with sorghum. Rabi crop alone is valued for both grain and bhusa.

In the ICAR Co-ordinated Advanced Varietal Trial of 1996, conducted at the Regional Agricultural Reseach Station, Pattambi of Kerala Agricultural University, eleven horsegram entries were evaluated, among which AK-21, AK-26 and Maru Kulthi flowered in about 30 days and came to harvest in around 65 days, compared to other entries which took around 45-55 days for flowering, and around 90 days for harvest (Kerala Agricultural University, 1999).

2.1.7. Discriminant function analysis

Discriminant function technique was first developed by Fisher (1936) and application of discriminant function for plant selection was first described by Smith (1939). He suggested that a better way of exploiting genetic correlation with several traits having high heritability, is to construct a selection index which is a linear combination of all characters associated with yield, based on the relative importance of the characters. He coined the term 'classical selection index' for this method, which discriminates between desirable and undesirable genotypes on the basis of selection efficiency. Hazel (1943) applied the technique for animal selection. The method of setting up a discriminant function as an index in selection has been tested with limited success in the recent past in certain cultivated plants. Selection indices constructed by the application of discriminant function of pulses are meager.

In cowpea, Singh and Mehndiratta (1970) formulated a discriminant function based on two yield components namely grains per pod and 100 grain weight and another based on three yield components viz. grains per pod, hundred grain weight and pods per plant and these were fond to be superior to selection based on yield alone, by 24 and 33 per cent respectively.

Malhotra *et al.* (1974) reported that discriminant function including pod number; seeds per pod and hundred seed weight, had maximum genetic advance and efficiency in greengram.

2.2. Varietal Evaluation Studies

In the Co-ordinated Advanced Varietal Trial on horsegram conducted under All India Co-ordinated Research Project on Arid legumes, eight genotypes were evaluated in six centers. The check variety PHG-9 ranked first in terms of grain yield per plant during 1998-99 with an overall mean of 1274.55 Kg./ ha (I.C.A.R., 1999).

This was followed by DPI-2278 (1235.75 Kg./ ha), KS-2 (802.02 Kg./ ha), Maru Kulthi (792.23 Kg./ ha), and AK-42 (765.55 Kg./ ha). Flowering duration was the minimum for Maru Kulthi and AK-42 (38days each). KS-2 flowered in 49 days and PHG-9 took 57 days to flower. Flowering duration was the maximum for DPI-2278 (61 days). Total duration of these entries were as follows: KS-2 (79 days), Maru Kulthi and AK-42 (80 days each), PHG-9 and DPI-2278 (97 days each). During 1999-2000, the trial was conducted in nine centers with fifteen entries. DPI-2278 and PHG-9 were the best two entries in terms of grain yield, with a mean yield of 885.3 Kg./ ha. and 840.1 Kg./ ha, respectively (I.C.A.R., 2000).

2.3. Hybridisation Studies

2.3.1. Studies on anthesis and techniques for selfing and crossing:

Sundararaj and Thulasidas (1976) have reported that as in many other leguminous crops, self-pollination is the rule in horsegram due to cleistogamous nature of flowers. Anthers dehisce from 4 pm on previous day of flower opening through longitudinal sutures. Pollen grains are very big in size and are massed together and fully cover the stigma, which is seen at the same level. The flowers open by night and petals fold back after 24 hours making it difficult to distinguish from mature unopened buds.

Sen and Jana (1963) and Nainar Mohammed (1991), had described procedures for selfing and crossing in blackgram. Since anthesis starts in the crop by evening of the previous day of flower opening and pollination occurs in closed buds before midnight, emasculation is to be done before that, by cutting open the flower bud. Pollination is done on the next day, early in the morning. In greengram Sen and Ghosh (1959), Boiling *et al.* (1961) and Jiji Joseph (1998) have investigated about the floral biology, anthesis and techniques for selfing and crossing. Here, the procedure is similar to that in blackgram. Achamma Oommen (1990) has described

techniques of selfing and crossing in redgram. Here, the emasculation is done at around 2 pm on the previous day of flower opening and pollination is done soon after. Reports regarding techniques applicable to horsegram, however, are limited.

2.3.2. Inheritance Studies

In horsegram, Ayyangar *et al.* (1934) studied mode of inheritance of purple pigment in hypocotyl, internodes, petioles, stipules and pods in one variety, from natural cross with another variety having all green parts. He reported that a single factor was responsible for presence or absence of pigmentation. They also reported that the purple spot on standard petal, is however independent of these genes and is present in both genotypes.

According to Sen and Bhowal (1959), inheritance of black seed colour and pigmentation on different plant parts in horsegram are the effects of a single gene or a pair of closely linked genes. These traits are dominant over brown seeds and green parts. They also reported that earliness of flowering in black seeded types is dominant over late flowering of brown seeded types. They estimated that the number of effective factors controlling this trait as 1.5. The factor for pigmentation and factor for flowering duration are inherited independently. Sundararaj and Thulasidas (1976) also have described two distinct varieties in horsegram, based on seed colour viz. those having buff or brown seeds and others having black seeds. They also observed that brown as well as chocolate coloured seeds are formed on same plant itself, due to differential environment during ripening process. In black seeded types, black mottled and black patchy seeds also are met with.

2.3.3. Diallel Analysis

The success of plant breeding programme primarily depends on the judicious choice of parents for hybridization and proper selection procedures that are employed. Genetic information especially about the nature of combining ability,

heterosis and the type of gene action governing the inheritance of economic traits are the pre-requisite in fixing the suitable parents and designing appropriate breeding programmes. Different methods have been developed to estimate the general and specific combining abilities. The diallel analysis is one of the important method to study the combining ability and gene action.

The diallel method of analysis was proposed by Jinks and Hayman (1953) and was elaborated by Jinks(1954) and Hayman (1954 a and 1954 b).Griffings (1956.a. and 1956.b.) gave the methods of estimating combining ability in diallel crosses. The diallel analysis proposed by Jinks and Hayman(1953) is called as graphical analysis and had many assumptions for its applicability. The analysis proposed by Griffings is known as combining ability analysis. Tandon *et al.* (1970) opined that the combining ability analysis was found to be better than graphical analysis in predicting the pre-potency of genotypes especially in the latter generations. Arunachalam (1976) in his comparative study on the efficiency of the combining ability and graphical analysis of diallel, concluded that combining ability analysis could be more reliable since it was not restricted to one gene model and it operated with flexible assumptions.

In horsegram, Kabir and Sen (1990) conducted diallel analysis for estimation of combining ability parameters for pod yield and five yield influencing traits viz. days to flower, pod length, pod width, 100 seed weight, pod number per plant, and pod yield per plant and suggested that biparental mating between selected recombinants followed by recurrent selection may prove most effective so as to exploit additive and dominance components of variation.

2.3.3.1. Combining ability studies

The concept of combining ability is increasingly used now a days in plant and animal breeding for selection of desirable parents. The genetic values of parents are

expressed in terms of combining abilities, which denotes the ability of a parent to combine favorably with other individuals and produce progenies with favorable characters. Combining ability is defined as the relative ability of a genotype to transmit its desirable performance to its crosses. It is classified as general combining ability and specific combining ability. General combining ability is defined as the average performance of a strain in a series of crosses. Specific combining ability is defined as the deviation of specific crosses from the performance predicated on the basis of general combining ability (Allard, 1960). Only limited studies for various characters in pulse crops have been reported and they are reviewed here.

a) Combining ability variances and gene action

In horsegram, Kabir and Sen (1990) conducted diallel analysis and reported that additive genetic variance was important for days to flowering. In cowpea also, predominance of additive gene action on days to 50 per cent flowering was reported by Tikka *et al.* (1976), Patil and Bhapkar (1986), Patil and Patil (1987) and Patel (1990). However, both additive and non-additive gene actions were recorded by Zaveri *et al.* (1980) in cowpea. Predominance of non-additive gene action on days to 50 per cent flowering was reported by Zaveri *et al.* (1983).

In general, additive gene action was found to be important for plant height in cowpea. Yap and Mak (1982) and Patil and Patil (1987) reported the higher magnitude of additive genetic variance, while Zaveri *et al.* (1983) Vijaya kumar (1989) and Jhorar and Jatasra (1990) observed both additive and non-additive gene actions which were important for this trait. Both GCA and SCA were significant, but predominance of additive gene action was observed by Patel (1990). Singh 1982) observed equal contribution of GCA and SCA variances for plant height in cowpea.

Yap and Mak (1982), Patil and Patil (1987), Hebbal (1988) and Vijayakumar (1989) reported that the gene action was mostly additive for primary branches in

cowpea. Patel (1990) observed both GCA and SCA were significant but additive gene action was predominant. Zaveri *et al.*(1983) and Jhorar and Jatasra(1990) observed non-additive gene action for this trait in cowpea.

Various workers reported divergent views on the inheritance of pod number based on the materials studied by them. In horsegram, Kabir and Sen (1990) reported non-additive genetic variance for this trait. Predominance of additive gene action for this trait was reported in cowpea by Chauhan and Joshi (1981), Patil and Patil (1987), Vijayakumar (1989) and Patel (1990). However, Mak and Yap (1980), Patil and Bhapkar (1986) and Hebbal (1988) recorded non-additive gene action for this trait in cowpea. Zaveri *et al.* (1983) and Singh and Dabas (1986) reported the influence of both GCA and SCA variances in cowpea.

In horsegram, Kabir and Sen (1990) reported additive genetic variance for pod length. In cowpea, Ogunbodede (1986), Hebbal (1988) and Patel (1990) observed that the pod length was governed by both GCA and SCA variances. However, additive gene action was found to be predominant over non-additive gene action. The higher magnitude of SCA variance was also reported by Singh (1982) and Patil and Bhapkar (1986) in cowpea.

In cowpea, seed number per pod was reported to be controlled by both additive (Ogunbodede, 1986; Patil and Patil, 1987 and Hebbal, 1988) as well as non-additive (Mak and Yap, 1980; Singh, 1982 and Patil and Bhapkar, 1986) gene action.

For hundred seed weight, Kabir and Sen (1990) reported that additive genetic variance was important in horsegram. Mak and Yap (1980), Chauhan and Joshi (1981), Singh and Dabas (1986) and Vijayakumar (1989) observed the high magnitude of additive genetic variance for this trait in cowpea. In the same crop, dominant gene action was reported by Patil andBhapkar (1986) and Hebbal (1988),

whereas Jatasra (1980) observed both additive and non-additive gene action for this trait in cowpea.

In horsegram, Kabir and Sen (1990) reported non-additive genetic variance for pod yield per plant. In the case of seed yield per plant, the importance of additive gene action was realized in cowpea, from the estimates of additive component of gca variance by Chauhan and Joshi (1981), Patel and Shete (1986), Hebbal (1988), Vijayakumar (1989) and Patel (1990). However, according to Zaveri *et al.* (1983) and Singh and Dabas (1986), seed yield was controlled by non-additive genetic variance.

Combining ability analysis of 10 blackgram lines by Singh *et al.* (1987) revealed highly significant gca and sca variances for all the characters. They also noticed that the estimates of sca variances were greater than their gca variances, indicating predominance of non additive gene action. Sharma *et al.* (1987) found that sca variance was greater than gca variance in the control of seed weight in blackgram.

In greengram, Luthra *et al.* (1974) reported that gca variances were significant for all traits and were greater than sca variances for yield per plant, and the components, viz., pod number per plant, pod length, 100 seed weight and seed number per pod. Luthra *et al.* (1974) in a diallel analysis of 7 varieties of greengram, revealed that gca and sca variances were highly significant for all 7 characters and gca variances were higher than sca variances. Reddy and Sreeramulu (1982) recorded a higher gca variance for all traits except plant hight, indicating the predominance of additive gene action in greengram. A study of combining ability for seed yield and yield components in greengram by Reddy and Sreeramulu (1983) showed high sca estimates for seed yield and its components in two hybrids, and low sca estimates for other two hybrids. Thimmappa (1987) observed greater gca variances than sca variances for all characters except pods per plant in greengram.

b) Combining ability effects

In horsegram, there are only very few reports on combining ability studies. However reports are available in the case of other related pulse crops. The general combining ability effects of parents and specific combining ability effects of hybrids as reported by various authors in other related pulse crops are presented below: -

In cowpea, Lal *et al* (1975), Subash Jain *et al.* (1981) and Mishra *et al.* (1987) have reported about the parents that are good general combiners for early flowering. Parents having negatively significant gca effects and hybrids having negatively significant sca effects also have been identified by these workers. Lal *et al.* (1975), Singh *et al.* (1985) and Thiyagarajan *et al.* (1990) also have identified best general combiners and best cross combinations for this trait in cowpea. Parents and crosses showing positively significant gca and sca effect for number of primary branches per plant was reported by Subash Jain *et al.* (1981), Vijayakumar (1989) and Jhorar and Jatasra (1990).

Combining ability analysis for yield and yield attributes in cowpea, was studied by Mak and Yap (1980), Selvaraj (1984) and Thiyagarajan *et al.* (1990) and they have reported about parents with positively significant gca effect for number of clusters per plant and crosses having positively significant sca effects.

For pod length, Singh and Jain (1972) and Vijayakumar (1989) have reported about the parents that were found to be the best general combiners and hybrids that are desirable specific combiners, in cowpea.

Lal *et al.* (1975), Vijayakumar (1989) and Thiyagarajan *et al.* (1990) have listed the varieties which are good general combiners and crosses having high sca effects for seeds per pod. Jatasra (1980) reported that the bold seeded cowpea varieties viz., HFC 20, C28 and FOS-1 were good general combiners and the crosses

C28 x HFC 139, HFC 20 x C28 and HFC 20 x FOS-1 were best specific combiners for hundred seed weight. Parents having positively significant gca effects, and crosses with high sca effects were also reported by Vijayakumar(1989) and Thyagarajan *et al.* (1990) in the crop.

In cowpea, Lal *et al.* (1975), Mishra *et al.*(1987), (Vijayakumar,1989) and Thiyagarajan *et al.* (1990) have identified the parents that are good general combiner and the crosses having good specific combining effects for seed yield.

2.3.3.2. Heterosis

The most basic comparison that is important to plant breeders, is that of parental vs. hybrid performance. Information on magnitude of heterosis is of immense value from the standpoint of choice of best breeding methodology. Several workers have demonstrated the existence of varying degrees of heterosis for yield and other traits in grain legumes, which are reviewed hereunder.

Premsagar and Chandra (1977) recorded heterosis for plant height, number of pods and seed yield in F1 hybrids of a six parent diallel cross in *Phaseolus mungo*. From a diallel analysis of blackgram, Dasgupta and Das (1987) reported that two crosses showing high genetic divergence exhibited highly positive economic heterosis.

In a heterosis study of greengram, Sreekumar and Abraham (1978) noticed positive heterosis for number of pods and seed yield; and negative heterosis for 100 seed weight. According to Reddy and Sreeramulu (1982), heterosis over the mean of the parents was found to be high for plant height, clusters per plant and seed yield. In a genetic analysis of quantitative traits in greengram, Thimmappa (1987) reported heterosis over the better parent for plant height, pods per cluster, pods per plant,

seeds per pod and seed yield; but most hybrids were showing negative heterosis for 100 seed weight.

In the case of days to flowering, low or negative heterosis is relatively important, as it is an indicator for early maturity. In cowpea, Vijayakumar (1989) reported average negative heterosis over mid parent (-12.65 per cent), better parent (-21.7 per cent) and standard parent (-11.36 per cent). Tikka *et al.* (1976) and Hebbal (1988) recorded negative heterosis in cowpea for this trait. Zaveri *et al.* (1983) recorded positive heterosis for this trait, in cowpea.

Higher manifestation of heterosis for plant height was recorded in cowpea by Vijayakumar (1989). Selvaraj (1984) observed heterosis ranging between –27.36 and 58.94 per cent and Zaveri *et al.* (1983) reported positive heterosis ranging between 1.1 and 37.2 per cent in cowpea.

For primary branch number, Vijayakumar (1989) observed the range of relative heterosis from –2.13 to 41.35 per cent, heterobeltiosis from -22.47to 35.71 per cent and standard heterosis from –19.52 to40.74 per cent in cowpea. Selvaraj (1984) also reported positive heterosis for this trait in cowpea.

In the case of number of pods, significant and positive heterosis have been reported by Mak and Yap (1980), Zaveri *et al.* (1983), Patil and Patil (1987) and Vijayakumar (1989) in cowpea. Relative heterosis ranging from zero to 40 per cent and heterobeltiosis ranging from from zero to 31.47 per cent was observed by Selvaraj (1984). Hebbal (1988) recorded highest negative heterosis for pod number.

Zaveri *et al.* (1983), Patel and Shete (1987) and Hebbal (1988) reported negative heterosis for pod length in cowpea. Range of relative heterosis from –0.35 to 50.2 per cent and heterobeltiosis from –9.84 to 35.0 per cent on cowpea were

observed by Singh (1983a). However, Selvaraj (1984) and Vijayakumar (1989) observed positive heterosis for this trait in cowpea.

In cowpea, low and negative heterosis for number of seeds per pod was reported by Zaveri *et al.* (1983) and Patel and shete (1987). However, Bhaskaraiah *et al.* (1980), Singh (1983a), Hebbal(1988) and Patel (1990) found positive heterosis for this trait in the same crop. The range of relative heterosis and heterobeltiosis reported by Selvaraj (1984) were between zero to 13.11 per cent and zero to 6.72 per cent, respectively.

Heterosis was higher for hundred seed weight in cowpea as reported by Singh (1983 a), Selvaraj (1984) and Vijayakumar (1989). Negative heterosis was reported by Zaveri *et al.* (1983) and Hebbal (1988). Patel and Shete (1987) found positive relative heterosis and negative heterobeltiosis in cowpea. Bhaskariah *et al* (1980) reported least average heterosis for this trait in cowpea.

Zaveri *et al.* (1983), Selvaraj and Annappan (1983), Patel and shete (187), Hebbal (1988), Vijayakumar (1989) and Patel (1990) observed significant and positive heterosis for seed yield per plant in cowpea. Bhaskariah *et al* (1980) reported about relative heterosis ranging from –36 to 186 per cent for seed yield. Singh (1983a) recorded that the heterosis was from –7.48 to 47.3 per cent over mid parent and –2.76 to 24.56 per cent over better parent for seed yield in cowpea.

2.3.4. Studies on F2 ratios and inheritance pattern of traits in pulses

Ayyangar *et al.* (1934) studied the mode of inheritance of purple pigmentation in various plant parts of a variety from natural cross with another variety having green plant parts and proposed that a single factor to be responsible for presence or absence of pigmentation. However the purple spot on standard petal was found to be independent of this gene and is present in both varieties.

Sen and Bhowal (1959) studied inheritance of seed colour, pigmentation and duration of the crop. They identified two distinct varieties in horsegram. One is black-seeded with low vigour, shorter duration and purple pigmentation on stem, petioles and pods. The other types have buff (brown) coloured seeds and green parts. In black seeded types black mottled and black patchy seeds are also met with. The inheritance studies revealed that black seed colour and pigmentation of different plant parts are the effect of a single gene or a pair of closely linked genes. This black seed colour and purple pigmentation of plant parts are dominant over brown seed colour and green parts.

MATERIALS AND METHODS

MATERIALS AND METHODS

The study was undertaken at the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara of Kerala Agricultural University. The field experiments were conducted at Regional Agricultural Research Station, Pattambi of Kerala Agricultural University, which is located at 10.48 ^{o} North latitude and 76.12 ^{o} East longitude, at an elevation 25.5 m. above MSL. The whole investigation was carried out as three sections.

3.1. Genetic Evaluation of germplasm accessions

3.1.1. Materials:

The experimental material for the study included 115 horsegram genotypes having diverse origin obtained from NBPGR Regional Stations at Trichur (Kerala) and Akola (Maharashtra) and those available under the All India Co-ordinated Research Project on Arid Legumes scheme at RARS, Pattambi. The accession number and source of materials used for the study are presented in Table. 1

3.1.2. Methods:

The 115 genotypes collected were evaluated in research plots of Regional Agricultural Research Station of Kerala Agricultural University at Pattambi, in rabi (traditional) season and also in summer season of 1995-96. Seeds were sown @ 3 seeds per hill in 3 rows of 2m length, with a row to row spacing of 50 cm. and plant to plant spacing of 25 cm. Each line was raised in two replications. One week after germination, the lines were thinned to retain single plant at each hill.

TABLE 1. PARTICULARS OF HORSEGRAM GENOTYPES USED FOR THE STUDY

Sl. No	Genotypes / Accession No.)	Source	Trt. No
1	AK-21	Rajasthan	V-1
2	IC-7588	Karnataka	V-2
3	IC-19432	Manipur	V-3
4	IC-19433	Manipur	V-4
5	IC-19441	Madhya Pradesh	V-5
6	IC-19444	Madhya Pradesh	V-6
7	DPI-1584	Utter Pradesh	V-7
8	IC-22784	Madhya Pradesh	V-8
9	IC-22799	Madhya Pradesh	V-9
10	IC-22805	Madhya Pradesh	V-10
11	IC-22812	Bihar	V-11
12	IC-22813	Madhya Pradesh	V-12
13	IC-23453	Madhya Pradesh	V-13
14	IC-23460	Madhya Pradesh	V-14
15	IC-23462	Madhya Pradesh	V-15
16	DPI-1574	Tamil Nadu	V-16
17	IC-23464	Madhya Pradesh	V-17
18	IC-23467	Madhya Pradesh	V-18
19	IC-23495	Madhya Pradesh	V-19
20	IC-23508	Madhya Pradesh	V-20
21	IC-24842	Andhra Pradesh	V-21
22	IC-26125	Tamil Nadu	V-22
23	IC-26128	Karnataka	V-23
24	IC-26120	Karnataka	V-24

Sl. No	Genotypes / Accession No.)	Source	Trt. No
25	IC-26136	Manipur	V-25
26	IC-26144	Goa	V-26
27	BGM-1	Karnataka	V-27
28	IC-32760	Maharashtra	V-28
29	IC-32848	Maharashtra	V-29
30	IC-33072	Maharashtra	V-30
31	IC-33183	Maharashtra	V-31
32	IC-33198	Maharashtra	V-32
33	IC-33765	Maharashtra	V-33
34	IC-45698	Karnataka	V-34
35	IC-45702	Thirunelveli – Tamil Nadu	V-35
36	IC-45703	Thirunelveli – Tamil Nadu	V-36
37	IC-45713	Thirunelveli – Tamil Nadu	V-37
38	IC-45724	Thirunelveli – Tamil Nadu	V-38
39	IC-45732	Dindigul - Tamil Nadu	V-39
40	IC-45733	Dindigul - Tamil Nadu	V-40
41	IC-45743	Tamil Nadu	V-41
42	IC-45749	Pudukkottai - Tamil Nadu	V-42
43	IC-45752	Tamil Nadu	V-43
44	CODB-8	Tamil Nadu	V-44
45	IC-45756	Dindigul - Tamil Nadu	V-45
46	IC-50707	Karnataka	V-46
47	IC-50712	Karnataka	V-47
48	IC-50714	Karnataka	V-48
49	IC-50727	Madurai - Tamil Nadu	V-49
50	IC-50728	Madurai - Tamil Nadu	V-50
51	IC-145267	Joginder Nagar - Himachal Pradesh	V-51

Sl. No	Genotypes / Accession No.)	Source	Trt. No
52	AK-42	Rajasthan	V-52
53	IC-145344	Sarsai - Himachal Pradesh	V-53
54	IC-121641	Singhreli – Uttar Pradesh	V-54
55	IC-123024	Bookala - Himachal Pradesh	V-55
56	IC-145252	Rampur - Himachal Pradesh	V-56
57	IC-145254	Ka. Bhoor- Himachal Pradesh	V-57
58	IC-145258	Gonnola – Guarat	V-58
59	IC-145259	Orissa	V-59
60	IC-68591	Kasargode – Kerala	V-60
61	IC-68602	Palakkad – Kerala	V-61
62	IC-88990	South Kerala	V-62
63	IC-89000	South Kerala	V-63
64	IC-71725	Thirunelveli – Tamil Nadu	V-64
65	IC-71733	Thirunelveli – Tamil Nadu	V-65
66	IC-71748	Thirunelveli – Tamil Nadu	V-66
67	IC-71760	Tamil Nadu	V-67
68	IC-71769	Tamil Nadu	V-68
69	IC-71770	Madurai - Tamil Nadu	V-69
70	IC-71778	Madurai - Tamil Nadu	V-70
71	IC-71787	Madurai - Tamil Nadu	V-71
72	IC-71791	Madurai - Tamil Nadu	V-72
73	IC-71808	Madurai - Tamil Nadu	V-73
74	IC-71809	Madurai - Tamil Nadu	V-74
75	IC-71812	Madurai - Tamil Nadu	V-75
76	IC-71813	Madurai - Tamil Nadu	V-76
77	IC-71814	Madurai - Tamil Nadu	V-77
78	IC-71816	Madurai - Tamil Nadu	V-78

Sl. No	Genotypes / Accession No.)	Source	Trt. No
79	IC-71817	Madurai - Tamil Nadu	V-79
80	IC-71823	Madurai - Tamil Nadu	V-80
81	IC-55085	Manipur	V-81
82	IC-55973	Tamil Nadu	V-82
83	IC-56126	Andhra Pradesh	V-83
84	IC-56141	Andhra Pradesh	V-84
85	IC-56148	Andhra Pradesh	V-85
86	IC-89004	South Arcot – Tamil Nadu	V-86
87	IC-89005	Tamil Nadu	V-87
88	IC-89010	Tamil Nadu	V-88
89	IC-89015	Tamil Nadu	V-89
90	IC-89036	Tamil Nadu	V-90
91	IC-89038	Tamil Nadu	V-91
92	IC-89039	Tamil Nadu	V-92
93	IC-89041	Tamil Nadu	V-93
94	IC-22760	Akola - Maharashtra	V-94
95	IC-23460	Akola - Maharashtra	V-95
96	IC-26143	Akola - Maharashtra	V-96
97	IC-56147	Akola - Maharashtra	V-97
98	IC-65463	Akola - Maharashtra	V-98
99	EC-27602	Australia	V-99
100	IC-145270	Delhi	V-100
101	IC-19446	Madhya Pradesh	V-101
102	Maru Kulthi	Rajasthan	V-102
103	AK-26	Rajasthan	V-103
104	IC-1102	Karnataka	V-104
105	PHG-9	Karnataka	V-105

Sl. No	Genotypes / Accession No.)	Source	Trt. No
106	IC-45753	Tamil Nadu	V-106
107	CO-1	Tamil Nadu	V-107
108	Muthalamada Local	Palakkad – Kerala	V-108
109	EC-18679	Nepal	V-109
110	IC-16978	Manipur	V-110
111	IC-32746	Maharashtra	V-111
112	IC-23462	Madhya Pradesh	V-112
113	IC-24849	Andhra Pradesh	V-113
114	PHML-64	Rajasthan	V-114
115	KS-2	Rajasthan	V-115

All cultural operations were carried out as per Package of Practices Recommendations of KAU, 1993. Observations on the following biometric traits were recorded on per plant basis, computed from the mean of five randomly selected sample plants for each replication, avoiding border plants.

1. Plant height

The height of the stem from the soil surface level to the tip of the stem at the time of complete maturity was recorded in centimeter.

2. Number of branches

The total number of branches from the main stem were counted and recorded.

3. Days to flowering

Number of days from seeding to flowering in 50% of the plants in each genotype, was recorded.

4. Number of pods

The total number of developed pods obtained from the five sample plants was counted and the mean number per plant was recorded.

5. Pod yield

Total pods collected from the five samples plants were dried first in sun and then in oven at 60°C for eight hours to get a constant weight. Mean pod yield per plant was recorded in grams.

6. Length of pods

One well-developed pod each were selected at random from the pods of the five samples plants to measure the length and mean length recorded in centimeter.

7. Number of seeds per pod

The number of seeds in the pod selected for recording length of pod was counted and mean number of seeds per pod was recorded.

8. Hundred seed weight

One hundred matured seeds were selected randomly from each genotype and dried in oven to a constant weight. The mean value per plant was recorded in grams.

9. Haulms yield.

All the plant parts excluding seeds were dried in oven to a constant weight, which was recorded in grams.

10. Number of days to maturity

Number of days taken from seeding to drying of more than eighty per cent of pods in a plant, was recorded.

11. Harvest index

The total economic yield (seed yield per plant) and total biological yield (including seed) of the sample plants were recorded and the harvest index was computed as follows:

$$\text{Harvest index} = \frac{\text{Economic Yield}}{\text{Biological yield}}$$

12. Crude protein percentage

Representative samples of fresh dried seeds were taken from each accession in each replication and nitrogen content was estimated by the microkjeldhal method given by Jackson (1973). The crude protein content of grain was then calculated by multiplying the nitrogen content with the factor 6.25 (Black and Weiss, 1956).

13. Seed yield

Seeds were extracted from the pods of the sample plants after recording pod yield and mean seed yield per plant was recorded in grams.

3.1.3. Statistical Analysis

3.1.3.1. Analysis of variance and estimation of components of variation

a) Analysis of variance (ANOVA)

The mean values of the five sample plants in each replication were used for the Analysis of variance for all characters.

b) Variability

Genotypic Variance, Phenotypic Variance, Environmental Variance, Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) were estimated as per the procedure suggested by Burton (1952). The estimates of PCV and GCV were classified as:

< 10 per cent	=	Low
10-20 per cent	=	Moderate
> 20 per cent	=	High

c) Heritability

Heritability, in a broad sense (H^2), was calculated according to the formula suggested by Hanson *et al.* (1956). The heritability estimates were categorized as:

< 80 per cent	=	Low
80-90 per cent	=	Moderate
> 90 per cent	=	High

d) Genetic advance (G A)

The expected genetic advance under selection was estimated using formula suggested by Johnson *et al.* (1955).

e) Genetic gain (g g)

Expected genetic grain under selection was calculated by the formula suggested by Johnson *et al.* (1955). Genetic gain was categorized as:

< 80 per cent	=	Low
80-100 per cent	=	Moderate
> 100 per cent	=	High

3.1.3.2. Correlation Analysis

Phenotypic and genotypic correlation coefficients were calculated for yield and yield components as per the method given by Johnson *et al.*, (1955).

3.1.3.3. Path coefficient Analysis

Path coefficients analysis as suggested by Wright (1934) and elaborated by Dewey and Lu (1959) was adopted to partition the genotypic correlation coefficients into the direct and indirect effects.

3.1.3.4. D^2 Analysis

The genetic divergence among the genotypes was studied using the D^2 statistic of Mahalanobis (1936). The data were subjected to multivariate analysis as per Rao, (1952). The original mean values (x's) were transformed to normalized variables (X's) by using pivotal condensation method. Thus the correlated

normalized variables were converted into uncorrelated variables (Y's). All possible D^2 values were calculated by taking the sum of difference between pairs of corresponding 'Y' values, considering two genotypes at a time. The genotypes were grouped into clusters based on D^2 values as suggested by Tocher (Rao, 1952).

Determination of group constellation of clusters

For determining the group constellations, a relatively simple criterion suggested by Rao (1952) was followed. The criterion of grouping was that any two populations belonging to the same cluster should at least on an average show a similar D^2 than those belonging to different clusters. To start with, two closely associated genotypes were selected and a third genotype, which had the smallest D^2 from the first, was added. Similarly, the fourth genotype was chosen to have the smallest average from the first three and the process was continued up to a stage where there was disruptive increase in the average, by the addition of a particular genotype. This genotype was excluded from that cluster and the clustering was continued, omitting the genotypes that had already been included in other clusters. The process was continued until all the genotypes were included in one or the other cluster.

Intra and inter-cluster distances

After establishing the clusters, the intra-cluster distances were worked out by taking the average of the component genotypes in that cluster. The average inter cluster divergences were arrived at by taking into consideration, all the component D^2 values possible among the members of the two clusters considered. The square root of the average D^2 values gave the genetic distance 'D' between the clusters. Based on D values (inter-cluster distances), the following scale for rating of the distances was adopted (Rao 1952).

D values	Category
Less divergent (L)	99 and below
Moderately divergent (M)	Between 100 and 200
Highly divergent (H)	above 200

3.1.3.5. Selection index using discriminant function analysis

Selection index based on descriminant function technique as suggested by Smith (1939), Hazel (1943) and Falconer (1989) was evolved. The relative efficiency of selection was worked out for one, two, three or multiple traits and expressed as the percentage ratio of genetic advance for discriminant function to genetic advance for direct selection.

3.2. Varietal Evaluation Studies

The best five genotypes belonging to the photosensitive (short-day) and day-neutral types, were selected for further evaluation in terms of seed yield and pod yield during the years 1997, 1998 and 1999 in both rabi and summer seasons. Each of them belonged to the ten different clusters. The selected genotypes are listed in Table 12. Out of these ten genotypes, five (viz., PHML-64, DPI-1574, PHG-9, Muthalamada Local and CO-1) were season bound (phtosensitive) genotypes and these could be evaluated only during rabi season, since they did not flower or set pods properly during summer season. The remaining five were genotypes (viz., AK-21, AK-42, AK-26, KS-2 and Maru Kulthi) and these were evaluated in both rabi and summer. The evaluation was done in RBD with four replications. The data over

the three years and two seasons were subjected to pooled analysis, following the procedure suggested by Cochran and Cox (1957).

3.3. Hybridisation studies

The hybridization studies included standardization of techniques for selfing and crossing followed by evaluation of successful crosses in rabi and summer.

3.3.1. Materials

The same genotypes that were selected for varietal evaluation studies as described in 3.2. were utilized for undertaking hybridization studies. The parents selected included both day-neutral types as well as photosensitive types (Table 12).

3.3.2. Methods

3.3.2.1. Standardisation of techniques for selfing and crossing

Single plants of the selected genotypes were raised during 1997 rabi season, in mud pots to study floral biology, time of anthesis, stigma receptivity etc., so as to standardise techniques for selfing and crossing. For the convenience of crossing and synchronization of flowering, two staggered sowings were done at ten days interval. Recommended agronomic practices and need based plant protection measures were adopted. Large number of crosses were attempted among the selected genotypes, in all possible combinations.

3.3.2.2. Crossing

The flower buds that were due to open on next morning were selected for emasculation, which was done in the morning between 9am -10am. The flower buds were gently held between thumb and forefinger of the left hand. Looking through a magnifying glass, a longitudinal slit was made on the dorsal side of the standard petal using a fine pointed needle and the upper half was folded up and held under the thumb. The wings were separated and the keel was cut open without hurting the pistil, using the point of a fine needle to expose the anthers. The ten unopened anthers were then removed carefully, using a fine pointed forceps. Buds other than the emasculated one were removed. Then the petals were pressed gently to bring them back to original position and tied gently with a loop of fine cotton thread. The emasculated bud was then protected using an oilpaper cover. Pollination was done between 5 pm and 6 pm in the evening on the same day. Staminal column of the pollen parent with anthers in dehisced condition was drawn out with a forceps and rubbed against receptive stigma of the emasculated flower. The petals were again pressed back retaining the staminal column of male parent in between them. After pollination, the flowers were covered with oilpaper cover and tagged with a label. The oilpaper cover used for protection was removed after one week. Mature pods from successful crosses were collected in oil paper covers and stored individually, after proper drying.

3.3.2.3. Diallel analysis

Data from crosses involving the following parents were utilized for carrying out a 6x 6 diallel analysis as outlined by Griffing (1956) for Model I, Method II (excluding reciprocals). In other crosses, sufficient quantities of seeds were not obtained to undertake replicated evaluation as required in diallel analysis. The six

parents involved in the diallel analysis, designated as P1, P2, P3, P4, P5 and P6 were:

P1 - PHML-6	P4 - AK-21
P2 - Muthalamada local	P5 - AK-42
P3 - Maru Kulthi	P6 - AK-26

Among the six parents, two were photosensitive (viz., PHML-64 and Muthalamada Local) and four were day-neutral (viz., Maru Kulthi, AK-21, AK-42 and AK-26) genotypes. During 1998 rabi season, the hybrids and their parents were raised in RBD with three replications. Observations were recorded on following nine biometric traits, as described in 3.1.2 :

1. Days to flowering	2. Plant height
3. Number of branches	4. Number Pods
5. Seeds per pod	6. Hundred seed weight
7. Pod yield	8. Pod length
9. Seed yield	

a) Analysis of variance

Analysis of variance was done to test the significance of the differences among the parents and crosses, for the nine biometric traits selected for the study.

b) Combining ability analysis

Since the statistical differences for all the traits included in the study were highly significant, further analyses were carried out to assess the combining ability, as per the procedure outlined by Griffing (1956) for Model I (Fixed effect model),

Method 2, involving parents and one set of F1s. Estimation of general combining ability effects (g_i) and specific combining ability effects (s_{ij}) was done. The effects estimated in combining ability analysis were tested for their significance with the standard errors obtained by taking square root of the corresponding variances. The standard error of the corresponding effect was multiplied with the table 't' value for error degrees of freedom, both at 5 per cent and 1 per cent levels. The resulting value was then compared with the corresponding effects for their significance.

c) Analysis of genetic components

The graphic and genetic component analysis of the diallel cross was done following the methods suggested by Jinks (1954), Hayman (1954) and Aksel and Johnson (1962). The diallel hypothetic assumptions were tested by 't^2' test and uniformity of Wr and Vr (Hayman, 1954).

The theory and method of Hayman (1954) was used to estimate the genetic components of variation viz.:

D = additive genetic variance;

H_1 = dominance variance;

H_2 = $H_1[\ 1- (u-v)^2]$, which measures the dominance variance due to positive (u) and negative (v) effects of genes, where 'u' is the proportion of positive alleles and 'v is the proportion of negative alleles in the parents, since u+v = 1;

h^2 = net dominance effects;

F = covariance of additive and dominance effects;

E = expected environmental component of variance.

All these genetic parameters were tested for significance by 't' test. The 't' value for each of the parameter was computed by dividing the parameter value by its standard error. This computed 't' values were compared to tabular values of 't' for n - 2 degrees of freedom, where 'n' is the number of genotypes included in the study. The following genetic ratios were computed from the different components as per the equations given by Crumpacker and Allard (1962), as follows:

1. $(H_1 / D)^{1/2}$ = Mean degree of dominance
2. $H_2 / 4H_1$ = Proportion of genes with positive and negative effect in parents
3. $[(4D\ H_1)^{1/2}+F] / [(4D\ H_1)^{1/2}-F]$ = Ratio of dominant and recessive genes in parents
4. h^2 / H_2 = Number of groups of genes controlling the character and exhibiting dominance,
5. Narrow sense heretability estimates
6. Correlation between parental order of dominance (Wr + Vr) and parental measures (Yr).

d) Estimation of heterosis

The magnitude of heterosis in hybrids was expressed as per cent of increase or decrease of a character over mid-parent and better parent and was estimated following the formula of Hayes *et al.*(1955) and Briggle (1963).

Relative heterosis(d_i) or heterosis of hybrid over mid parental value, was calculated as:

$$(d_i) = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Where $\overline{F_1}$ = Mean value of F_1 hybrid and $\overline{MP}$ = mid-parental value.

Heterobeltiosis (d_{ii}) or heterosis of hybrid over better parent value, was calculated as:

$$(d_{ii}) = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where F_1 = Mean value of F_1 hybrid and BP -= better parent value.

Standard Heterosis (d_{iii}) or heterosis of hybrid over standard parent. The parent P2 (Muthalamada local) which is a locally popular traditional cultivar, was used as the standard parent, to calculate standard heterosis as:

$$(d_{iii}) = \frac{\overline{F_1} - \overline{SP}}{\overline{SP}} \times 100$$

Where F_1 = Mean value of F_1 hybrid and SP = values for standard parent.

The significance of estimated heterosis was tested at error degrees of freedom as per the 't' test suggested by Wynne *et al.* (1970). The computed 't' values were derived by the formula :-

't' for relative heterosis $= \dfrac{\overline{F_1} - \overline{MP}}{\sqrt{EMS / r / 3 / 2}}$

't' for heterobeltiosis $= \dfrac{\overline{F_1} - \overline{MP}}{\sqrt{EMS / r \times 2}}$

't' for standard heterosis $= \dfrac{\overline{F_1} - \overline{MP}}{\sqrt{EMS / r \times 2}}$

where ' EMS ' is the error variance and ' r ' is the number of replications.

3.3.2.5. Evaluation of parents, F_1 and F_2 for studying inheritance of photoperiodic response and grain colour

Materials:

Data from selected crosses in which comparatively larger number of F_2 segregants had been obtained, were used for studying the inheritance of photoperiodic response and grain colour.

Methods:

The flowering duration of parents, F_1 and F_2 during summer season was taken as the indicator to classify them into either photosensitive (PS) or day-neutral (DN), since photoperiod favorable for induction of flowering in photosensitive (short day) types, are not available during summer months and as such, they do not flower or set pods properly. The planting was done around last week of January. The day-neutral types flowered by 30-35 days whereas photosensitive types continued in vegetative phase even after 60 days thus helping to classify parents, F_1 and F_2 into either photosensitive or day-neutral.

The observed F_2 segregation ratios were compared with ratios as expected for standard segregation ratios that are typical to different types of gene interactions. The observed (O) and expected (E) ratios were subjected to χ^2 goodness of fit test using the following formula:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

The degrees of freedom for χ^2 was taken as (n – 1), where n = number of classes of phenotypes. In the case of photoperiodic response, the genotypes were grouped into two classes (either photosensitive or day-neutral) and accordingly the χ^2 had one degrees of freedom. For grain colour, there were three classes (black, gray and brown) and the degrees of freedom was taken as 2. The χ^2 values thus obtained were compared with tabulated values for χ^2 as given by Fisher and Yates (1963) for the corresponding degrees of freedom, to test the goodness of fit to standard F_2 segregation ratios typical to various gene actions.

RESULTS

RESULTS

The present investigation was carried out to evaluate the performance of diverse horsegram genotypes in rabi (traditional) and summer seasons, with respect to photoperiodic response, earliness and yield. The field experiments were laid out at the Regional Agricultural Research Station, Pattambi of Kerala Agricultural University during the period 1995 to 2000. The whole investigation was carried out in three experiments. The first phase consisted of evaluation of 115 germplasm accessions in rabi and summer seasons during 1995-96. Genotypes selected based on this preliminary evaluation was further tested in Comparative Yield Trials in rabi and summer seasons during 1997 to 1999. Simultaneously, hybridisation studies involving selected genotypes also were undertaken to understand the nature of gene action, especially in the case of inheritance of photoperiodic response. The results obtained are presented below:

4.1 Genetic Evaluation of germplasm accessions

Though the 115 germplasm accessions were evaluated during both rabi and summer seasons, only five accessions flowered in summer. Hence detailed biometrical analysis was done with rabi data alone.

4.1.1 Variability Studies

The data on seed yield and twelve other biometric traits (viz. plant height, number of branches, days to flowering, number of pods, pod yield, pod length, seeds per pod, hundred seed weight, haulms yield, days to maturity, harvest index and crude protein percentage) collected from the 115 germplasm accessions, were subjected to analysis of variance (ANOVA), association analysis and path analysis. The genotypes were clustered using Mahalanobis D^2 statistics.

Plate 1. Field view of experimental plots

Plate 2. Field view showing photosensitive and day-neutral genotypes

TABLE 2. ANOVA FOR THIRTEEN BIOMETRIC TRAITS DURING RABI SEASON

Characters		Mean Squares			F Value	Grand Mean	CV (%)
		Replication	Genotypes	Error	Genotypes		
Seed yield (g)	(Y)	0.252	1.678	0.061	27.58**	1.766	13.96
Plant height (cm)	(X_1)	0.452	425.570	8.044	52.91**	35.179	8.06
Number of branches	(X_2)	0.004	5.410	0.079	68.21**	1.773	15.89
Days to Flowering	(X_3)	0.017	32.573	0.377	86.39**	35.817	1.71
Number of pods	(X_4)	48.944	210.551	27.814	7.57**	18.760	28.11
Pod yield (g)	(X_5)	0.720	4.475	0.160	27.88**	2.914	13.75
Pod length (cm)	(X_6)	0.077	0.472	0.080	5.89**	4.475	6.32
Seeds per pod	(X_7)	0.084	0.575	0.130	4.34**	5.828	6.25
100 seed weight (g)	(X_8)	0.074	0.525	0.031	16.75**	2.930	6.04
Haulms yield (g)	(X_9)	0.148	1.169	0.044	26.82**	1.764	11.83
Days to maturity	(X_{10})	1.113	42.794	0.210	204.23**	76.313	0.60
Harvest index	(X_{11})	0.001	0.054	0.005	11.39**	0.600	11.52
Crude protein (%)	(X_{12})	4.060	10.932	0.340	32.11**	15.906	3.67

** Significant at 0.01 level

TABLE 3. MEAN VALUES OF THIRTEEN BIOMETRIC TRAITS DURING RABI SEASON

Sl. No	Variety / Accession Number	Seed yield (g)	Plant height (cm)	Number of branches	Days to flowe-ring	Number of pods	Pod yield (g)	Pod length (cm)	Seeds per pod	100 seed weight (g)	Haulms yield (g)	Days to maturity	Harvest index	Crude protein (%)
1	AK-21	3.585	64.70	7.20	35.50	70.20	5.82	5.30	6.65	2.660	3.105	76.00	0.67	16.23
2	IC-7588	2.700	35.90	1.50	35.00	6.60	4.78	4.60	6.10	3.105	2.325	75.00	0.57	17.97
3	IC-19432	1.265	39.30	3.70	33.00	22.80	2.53	5.20	6.20	3.135	2.725	72.00	0.32	16.89
4	IC-19433	1.880	31.10	3.10	40.00	25.90	2.72	5.00	6.50	3.050	1.965	78.00	0.67	12.10
5	IC-19441	1.040	24.00	1.00	42.00	18.00	2.05	4.40	5.60	2.805	1.035	80.00	0.51	16.43
6	IC-19444	1.820	33.20	1.70	42.00	12.50	2.88	5.00	5.90	2.740	1.730	83.00	0.84	13.15
7	DPI-1584	1.535	38.80	1.60	36.00	17.80	2.23	3.70	5.20	3.265	1.885	76.00	0.60	18.68
8	IC-22784	1.740	26.05	0.95	35.00	13.60	3.54	4.00	5.10	4.770	2.350	75.00	0.42	16.15
9	IC-22799	3.335	34.40	1.10	35.00	17.80	6.14	4.90	6.30	2.840	2.725	75.00	0.61	18.34
10	IC-22805	2.170	40.15	2.25	39.00	22.50	3.46	4.70	5.70	3.615	2.310	76.00	0.73	16.60
11	IC-22812	0.900	40.80	3.10	39.00	36.25	1.66	4.60	5.70	2.935	2.010	78.00	0.32	14.40
12	IC-22813	1.915	32.00	1.30	32.00	12.30	3.71	4.70	5.90	2.365	1.535	70.00	0.59	12.07
13	IC-23453	3.375	27.80	1.35	32.00	13.60	6.02	4.35	6.20	3.890	2.095	72.00	0.71	11.15
14	IC-23460	2.695	43.70	3.60	32.00	38.05	4.80	5.30	6.80	3.105	2.675	72.00	0.57	14.50
15	IC-23462	1.205	40.70	3.60	32.00	26.60	2.60	5.10	6.40	3.545	3.235	72.00	0.58	19.56
16	DPI-1574	0.795	35.50	2.25	34.00	26.30	1.55	5.20	6.60	2.820	1.740	74.50	0.32	13.24
17	IC-23464	2.465	21.10	1.75	35.00	11.20	4.34	5.35	5.40	2.080	2.305	74.50	0.59	13.78
18	IC-23467	2.420	15.80	1.20	38.00	7.30	4.65	4.30	5.80	2.995	2.415	80.50	0.52	15.10

Sl. No	Variety / Accession Number	Seed yield (g)	Plant height (cm)	Number of branches	Days to flowe-ring	Number of pods	Pod yield (g)	Pod length (cm)	Seeds per pod	100 seed weight (g)	Haulms yield (g)	Days to maturity	Harvest index	Crude protein (%)
19	IC-23495	1.980	16.90	3.10	38.00	14.20	3.51	4.25	5.70	3.145	2.065	81.00	0.55	14.43
20	IC-23508	3.390	31.20	3.10	31.00	36.50	5.30	4.50	5.70	2.530	2.000	72.00	0.97	20.40
21	IC-24842	2.230	30.90	3.00	36.00	21.00	3.61	5.40	6.00	2.465	1.710	75.00	0.73	18.86
22	IC-26125	1.280	32.10	2.20	35.00	23.00	2.33	4.90	6.30	2.900	1.540	75.00	0.54	16.84
23	IC-26128	0.715	43.80	1.90	30.00	23.50	1.25	4.40	5.70	2.970	0.955	69.00	0.49	11.72
24	IC-26120	1.350	30.50	1.10	32.00	15.50	2.52	4.70	6.10	3.420	1.455	71.00	0.51	10.73
25	IC-26136	0.695	24.65	0.90	32.00	15.50	1.16	4.70	6.10	2.630	0.875	71.50	0.52	15.16
26	IC-26144	2.285	27.00	0.90	35.00	15.10	3.72	4.20	5.90	3.045	1.445	75.00	0.66	17.08
27	BGM-1	1.710	24.60	1.70	32.00	22.70	2.64	4.10	5.75	3.005	2.040	71.50	0.69	16.59
28	IC-32760	1.455	24.10	1.50	32.00	17.60	2.43	4.30	5.85	2.610	1.390	73.00	0.80	15.94
29	IC-32848	1.315	40.90	0.55	31.50	10.20	1.98	4.25	5.80	3.115	1.300	71.50	0.60	13.24
30	IC-33072	1.825	31.10	1.70	38.50	18.30	3.14	5.20	7.00	2.835	0.945	80.00	0.78	15.33
31	IC-33183	1.170	24.60	1.00	36.00	16.40	1.87	4.10	5.85	3.260	0.805	84.00	0.74	16.85
32	IC-33198	0.765	45.70	2.30	39.00	26.65	1.18	4.30	6.10	2.980	2.315	80.50	0.28	20.16
33	IC-33765	0.895	30.35	1.70	32.00	15.00	1.53	4.90	6.00	3.195	2.175	72.00	0.32	16.40
34	IC-45698	2.700	22.90	0.60	32.00	15.50	4.55	4.55	6.10	2.695	1.235	73.00	0.85	18.10
35	IC-45702	1.125	22.90	3.05	39.00	28.30	1.97	4.50	5.80	3.015	2.775	81.00	0.31	16.84
36	IC-45703	1.900	23.30	0.40	36.00	5.40	3.09	4.00	5.50	2.900	0.890	75.00	0.88	19.80
37	IC-45713	1.170	35.40	0.25	35.00	13.35	1.87	4.40	5.60	2.700	0.820	73.00	0.78	17.34
38	IC-45724	1.500	37.10	1.50	32.00	23.90	2.18	4.80	6.10	2.840	2.500	72.50	0.47	18.59
39	IC-45732	1.780	44.90	0.70	32.00	10.10	2.30	5.50	6.00	3.555	2.555	72.00	0.60	13.56

Sl. No	Variety / Accession Number	Seed yield (g)	Plant height (cm)	Number of branches	Days to flowe-ring	Number of pods	Pod yield (g)	Pod length (cm)	Seeds per pod	100 seed weight (g)	Haulms yield (g)	Days to maturity	Harvest index	Crude protein (%)
40	IC-45733	2.470	22.80	0.20	36.00	13.20	3.94	5.05	5.80	3.115	0.910	75.00	0.95	14.33
41	IC-45743	0.400	27.80	1.50	32.00	11.50	0.65	4.50	5.70	3.285	1.970	72.00	0.18	16.93
42	IC-45749	0.935	24.90	0.40	32.00	13.30	1.61	4.90	6.50	2.870	0.935	72.00	0.48	14.43
43	IC-45752	0.655	24.85	0.35	35.00	17.60	1.08	4.95	5.70	3.000	0.845	75.00	0.52	13.29
44	CODB-8	1.890	25.10	0.40	39.00	13.50	2.90	4.70	6.50	2.800	0.915	78.00	0.87	17.65
45	IC-45756	0.585	22.70	0.55	38.50	13.30	0.95	4.70	6.20	2.390	1.565	81.50	0.31	15.76
46	IC-50707	0.905	26.90	0.60	32.00	15.10	1.50	3.95	5.70	3.030	1.550	71.00	0.43	14.23
47	IC-50712	2.355	24.90	0.95	38.00	11.30	3.85	4.70	6.10	3.505	1.215	78.00	0.88	18.16
48	IC-50714	1.510	26.90	0.50	36.00	18.60	2.41	4.00	5.90	2.720	1.190	76.00	0.68	16.67
49	IC-50727	2.000	22.70	0.70	40.50	5.80	3.22	4.10	5.00	2.425	1.510	79.00	0.73	14.63
50	IC-50728	2.275	29.20	1.30	40.00	14.90	3.58	4.20	6.40	2.835	1.490	82.00	0.77	17.71
51	IC-145267	1.000	24.10	0.50	39.00	20.80	1.60	4.80	5.80	2.495	1.300	85.00	0.52	16.10
52	AK-42	4.445	21.55	1.40	40.00	18.60	6.88	5.40	5.70	2.735	2.045	83.00	0.96	15.55
53	IC-145344	1.530	25.35	0.70	40.50	25.40	2.43	4.70	6.20	2.830	1.570	81.00	0.62	19.05
54	IC-121641	1.530	20.90	0.15	32.00	12.60	2.43	4.50	5.80	3.345	1.170	72.00	0.74	17.66
55	IC-123024	1.235	22.70	1.10	39.00	12.50	1.99	4.40	6.20	3.525	2.180	78.00	0.43	10.91
56	IC-145252	1.295	27.00	1.10	36.00	13.75	2.07	4.42	5.60	3.200	2.160	78.00	0.53	19.66
57	IC-145254	1.360	27.60	2.20	36.00	13.70	2.26	4.40	5.70	3.105	1.615	77.00	0.54	15.18
58	IC-145258	2.775	46.00	3.00	38.00	19.00	4.43	4.45	5.65	3.245	2.535	78.00	0.66	14.37
59	IC-145259	3.075	17.50	0.80	37.00	8.95	4.94	4.80	5.15	2.715	0.980	78.00	0.93	13.06
60	IC-68591	1.120	54.50	0.70	36.00	4.50	1.87	4.05	6.30	2.530	1.190	76.00	0.58	19.10

Sl. No	Variety / Accession Number	Seed yield (g)	Plant height (cm)	Number of branches	Days to flowe-ring	Number of pods	Pod yield (g)	Pod length (cm)	Seeds per pod	100 seed weight (g)	Haulms yield (g)	Days to maturity	Harvest index	Crude protein (%)
61	IC-68602	1.315	43.60	1.40	32.00	8.60	2.28	4.15	3.85	2.805	0.850	72.00	0.72	16.80
62	IC-88990	0.825	32.80	0.35	35.00	7.80	1.33	4.10	6.00	2.505	1.285	77.00	0.48	18.43
63	IC-89000	0.785	18.35	0.80	39.00	6.00	1.28	3.85	5.35	2.525	1.515	81.00	0.39	12.51
64	IC-71725	0.660	50.95	0.15	42.50	37.50	1.09	3.80	4.60	2.685	0.870	86.00	0.52	14.21
65	IC-71733	1.795	40.05	0.90	30.00	17.00	2.92	3.90	5.80	3.265	1.265	69.00	0.76	19.69
66	IC-71748	3.075	72.70	1.30	32.00	22.30	4.99	5.10	5.60	2.580	0.910	71.00	0.86	16.04
67	IC-71760	1.340	73.15	0.60	31.00	19.80	2.22	4.60	6.00	2.510	2.300	73.00	0.43	13.36
68	IC-71769	0.890	31.60	4.40	32.00	36.35	1.48	3.20	6.95	2.745	0.950	73.00	0.58	15.40
69	IC-71770	1.560	25.20	2.80	36.00	27.50	2.49	4.30	6.35	2.630	2.165	78.00	0.51	15.32
70	IC-71778	0.940	32.30	1.05	35.00	27.25	1.56	4.05	6.00	2.445	0.920	78.00	0.61	13.82
71	IC-71787	1.960	77.30	1.50	35.00	46.10	3.17	4.70	6.00	2.995	1.450	76.00	0.78	18.08
72	IC-71791	1.595	63.50	4.70	31.00	22.00	2.64	4.40	6.00	2.865	1.495	72.00	0.63	17.03
73	IC-71808	1.090	25.60	1.10	36.00	26.45	1.76	4.00	6.35	2.805	1.640	76.00	0.48	15.57
74	IC-71809	1.130	37.60	0.50	38.00	17.85	1.83	4.10	5.05	3.380	1.600	78.00	0.50	13.23
75	IC-71812	0.975	23.60	0.15	40.50	9.30	1.59	4.20	6.00	4.490	1.620	79.00	0.44	14.43
76	IC-71813	0.605	19.50	0.35	40.00	5.10	1.05	4.15	5.20	2.740	0.830	81.00	0.48	17.73
77	IC-71814	0.420	23.20	0.20	40.00	11.90	0.73	4.25	5.50	1.905	0.925	81.00	0.35	15.41
78	IC-71816	0.530	27.20	0.15	35.00	3.60	0.87	3.10	4.10	1.275	1.070	75.00	0.38	*15.01*
79	IC-71817	3.630	43.25	2.30	40.00	31.45	5.73	4.90	5.25	2.990	2.195	81.00	0.84	14.84
80	IC-71823	1.720	32.65	1.60	40.50	12.60	2.79	3.90	4.95	2.570	1.460	81.00	0.68	18.19
81	IC-55085	1.010	22.35	0.15	39.00	4.50	1.84	4.28	4.60	2.510	1.620	78.00	0.42	18.99

Sl. No	Variety / Accession Number	Seed yield (g)	Plant height (cm)	Number of branches	Days to flowe-ring	Number of pods	Pod yield (g)	Pod length (cm)	Seeds per pod	100 seed weight (g)	Haulms yield (g)	Days to maturity	Harvest index	Crude protein (%)
82	IC-55973	1.760	23.60	1.20	39.00	15.80	2.85	4.90	6.20	2.875	1.645	78.00	0.65	17.05
83	IC-56126	1.150	24.30	0.40	38.00	5.30	1.96	4.70	4.55	2.175	0.920	78.00	0.67	19.05
84	IC-56141	0.860	28.35	0.70	36.00	26.55	1.40	4.20	6.00	2.790	1.285	78.00	0.47	11.55
85	IC-56147	2.095	17.40	2.70	32.00	5.05	3.39	3.70	5.60	3.030	1.865	73.00	0.66	11.76
86	IC-89004	0.965	26.15	0.15	32.00	21.55	1.55	4.90	5.95	2.785	0.900	73.00	0.65	18.16
87	IC-89005	1.305	24.50	0.60	32.00	25.95	2.14	4.70	6.75	2.895	0.915	73.00	0.69	19.07
88	IC-89010	1.155	26.35	1.90	38.00	6.35	1.97	4.10	5.40	2.430	0.905	79.50	0.58	18.01
89	IC-89015	1.900	24.40	2.30	43.00	6.35	3.07	4.30	5.70	2.610	1.210	88.00	0.63	16.28
90	IC-89036	0.845	51.65	0.15	38.00	17.85	1.35	4.40	5.60	2.515	0.855	78.00	0.63	17.12
91	IC-89038	0.585	43.05	0.20	38.00	18.35	0.96	3.80	4.85	3.240	0.945	78.00	0.45	12.19
92	IC-89039	1.600	23.40	0.70	35.00	10.20	2.31	3.90	5.70	1.860	1.625	77.00	0.66	18.06
93	IC-89041	1.390	35.30	1.90	35.00	16.80	2.23	4.10	6.00	2.415	0.940	78.00	0.79	15.66
94	IC-22760	0.925	22.10	0.30	37.00	8.60	1.50	4.60	5.90	2.995	0.920	78.00	0.62	17.01
95	IC-23460	0.910	19.85	0.50	32.00	10.70	1.53	4.50	5.40	2.915	2.695	71.00	0.28	11.73
96	IC-26143	1.405	25.50	0.75	32.00	13.30	2.42	4.80	6.50	2.795	1.265	71.00	0.60	17.68
97	IC-56147	2.115	37.65	0.70	32.00	8.90	3.44	4.50	4.85	2.665	1.540	72.00	0.74	19.21
98	IC-65463	1.075	46.40	0.85	30.00	12.80	1.69	4.50	6.00	2.685	1.675	68.50	0.47	18.66
99	IC-27602	1.735	17.40	2.70	32.50	14.05	2.81	4.50	5.00	2.275	1.825	76.00	0.60	14.14
100	IC-145270	3.215	36.60	0.30	40.00	13.90	5.23	4.80	6.70	2.725	1.520	79.00	0.86	15.77
101	IC-19446	3.310	66.70	6.40	43.00	35.30	5.45	4.10	6.00	3.685	3.675	86.00	0.57	14.43
102	Maru Kulthi	3.750	45.15	1.10	29.00	22.95	5.97	4.50	5.70	3.920	2.345	68.00	0.83	15.41

Sl. No	Variety / Accession Number	Seed yield (g)	Plant height (cm)	Number of branches	Days to flowe-ring	Number of pods	Pod yield (g)	Pod length (cm)	Seeds per pod	100 seed weight (g)	Haulms yield (g)	Days to maturity	Harvest index	Crude protein (%)
103	145245	2.395	46.95	1.20	29.00	20.50	3.84	4.30	5.85	3.525	1.675	69.00	0.77	13.78
104	1102	2.575	37.80	2.60	29.00	24.80	4.24	5.50	5.85	2.395	2.140	68.00	0.69	13.45
105	PHG-9	4.425	64.05	6.00	42.00	41.05	7.12	4.00	6.05	2.800	3.875	88.00	0.68	15.09
106	IC-45753	1.590	65.80	6.05	43.00	27.75	2.57	4.10	6.20	2.810	2.950	81.50	0.40	15.80
107	CO-1	1.620	67.20	5.40	45.00	19.10	2.91	4.10	6.00	2.950	2.730	82.00	0.40	15.70
108	Muthalamada Local	2.885	65.40	6.90	52.00	36.80	4.68	4.45	5.85	4.160	3.670	90.50	0.53	14.43
109	EC-18679	2.415	74.00	2.35	32.00	24.60	3.91	6.25	6.15	4.300	3.220	72.00	0.51	18.65
110	IC-16978	2.765	43.50	0.95	29.00	18.20	4.51	4.40	6.20	3.790	2.050	68.50	0.73	13.33
111	IC-32746	2.410	61.55	5.35	35.00	20.50	3.91	4.40	6.40	2.850	2.670	76.00	0.58	17.10
112	IC-23462	2.600	52.40	4.55	38.00	33.05	4.21	4.25	5.95	2.710	2.695	79.00	0.60	19.64
113	IC-24849	3.105	50.70	4.25	40.00	25.35	5.03	4.15	6.05	2.815	2.665	81.00	0.69	13.82
114	PHML-64	3.925	57.20	6.30	35.00	34.00	6.36	3.85	5.50	2.885	4.410	78.00	0.57	17.84
115	KS-2	3.115	40.95	4.50	32.00	29.20	5.14	4.00	5.70	4.255	2.935	72.00	0.63	14.01
Grand Mean		1.766	35.18	1.77	35.82	18.76	2.91	4.48	5.83	2.930	1.764	76.31	0.60	15.91
Critical Difference		0.49	5.62	0.56	1.22	10.44	0.79	0.56	0.72	0.39	0.42	0.91	0.14	1.15
Maximum		4.445	77.30	7.20	52.00	70.20	7.12	6.25	7.00	4.770	4.410	90.50	0.97	20.40
Minimum		0.400	15.80	0.15	29.00	3.60	0.65	3.10	3.85	1.275	0.805	68.00	0.18	10.73
Range		4.045	61.50	7.05	23.00	66.60	6.47	3.15	3.15	3.495	3.605	22.50	0.79	9.68
% of magnitude of range over mean		229.049	174.82	398.31	64.21	355.01	222.34	70.31	54.03	119.283	204.365	29.48	131.67	60.84

Plate 3. Field view of the genotype Muthalamada local

Plate 4. Field view of the genotype CO-1

Plate 5. Variability among genotypes for root spread

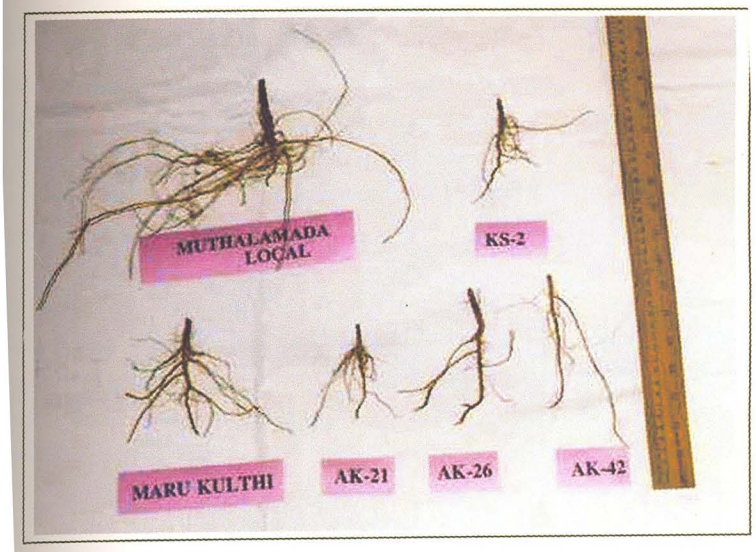


Plate 6. Variability among genotypes for growth habit

Analysis of variance was done for the traits to test the significance of the differences among the genotypes and the abstract of ANOVA is presented in Table 2. It was observed that the 'F' ratio was significant for all the thirteen traits, even at 0.01 level, indicating that there were significant inherent differences among the genotypes for all these traits.

Mean performances of the genotypes with respect to the thirteen biometric traits studied, are presented in Table 3, along with grand mean and range. The variability expressed for the 13 biometric traits estimated on the basis of phenotypic and genotypic coefficients of variability are presented in Table 4, along with heritability (broad sense), genetic advance and genetic gain.

Wide range of variation was observed for all the traits. Mean seed yield was the maximum for V-52 (4.445g), which was statistically on par with that of V-105 (4.425g) and minimum for V-41 (0.400g). Grand mean for the trait was 1.766 g and forty-eight genotypes had mean values above grand mean. V-71 was the tallest genotype with 77.30 cm height and three other entries viz. V-107, V-67, and V-66 with values of 74.0, 73.15 and 72.7 cm respectively, were statistically on par with this entry. V-18 was the shortest with a height of 15.80 cm. Forty-eight genotypes had mean height above the grand mean of 35.179 cm. In the case of number of branches, values ranged from 0.15 in V-54 to 7.2 in V-1, which was statistically on par with V-108, which had a value of 6.9. Thirty-nine genotypes had mean values above the general mean of 1.773.

Days to flowering ranged from 29 days for V-102, V-103, V-104 and V-110, to 52 days for V-108. Three other entries that flowered in thirty days, viz. V-23, V-65 and V-98, were on par with the four early flowering entries. The grand mean for the trait was 35.817 days and fifty-eight genotypes had flowering duration above this value. The genotype V-1 produced maximum number of pods (70.2), which was significantly superior over other entries. V-78 had the minimum number (3.6). Forty-

five genotypes produced more number of pods per plant than the grand mean of 18.760. Pod yield per plant ranged from 0.65 g in V-41 to 7.12 g in V-105. Two other entries viz. V-52 and V-114 with a mean pod yield of 6.88 g and 6.36 g also were on par with the best entry V-41. Average for the trait was 2.91 g and forty-six genotypes had values above that. Length of pod was maximum for V-109 (6.25 cm), which was significantly superior over others. V-78 had the shortest pods with 3.1 cm length. The grand mean for this trait was 4.475 cm and as many as fifty-five genotypes had values above this. Number of seeds per pod was maximum in genotype V-30 and minimum for V-61, the values being 7.00 and 3.85 respectively. Nineteen other entries, which had mean values above 6.28, were on par with V-30. Sixty-four genotypes had more number of seeds per pod than the grand mean of 5.828.

Boldness of grains, as measured by hundred seed weight, was maximum for V-8 (4.770g) followed by V-75 (4.490 g), which were statistically on par. The minimum value was for V-78 (1.275 g). Forty-eight genotypes had values above the over all mean value of 2.930 g. In the case of haulms yield per plant, V-114 was superior to others (4.410 g). Minimum for the trait was for V-31 (0.805 g) and forty-eight genotypes had values above the grand mean (1.764 g).

Genotypes V-102 and V-104 had the maximum duration (90.5 days each). Two other entries viz. V-110 and V-98 with mean duration of 68.5 days each, also were on par. V-108 took the minimum number of days for maturity (68.0 days). The average for this trait was 76.31 days. Fifty-five genotypes were had longer duration than this. Harvest index values were found to be the highest for V-20 (0.97) and thirteen other entries that had mean values above 0.80 were on par to this. The lowest value was for V-41 (0.18). Fifty-five genotypes had harvest index above the grand mean of 0.60. The crude protein percentage of the grains ranged widely from 20.40 in V-20 to 10.73 in V-24. Six more entries that had mean values above 19.26 were

statistically on par to V-20 in high protein content. Average for the trait was 15.906 and as many as fifty-nine genotypes had higher crude protein content than that.

4.1.2 Phenotypic and Genotypic Coefficients of Variation

The variability among the genotypes, expressed as percentage over mean (Phenotypic coefficient of variation or PCV and Genotypic coefficient of variation or GCV) are presented in Table 4. Lowest PCV values were recorded for days to maturity (6.08) and highest for number of branches (93.44). GCV estimates also followed a similar trend (lowest value of 6.05 for days to maturity and highest value of 92.08 for branches per plant). Other characters having relatively higher PCV and GCV were number of pods (58.19, 50.95), seed yield (52.80, 50.92), pod yield (52.24, 50.41), haulms yield (44.15, 42.52) and plant height (41.86, 41.07).

Moderate PCV and GCV values were recorded for hundred seed weight (18.00, 16.98), crude protein percentage (14.93, 14.47) and days to flowering (11.33, 11.20). Moderate PCV and low GCV values were recorded for pod length (11.74, 9.89) and seeds per pod (10.21, 8.07). Environmental coefficient of variation (ECV) was high for number of pods (28.11), and moderate for number of branches (15.85), seed yield (13.99), pod yield (13.73), haulms yield (11.89), and harvest index (11.79). Low ECV was observed for days to maturity (0.60), days to flowering (1.71), crude protein percentage (3.67), hundred seed weight (6.01), seeds per pod (6.26), pod length (6.32) and plant height (8.06).

Difference between GCV and PCV was the least for days to maturity (0.03) followed by days to flowering (0.13) and crude protein percentage (0.46), indicating that these traits are less influenced by external (environmental) factors. The difference was maximum for number of pods per plant (7.24). For other traits the difference was 0.79 for plant height, 1.02 for hundred seed weight, 1.36 for number

TABLE 4. VARIANCE, COEFFICIENT OF VARIATION, HERITABILITY, GENETIC ADVANCE AND GENETIC GAIN FOR THIRTEEN BIOMETRIC TRAITS

Characters		Variance			PCV	GCV	ECV	Heritability	Genetic Advance	Genetic Gain
		Phenotypic	Genotypic	Environment						
Seed yield (g)	(Y)	0.87	0.81	0.06	52.80	50.92	13.99	93.06	1.79	101.22
Plant height (cm)	(X_1)	216.81	208.76	8.04	41.86	41.07	8.06	96.32	29.22	83.05
Number of branches	(X_2)	2.74	2.67	0.08	93.44	92.08	15.85	97.14	3.32	186.98
Days to Flowering	(X_3)	16.48	16.10	0.38	11.33	11.20	1.71	97.73	8.17	22.81
Number of pods	(X_4)	119.18	91.37	27.81	58.19	50.95	28.11	76.84	17.28	92.11
Pod yield (g)	(X_5)	2.32	2.16	0.16	52.24	50.41	13.73	93.13	2.92	100.23
Pod length	(X_6)	0.28	0.20	0.08	11.74	9.89	6.32	71.20	0.77	17.22
Seeds per pod	(X_7)	0.35	0.22	0.13	10.21	8.07	6.26	62.78	0.77	13.20
100 seed weight (g)	(X_8)	0.29	0.25	0.03	18.00	16.98	6.01	88.83	0.96	32.93
Haulms yield (g)	(X_9)	0.61	0.56	0.04	44.15	42.52	11.89	92.87	1.49	84.46
Days to maturity	(X_{10})	21.50	21.29	0.21	6.08	6.05	0.60	99.03	9.46	12.40
Harvest index	(X_{11})	0.03	0.02	0.01	28.58	26.04	11.77	83.99	0.30	49.45
Crude protein (%)	(X_{12})	5.64	5.30	0.34	14.93	14.47	3.67	94.01	4.60	28.90

of branches, 1.63 for haulms yield, 1.83 for pod yield, 1.85 for pod length, 1.88 for seed yield, 2.14 for seeds per pod and 2.54 for harvest index.

4.1.3. Heritability

Heritability estimates in broad sense (H^2) are presented in Table 4. The values were high for all the traits. It was the highest for days to maturity (99.03%), followed by days to flowering (97.73%), branches per plant (97.14%), plant height (96.32%), crude protein content (94.01%), pod yield per plant (93.13%), seed yield per plant (93.06%), haulms yield per plant (92.87%), hundred seed weight (88.83%), harvest index (83.99%), pods per plant (76.84%) and pod length (71.20%). Least heritability value was recorded for seeds per pod (62.78 %).

4.1.4. Expected Genetic Advance and Genetic Gain

Genetic advance estimates (GA) were the highest for plant height (29.22), followed by pods per plant (17.28). For other traits, the values were 9.46 for days to maturity, 8.17 for days to flowering, 4.60 for crude protein percentage, 3.32 for number of branches, 2.92 for pod yield, 1.79 for seed yield, 1.49 for haulms yield, 0.96 for hundred seed weight and 0.77 for pod length and seeds per pod. Harvest index recorded the least value (0.30). Genetic gain (genetic advance expressed as percentage over mean) estimates were high for number of branches (186.98), seed yield (101.22), pod yield (100.23), number of pods (92.11), haulms yield (84.46), plant height (83.05), harvest index (49.45), hundred seed weight (32.93), crude protein percentage(28.90) and days to flowering (22.81). It was moderate for the remaining traits viz. pod length (17.22), seeds per pod (13.20) and days to maturity (12.40).

4.1.5. Correlation Studies

The associations among the biometric traits under study were estimated both at genotypic and phenotypic levels by genotypic and phenotypic correlation analysis and the correlation coefficient values are presented in Table 5 and illustrated graphically in Fig. 3.

4.1.5.1. Correlation between seed yield and its components

Seed yield exhibited significant positive correlation (both at phenotypic and genotypic levels) with pod yield per plant (0.987*, 0.994**), harvest index (0.601*, 0.613**), haulms yield per plant (0.513*, 0.555**), number of branches per plant (0.440*, 0.469**) and plant height (0.302*, 0.324**). Significant positive correlation at genotypic level and non-significant positive correlation at phenotypic level was observed in the case of number of pods (0.289, 0.382**), pod length (0.216, 0.247**) and hundred seed weight (0.212, 0.225*). Positive but non-significant correlations at both phenotypic and genotypic levels were recorded in the case of seeds per pod (0.114, 0.175), days to maturity (0.062, 0.068) and days to flowering (0.050, 0.051). The phenotypic and genotypic correlations of crude protein percentage with seed yield, were not significant (0.004, -0.003).

4.1.5.2. Inter-correlations among yield components.

Plant height

Plant height had significant positive correlations at phenotypic and genotypic levels, with number of branches (0.542*, 0.556**), number of pods (0.525*, 0.598**) and haulms yield (0.449*, 0.470**). Inter-correlations of this trait with pod yield (0.289, 0.310**) and hundred seed weight (0.179, 0.198*) were significant at genotypic level only. In other cases, inter-correlations were not significant.

TABLE 5. PHENOTYPIC AND GENOTYPIC CORRELATION COEFFICIENTS FOR THE ASSOCIATION OF SEED YIELD AND TWELVE BIOMETRIC TRAITS.

Characters		Plant Height	Number of branches	Days to flowe-ring	Number of pods	Pod yield	Pod length	Seeds per pod	100 seed weight	Haulms yield	Days to maturity	Harvest index	Crude protein %
Seed yield	P	0.302*	0.440*	0.050	0.289	0.987*	0.216	0.114	0.212	0.513*	0.062	0.601*	0.004
	G	0.324**	0.469**	0.051	0.382**	0.994**	0.247*	0.175	0.225*	0.555**	0.068	0.613**	-0.003
Plant height	P		0.542*	0.039	0.525*	0.289	0.082	0.122	0.179	0.449*	0.005	-0.012	0.058
	G		0.556**	0.041	0.598**	0.310**	0.091	0.141	0.198*	0.470**	0.007	-0.001	0.064
Number of branches	P			0.227	0.615*	0.445**	0.011	0.234	0.148	0.710*	0.232	-0.065	-0.017
	G			0.234**	0.681**	0.477**	0.006	0.287**	0.171	0.745**	0.236**	-0.073	-0.020
Days to Flowering	P				0.058	0.040	-0.144	-0.085	-0.039	0.127	0.919*	-0.071	-0.007
	G				0.072	0.040	-0.156	-0.116	-0.040	0131	0.933**	-0.073	-0.003
Number of pods	P					0.279	0.142	0.305*	0.118	0.427*	0.097	0.006	0.000
	G					0.371**	0.178	0.425**	0.173	0.503**	0.108	0.028	-0.011
Pod yield	P						0.224	0.123	0.225	0.529*	0.047	0.550*	-0.003
	G						0.253**	0.182	0.246**	0.569**	0.053	0.582**	-0.013
Pod length	P							0.331*	0.092	0.145	-0.186	0.135	0.020
	G							0.418**	0.116	0.162	-0.218*	0.160	0.013
Seeds per pod	P								0.146	0.160	-0.083	0.027	0.001
	G								0.230**	0.217*	-0.110	0.040	0.025
100 seed weight	P									0.362*	-0.108	-0.015	-0.133
	G									0.389**	-0.116	-0.035	-0.145
Haulms yield	P										0.116	-0.228	-0.027
	G										0.120	-0.214*	-0.040
Days to maturity	P											-0.048	0.014
	G											-0.058	0.013
Harvest index	P												0.152
	G												0.169

P = Phenotypic correlation coefficient G = Genotypic correlation coefficient * = Significant at 5 % level ** = Significant at 1 % level

Number of branches

Association of this trait was positive and significant at phenotypic and genotypic levels, with plant height (0.542*, 0.556**), number of pods (00.615*, 0.681**), pod yield (0.445**, 0.477**) and haulms yield (0.710*, 0.745**). Inter-correlations of this trait with days to flowering (0.227, 0.234**), seeds per pod (0.234, 0.287**) and days to maturity (0.232, 0.236**) were significant at genotypic level only. With other traits, the inter-correlations were not significant.

Days to flowering

This trait had significant positive association at phenotypic and genotypic levels with days to maturity alone (0.919*, 0.933**).

Number of pods

The phenotypic and genotypic correlations for number of pods per plant were positive and significant with number of branches (0.615*, 0.681**), plant height (0.525*, 0.598**), seeds per pod (0.305*, 0.425**) and haulms yield (0.427*, 0.503**). Inter-correlations of this trait with pod yield (0.279, 0.371**) were significant at genotypic level only. With remaining traits, the inter-correlations were not significant.

Pod yield

This trait had significant positive inter-correlations at phenotypic and genotypic levels, with number of branches (0.445**, 0.477**), haulms yield (0.529*,0.569**) and harvest index (0.550*, 0.582**). Inter-correlations of this trait with plant height (0.0.289, 0.310**), number of pods (0.279, 0.371**), pod length (0.0.224, 0.253**) and hundred seed weight (0.225, 0.246*) were significant at genotypic level only. For other traits the inter-correlations were not significant.

Pod length

The phenotypic and genotypic inter-correlations of this trait were positive and significant only with seeds per pod (0.331*, 0.418**). The genotypic association

alone was significant and positive with pod yield (0.253*). Inter-correlation with days to maturity was significant at genotypic level only (- 0.218*). In the remaining cases, the associations were not significant.

Seeds per pod

This trait had significant positive phenotypic and genotypic correlations with number of pods (0.305*, 0.425**) and length of pods (0.331, 0.418**). Genotypic correlations alone were significant with number of branches (0.234, 0.287**), hundred seed weight (0.146, 0.230**) and haulms yield (0.160, 0.217*). Inter-correlations were not significant with other traits.

Hundred seed weight

In the case of hundred seed weight, the inter- correlations were not significant in most of the cases. However the trait had significant positive association at phenotypic and genotypic levels, with haulms yield (0.362*. 0.389**). It also had significant positive association at genotypic level with plant height (0.179, 0.198*), pod yield (0.225, 0.246**) and seeds per pod (0.146, 0.230**).

Haulms yield

The trait had significant positive association at phenotypic and genotypic levels with plant height (0.449*, 0.470**), number of branches (0.710*, 0.745**), number of pods (0.427*, 0.503**), pod yield (0.529*, 0.569**) and hundred seed weight (0.362*, 0.389**). Inter- correlation of the trait with seeds per pod (0.160, 0.217*) was significant at genotypic level only. The trait had negative association with harvest index that was significant at genotypic level (-0.228, -0.214*).

Days to maturity

Inter-correlation of this trait was positive and significant with days to flowering (0.919*, 0.933**) at both levels and with number of branches (0.232*, 0.236**), at genotypic level. The trait had negative correlation with pod length (-

0.186, -0.218*), significant at genotypic level. The negative correlations with seeds per pod (-0.083, -0.110), hundred seed weight (-0.108, -0.116) and harvest index (-0.048, -0.058), were however not significant.

Harvest Index

The phenotypic and genotypic inter-correlations of this trait were positive and significant with pod yield (0.550*, 0.582**) only. The genotypic values were negative and significant with haulms yield (-0.228, -0.214*). Non-significant negative associations were observed for plant height, number of branches, days to flowering, days to maturity and hundred seed weight. In remaining cases, the inter-correlations were positive and non-significant.

Crude protein percentage

This trait did not appear to have significant inter-correlations with any of the traits under study at either phenotypic or genotypic levels.

4.1.6. Path Analysis

Eight traits that had significant association with seed yield at genotypic levels, were used for path analysis, to apportion the total correlation into direct and indirect effects on yield. The results are presented in Table 6 and Fig.6.

4.1.6.1. Direct effects

Out of the eight component characters used for path analysis, pod yield had the maximum positive direct effect on final seed yield (0.8842) followed by harvest index (0.1173), haulms yield (0.0982), number of pods (0.0250) and plant height (0.0174). The direct effects of number of branches (-0.0396), 100 seed weight (-0.0259) and length of pod (-0.0151) were found to be negative.

Table 6. PATH ANALYSIS - DIRECT AND INDIRECT EFFECTS OF EIGHT COMPONENT CHARACTERS ON SEED YIELD DURING RABI SEASON

Sl. No.	Component characters	Direct Effects	INDIRECT EFFECTS VIA-							Total Correlations
			Plant height (cm)	Number of branches	Number of pds	Pod yield (g)	Pod length (cm)	100 seed weight (g)	Haulms yield	Harvest Index	
1	Plant height (cm)	0.0174	*****	-0.0220	0.0149	0.2741	-0.0014	-0.0051	0.0462	-0.0001	0.3240
2	Number of branches	-0.0396	0.0097	*****	0.0170	0.4218	-0.0001	-0.0044	0.0732	-0.0086	0.4686
3	Number of pods	0.0250	0.0104	-0.0269	*****	0.3280	-0.0027	-0.0045	0.0494	0.0033	0.3820
4	Pod yield (g)	0.8842	0.0054	-0.0189	0.0093	*****	-0.0038	-0.0064	0.0559	0.0683	0.9940
5	Pod length (cm)	-0.0151	0.0016	-0.0002	0.0044	0.2246	*****	-0.0030	0.0159	0.0188	0.2470
6	100 seed weight (g)	-0.0259	0.0034	-0.0068	0.0043	0.2175	-0.0017	*****	0.0382	-0.0041	0.2249
7	Haulms yield	0.0982	0.0082	-0.0295	0.0126	0.5031	-0.0024	-0.0101	*****	-0.0251	0.5550
8	Harvest Index	0.1173	0.0001	0.0029	0.0007	0.5146	-0.0024	0.0009	-0.0210	*****	0.6125

Residual Effect = 0.0076

The residual effect was only 0.0076, indicating that most of the important traits have been included in this model.

4.1.6.2. Indirect effects

Plant height

The genotypic correlation between plant height and seed yield was 0.3240. Out of this, maximum contribution was through pod yield per plant (0.2741) followed by haulms yield per plant (0.0462) and pods per plant (0.0149) Indirect effects of this trait were negative via. number of branches, length of pod, 100 seed weight and harvest index.

Number of branches

Total genotypic correlation for this trait with seed yield was 0.4686 and the direct effect was negative. Among indirect effects, maximum positive influence was through pod yield per plant (0.4218) followed by haulms yield per plant (0.0732), pods per plant (0.0170) and plant height (0.0097). The trait had negative indirect effects through harvest index (-0.0086), 100 seed weight (-0.0044) and pod length (-0.0001).

Number of pods

Genotypic correlation for this trait with seed yield was 0.3820 and positive indirect effect through pod yield (0.3280) constituted the major part compared with the direct effect of 0.0250. Indirect effects through haulms yield (0.0494), plant height (0.0104) and harvest index (0.0033) also were positive. Indirect effects were negative through number of branches (-0.0269), 100 seed weight (-0.0045) and length of pod (-0.0027).

Pod yield

This trait had maximum genotypic correlation (0. 9940) with seed yield, among the various traits studied. The major influence was through direct effects (0.8842). Positive indirect effects were also observed through harvest index (0.0683), haulms yield/plant (0.0059), pods per plant (0.0093) and plant height (0.0054). Indirect effects were negative through number of branches (-0.0189), 100 seed weight (-0.0064) and pod length (-0.0038).

Pod length

Total genotypic correlation of this trait with seed yield was 0.2470 and the direct effect was negative. Positive indirect effect was maximum through pod yield (0.2246), followed by harvest index (0.0188), haulms yield/plant (0.0159), number pods (0.0044) and plant height (0.0016). Indirect effects of this trait through 100 seed weight (-0.0030) and number of branches (-0.0002) were negative.

Hundred seed weight

The trait had a genotypic correlation of 0.2249 with seed yield. The direct effect was negative. Indirect effects through number of branches (-0.0068), harvest index (-0.0041) and length of pods (-0.0017) also were negative. Maximum positive indirect effects were observed, through pod yield per plant (0.2175), followed by haulms yield per plant (0.0382), pods per plant (0.0043) and plant height (0.0034).

Haulms yield

This trait had high positive genotypic correlation with seed yield per plant (0.5550). Maximum contribution was through indirect effect of this trait via. pod yield per plant (0.5031), followed by pods/plant (0.0126) and plant height (0.0082). Indirect effects through number of branches (-0.0295), harvest index (-0.0251), 100 seed weight (-0.0101) and length of pods (-0.0024), were negative.

Harvest index

This trait also had strong positive association with seed yield (0.6125) and this was mainly through indirect effects via pod yield/plant (0.5146). Positive indirect effects were weak through other traits like number of branches (0.0029), 100 seed weight (0.0009), number of pods (0.0007) and plant height (0.0001). Maximum negative indirect effect was noticed through haulms yield per plant (-0.0210), followed by length of pods (-0.0024).

4.1.7. D^2 Analysis

Genetic divergence studies were carried out for the thirteen biometric traits in the 115 genotypes. The available divergence, both within the lines and the traits, was tested by Wilk's Lambda Criteria and it was found to be significant. The D^2 values corresponding to all possible n (n-1) / 2 pairs among the 115 genotypes were computed. Based on these values, the lines were grouped into ten clusters (Table 7.).

Cluster I consisted of eight genotypes of which three were from Madhya Pradesh, two from Tamil Nadu and one each from Orissa, Andhra Pradesh and Rajasthan. Cluster II contained 17 genotypes including five from Tamil Nadu, three each from Karnataka and Madhya Pradesh, and one each from Andhra Pradesh, Manipur, Maharashtra, Rajasthan, Himachal Pradesh and Delhi. Cluster III had only one entry. Cluster IV contained three genotypes, one each from Karnataka, Andhra Pradesh and Madhya Pradesh.

Cluster V and IX contained maximum number of genotypes (23 each). Cluster V consisted of ten genotypes from Tamil Nadu, four from Maharashtra, three from Karnataka, two from Manipur, and one each from Madhya Pradesh, Utter Pradesh, Himachal Pradesh and Kerala. Cluster VI had six genotypes, two from Madhya Pradesh and one each from Maharashtra, Karnataka, Manipur and Australia. Cluster VII consisted of ten entries from Tamil Nadu, three from Himachal Pradesh,

Table 7. D^2 ANALYSIS – LIST OF GENOTYPES INCLUDED IN THE TEN CLUSTERS

CLUSTER NUMBER	Total No. of Genotypes	Treatment No of Genotypes included
I	8	V-17, V-18, V-19, V-49, V-59, V-85, V-89, V-102
II	17	V-2, V-4, V-8, V-9, V-10, V-21, V-30, V-34, V-40, V-44, V-47, V-50, V-52, V-53, V-79, V-82, V-100
III	1	V-114
IV	3	V-84, V-101, V-105
V	23	V-3, V-12, V-22, V-23, V-24, V-25, V-27, V-29, V-33, V-38, V-39, V-41, V-42, V-43, V-46, V-61, V-67, V-68, V-86, V-87, V-96, V-98, V-103
VI	6	V-6, V-13, V-95, V-99, V-110, V-115
VII	18	V-5, V-11, V-32, V-35, V-45, V-51, V-55, V-57, V-63, V-64, V-69, V-70, V-73, V-74, V-75, V-77, V-91, V-108
VIII	7	V-58, V-106, V-107, V-109, V-111, V-112, V-113
IX	23	V-7, V-16, V-26, V-28, V-31, V-36, V-37, V-48, V-54, V-56, V-60, V-62, V-65, V-76, V-80, V-81, V-83, V-88, V-90, V-92, V-93, V-94, V-97
X	9	V-1, V-14, V-15, V-20, V-66, V-71, V-72, V-78, V-104, V-109

two from Kerala and one each from Maharashtra, Madhya Pradesh and Bihar. Cluster VIII had seven genotypes, including two from Tamil Nadu and one each from Maharashtra, Madhya Pradesh, Andhra Pradesh Gujarat and Nepal. Of the 23 genotypes of Cluster IX, nine were from Tamil Nadu, three each from Utter Pradesh and Maharashtra, two from Kerala and one each from Maharashtra, Himachal Pradesh, Andhra Pradesh, Karnataka, Manipur and Goa. Cluster X comprised of nine genotypes of which four were from Tamil Nadu three from Madhya Pradesh and the remaining one from Karnataka. The cluster diagram is presented as Fig. 5.

4.1.7.1. Intra and inter-cluster distances

The average intra and inter-cluster D^2 values and D values are presented in Table 8 and Fig.7. The intra-cluster divergence was maximum in cluster X (2.359). Inter-cluster divergence ranged from 2.431 between clusters I and II, to 10.922, between clusters III and IV. Based on the range of D values, the following ratings of the distance were assumed as least, moderate and highly divergent.

Ratings	D values
Least divergent	up to 6.00
Moderately divergent	6.01 to 9.00
Highly divergent	above 9.00

Cluster I was least divergent with all other clusters except cluster IV, to which it was moderately divergent. Cluster II also was least divergent with all other clusters except cluster III and IV to which it was moderately divergent. In the case of cluster III least divergence was noted from cluster VII and IX and moderate divergence from other clusters except cluster IV. Cluster III was highly divergent from cluster IV. Moderate divergence was noted for cluster IV with other clusters except cluster VIII, to which it was least divergent. Cluster V was observed to be least divergent with all clusters except clusters III and IV, wherein moderate

Table 8. D^2 ANALYSIS – INTRA AND INTER-CLUSTER DISTANCES

CLUSTER NUMBER	INTER-CLUSTER DISTANCES										INTRA-CLUSTER DISTANCES
	I	II	III	IV	V	VI	VII	VIII	IX	X	
I	****										2.260
II	2.431	****									2.339
III	5.767	7.569	****								****
IV	7.004	6.510	10.922	****							1.863
V	3.382	3.455	6.276	8.101	****						2.394
VI	4.098	3.896	8.329	6.948	3.918	****					2.264
VII	2.875	3.546	5.562	7.189	2.558	4.952	****				2.437
VIII	4.291	3.932	7.963	3.748	4.786	4.573	4.409	****			2.288
IX	2.600	2.966	5.145	8.000	2.712	4.564	2.537	4.805	****		2.164
X	4.821	3.514	8.745	6.300	3.864	3.798	5.035	3.545	4.742	****	2.359

Table 9. D^2 ANALYSIS - CLUSTER MEAN VALUES FOR THIRTEEN BIOMETRIC TRAITS

Clusters	Seed yield (g)	Plant height (cm)	Number of Branches	Days to Flowering	Number of Pods	Pod yield (g)	Pod length (cm)	Seeds per pod	100 seed weight (g)	Haulms yield (g)	Days to maturity	Harvest Index	Crude protein (%)
	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
I	2.21	19.15	1.91	37.00	9.11	3.74	4.41	5.42	2.66	1.77	78.75	0.65	14.14
II	2.48	30.12	1.39	38.24	17.54	4.04	4.86	6.14	2.93	1.67	78.24	0.77	16.50
III	0.53	27.20	0.15	35.00	3.60	0.87	3.10	4.10	1.27	1.07	75.00	0.38	15.01
IV	3.54	65.38	6.43	45.67	37.72	5.75	4.18	5.97	3.55	3.74	88.17	0.59	14.65
V	1.13	33.36	1.31	32.15	18.21	1.89	4.65	6.07	2.93	1.63	71.96	0.49	15.13
VI	2.86	38.40	1.68	31.00	19.68	4.83	4.26	5.79	4.03	2.24	70.75	0.68	13.90
VII	0.95	29.93	1.19	38.47	21.01	1.57	4.26	5.73	2.90	1.57	79.67	0.44	14.67
VIII	2.57	57.26	4.99	39.14	25.54	4.20	4.19	5.96	2.89	2.95	79.36	0.56	16.32
IX	1.37	31.05	0.82	35.63	11.51	2.21	4.19	5.47	2.74	1.22	76.37	0.66	17.94
X	2.50	56.18	3.33	32.17	34.57	4.16	5.13	6.13	3.00	2.25	72.33	0.69	17.10

divergence was observed. For cluster VI also, results were the same. In the case of cluster VII, least divergence was noted with all the clusters other than with cluster IV, where the divergence was moderate. Cluster VIII was moderately divergent with cluster III and least divergent with others. Moderate divergence was noted for cluster IX with cluster IV and least divergence with other clusters. In the case of cluster X, least divergence was observed with all clusters except clusters III and IV, where the divergence was moderate.

4.1.7.2. Cluster mean values

The mean values of the thirteen biometric characters for each cluster are presented in Table 9. Wide range of variation was observed for the traits like seed yield, plant height, number of branches, number of pods, pod yield, 100 seed weight and harvest index. Cluster IV recorded maximum values for most of the characters except pod length, seeds per pod, 100 seed weight, harvest index and crude protein percentage, whereas cluster III recorded minimum values, except for plant height, days to flowering, days to maturity and crude protein percentage. Cluster I recorded the least values for plant height. Cluster VI had minimum values (desirable) for days to flowering and days to maturity. Cluster X had maximum values for pod length. In the case of seeds per pod, cluster II recorded the highest values. Cluster VI had maximum values for hundred seed weight. Harvest index was maximum for cluster II. Crude protein content was maximum in cluster IX and minimum in cluster VI.

4.1.8. Selection Index using discriminant function analysis

In order to assess efficiency of simultaneous selection based on several characters over direct selection based on yield alone, a discriminant function analysis as suggested by Hazel (1943) was carried out. The results are presented in Table 10. All combinations of thirteen characters were formulated and their efficiency over

TABLE 10. DISCRIMINANT FUNCTION FOR DIFFERENT YIELD COMPONENTS, GENETIC ADVANCE THROUGH SELECTION INDEX , EFFICIENCY OVER DIRECT SELECTION AND GAIN IN SELECTION EFFICIENCY

Sl. No	Combination	Discriminant Function	Genetic Advance Through Selection Index	Efficiency Over Direct Selection. (Max.value)	Gain In Efficiency (%)
1.	Y, x1, x2, x3, x4, x5, x6, x7, x8, x9, x10, x11, x12	0.4728 y + 0.0004 x1 + (-)0.0157 x2 + (-)0.0058 x3 + 0.0046 x4 + 0.2177 x5 + (-)0.0297 x6 + 0.0238 x7 + (-)0.0274 x8 + 0.1242 x9 + 0.0067 x10 + 0.4770 x11 + (-)0.0071 x12	3.087	1.7947	79.47
2.	Y, x1, x2, x4, x5, x6, x8, x9, x11	0.4986y + (-)0.0001 x1 + (-)0.0114 x2 + 0.0051 x4 + 0.2081 x5 + (-)0.0253 x6 + (-)0.0226 x8 + 0.1119 x9 + 0.4155 x11	3.086	1.7940	79.40
3.	Y, x1, x2, x4, x5, x6, x9, x11	0.5086 y + (-)0.0001 x1 + (-)0.0093 x2 + 0.0051 x4 + 0.2034 x5 + (-)0.025 x6 + 0.1018 x9 + 0.3980 x11	3.086	1.7939	79.39
4.	Y, x1, x2, x4, x5, x9, x11	0.5175y + (-)0.0001 x1 + (-)0.0064 x2 + 0.0048 x4 + 0.1976 x5 + 0.0965 x9 + 0.3831 x11	3.085	1.7937	79.37
5.	Y, x2, x4, x5, x9, x11	0.5162y + (-)0.0067 x2 + 0.0048 x4 + 0.1983 x5 + 0.0962 x9 + 0.3837 x11	3.085	1.7937	79.37
6.	Y, x2, x5, x9, x11	0.5402 y + 0.0127 x2 + 0.1830 x5 + 0.0970 x9 + 0.3947 x11	3.082	1.7918	79.18
7.	Y, x5, x9, x11	0.5432 y + 0.1819 x5 + 0.1166 x9 + 0.4055 x11	3.081	1.7915	79.15
8.	Y, x5, x11	0.7022 y + 0.1457 x5 + (-)0.0590 x11	3.077	1.7888	78.88
9.	Y, x5	0.6773 y + 0.1571 x5	3.077	1.7887	78.87

TABLE 11. ESTIMATES OF SELECTION INDEX USING THE CHARACTERS SEED YIELD, POD YIELD AND HARVEST INDEX, AND RANKING OF 115 HORSEGRAM GENOTYPES ACCORDING TO SELECTION INDEX AND YIELD

Acc. to Seln. Index		Accession No. / Genotype		Acc. to yield alone	
Estimate	Rank			Estimate	Rank
4.1041	1	V-105	PHG-9	4.425	2
4.0671	2	V-52	AK-42	4.445	1
3.6484	3	V-114	PHML-64	3.925	3
3.4544	4	V-102	Maru Kulthi	3.750	4
3.3343	5	V-79	IC-71817	3.630	5
3.3251	6	V-1	AK-21	3.585	6
3.2044	7	V-13	IC-23453	3.375	8
3.2000	8	V-9	IC-22799	3.335	9
3.0950	9	V-20	IC-23508	3.390	7
3.0847	10	V-101	IC-19446	3.310	10
2.9684	11	V-100	IC-145270	3.215	11
2.8991	12	V-115	KS-2	3.115	12
2.8728	13	V-113	IC-24849	3.105	13
2.8348	14	V-66	IC-71748	3.075	15
2.8237	15	V-59	IC-145259	3.075	14
2.6760	16	V-108	Muthalamada Local	2.885	16
2.5588	17	V-2	IC-7588	2.700	19
2.5577	18	V-14	IC-23460	2.695	21
2.5549	19	V-110	IC-16978	2.765	18
2.5544	20	V-58	IC-145258	2.775	17

Acc. to Seln. Index		Accession No. / Genotype		Acc. to yield alone	
Estimate	Rank			Estimate	Rank
2.5083	21	V-34	IC-45698	2.230	33
2.4037	22	V-112	IC-23462	2.600	22
2.3848	23	V-104	IC-1102	2.575	23
2.3454	24	V-18	IC-23467	2.420	26
2.3277	25	V-17	IC-23464	2.465	25
2.2520	26	V-40	IC-45733	2.470	24
2.2374	27	V-109	EC-18679	2.415	27
2.2270	28	V-111	IC-32764	2.410	28
2.1954	29	V-103	AK-26	2.395	29
2.1623	30	V-47	IC-50712	2.355	30
2.1076	31	V-26	IC-26144	2.285	31
2.0737	32	V-50	IC-50728	2.275	32
2.0491	33	V-21	IC-24842	2.230	33
1.9848	34	V-10	IC-22805	2.170	34
1.9430	35	V-97	IC-56147	2.115	35
1.9254	36	V-85	IC-56148	2.095	36
1.8686	37	V-19	IC-23495	1.980	38
1.8500	38	V-12	IC-22813	1.915	40
1.8298	39	V-49	IC-50727	2.000	37
1.7925	40	V-71	IC-71787	1.960	39
1.7443	41	V-89	IC-89015	1.900	42
1.7317	42	V-36	IC-45703	1.900	41
1.7121	43	V-8	IC-22784	1.740	50
1.6984	44	V-44	CODB-8	1.890	43
1.6930	45	V-30	IC-33072	1.825	45
1.6769	46	V-4	IC-19433	1.880	44
1.6473	47	V-6	IC-19444	1.820	46

Acc. to Seln. Index		Accession No. / Genotype		Acc. to yield alone	
Estimate	Rank			Estimate	Rank
1.6413	48	V-65	IC-71733	1.795	47
1.6131	49	V-82	IC-55973	1.760	49
1.5923	50	V-99	EC-27602	1.735	51
1.5734	51	V-80	IC-71823	1.720	52
1.5492	52	V-39	IC-45732	1.780	48
1.5440	53	V-27	BGM-1	1.710	53
1.5380	54	V-107	CO-1	1.620	54
1.4673	55	V-106	IC-45753	1.590	57
1.4671	56	V-72	IC-71791	1.595	56
1.4284	57	V-69	IC-71770	1.560	58
1.4207	58	V-92	IC-89039	1.600	55
1.3921	59	V-53	IC-145344	1.530	60
1.3851	60	V-54	IC-121641	1.530	61
1.3716	61	V-48	IC-50714	1.510	62
1.3677	62	V-7	DPI-1584	1.535	59
1.3432	63	V-38	IC-45724	1.500	63
1.3278	64	V-28	IC-32760	1.455	64
1.3034	65	V-96	IC-26143	1.405	65
1.2843	66	V-24	IC-26120	1.350	68
1.2539	67	V-93	IC-89041	1.340	69
1.2517	68	V-57	IC-145254	1.360	67
1.2393	69	V-67	IC-71760	1.340	69
1.2373	70	V-3	IC-19432	1.265	75
1.2124	71	V-61	IC-68602	1.315	71
1.2060	72	V-22	IC-26125	1.280	74
1.1903	73	V-15	IC-23462	1.205	77
1.1875	74	V-87	IC-89005	1.305	72

Acc. to Seln. Index		Accession No. / Genotype		Acc. to yield alone	
Estimate	Rank			Estimate	Rank
1.1797	75	V-56	IC-145252	1.295	73
1.1758	76	V-29	IC-32848	1.315	70
1.1314	77	V-55	IC-123024	1.235	76
1.0631	78	V-88	IC-89010	1.155	80
1.0590	79	V-35	IC-45702	1.125	83
1.0539	80	V-83	IC-56126	1.150	81
1.0496	81	V-31	IC-33183	1.170	78
1.0476	82	V-37	IC-45713	1.170	79
1.0299	83	V-74	IC-71809	1.130	82
1.0244	84	V-60	IC-68591	1.120	84
0.9982	85	V-5	IC-19441	1.040	87
0.9938	86	V-73	IC-71808	1.090	85
0.9726	87	V-98	IC-65463	1.075	86
0.9521	88	V-81	IC-55085	1.010	88
0.9046	89	V-51	IC-145267	1.000	89
0.8896	90	V-75	IC-71812	0.975	90
0.8651	91	V-86	IC-89004	0.965	91
0.8631	92	V-42	IC-45749	0.935	93
0.8545	93	V-11	IC-22812	0.900	97
0.8514	94	V-70	IC-71778	0.940	92
0.8457	95	V-95	IC-23468	0.910	95
0.8318	96	V-33	IC-33765	0.895	98
0.8315	97	V-94	IC-22760	0.925	94
0.8282	98	V-46	IC-50707	0.905	96
0.8064	99	V-68	IC-71769	0.890	99
0.7801	100	V-84	IC-56141	0.860	100
0.7652	101	V-16	DPI-1574	0.795	103

Acc. to Seln. Index		Accession No. / Genotype		Acc. to yield alone	
Estimate	Rank			Estimate	Rank
0.7525	102	V-90	IC-89036	0.845	101
0.7448	103	V-62	IC-88990	0.825	102
0.7140	104	V-63	IC-89000	0.785	104
0.6926	105	V-32	IC-33198	0.765	105
0.6256	106	V-25	IC-26136	0.695	106
0.5919	107	V-64	IC-71725	0.660	107
0.5859	108	V-43	IC-45752	0.655	108
0.5816	109	V-23	IC-26128	0.620	109
0.5498	110	V-76	IC-71813	0.605	110
0.5305	111	V-45	IC-45756	0.585	111
0.5237	112	V-91	IC-89038	0.585	112
0.4758	113	V-78	IC-71816	0.530	113
0.3802	114	V-77	IC-71814	0.420	114
0.3642	115	V-41	IC-45743	0.000	115

direct selection and gain in efficiency were computed. Models with maximum efficiency were selected from models with equal number of character combinations.

The efficiency was maximum (1.7947) when all the thirteen biometric characters viz. seed yield (y), plant height (x1), number of branches (x2), days to flowering (x3), number of pods (x4), pod yield (x5), pod length (x6), seeds per pod (x7), 100 seed weight (x8), haulms yield (x9), days to maturity (x10), harvest index (x11) and crude protein content (x12) were considered together and this model gave 79.47% gain in efficiency over direct selection based on yield alone. However it was found that by inclusion of minimum number of characters viz. seed yield (y), pod yield (x5) and harvest index (x11), the efficiency remained almost the same (79.15). Hence this selection model was utilized to rank the 115 genotypes under study.

The ranking and estimates of selection index and yield are given in table 11. Based on selection index, the best 10 genotypes were identified as V-105, V-52, V-114, V-102, V-79, V-1, V-13, V-9, V-20 and V-101. The first 10 genotypes based on yield alone also were the same, however there was mutual change in the rank position occupied V-105 and V-52. Also rank positions of V-13, V-9 and V-20 were changed from 7, 8 and 9 according to selection index, to 8, 9 and 7, in direct selection based on yield alone. Based on selection index as well as yield, V-105, V-52, V-114, V-102 and V-79 were found to be superior in the order of ranking.

4.2. Varietal Evaluation Studies

Based on the preliminary evaluation, the 115 horsegram genotypes were grouped into ten clusters using Mahalanobis D^2 statistic. During estimation of selection index, the characters seed yield, pod yield and harvest index were identified as the most reliable traits for formulating selection index and the genotypes were ranked accordingly. Based on this ranking, the best five genotype belonging the

Table . 12. LIST OF GENOTYPES USED FOR VARIETAL EVALUATION AND HYBRIDISATION STUDIES

Sl. No	Variety / Accession Number	Cluster to which the genotype belongs	Source	Other salient features
1.	AK-21	X	Rajasthan	Day-neutral genotype with brown seeds
2.	AK-42	II	Rajasthan	Day-neutral genotype with grayish brown seeds
3.	AK-26	V	Rajasthan	Day-neutral genotype with brown seeds
4.	KS-2	VI	Karnataka	Day-neutral genotype with reddish brown seeds
5.	Maru Kulthi	I	Rajasthan	Day-neutral genotype with brown seeds
6.	PHML-64	III	Rajasthan	Photosensitive genotype with black seeds
7.	DPI-1574	IX	Tamil Nadu	Photosensitive genotype with brown seeds
8.	PHG-9	IV	Karnataka	Photosensitive genotype with brown seeds
9.	Muthalamada Local	VII	Kerala	Photosensitive genotype with brown seeds
10.	CO-1	VIII	Tamil Nadu	Photosensitive genotype with brown seeds

photosensitive (short-day) and day-neutral types, were selected for further evaluation in terms of seed yield and pod yield during the years 1997, 1998 and 1999 in both rabi and summer seasons. Each of them belonged to the ten different clusters. The selected genotypes are listed Table 12.

Out of these ten genotypes, five (viz., PHML-64, DPI-1574, PHG-9, Muthalamada Local and CO-1) were photosensitive (short-day) genotypes and they did not flower or set pods properly during summer season, since short-days required for flowering initiation in such types are not available during summer. Hence these could be evaluated only during rabi season. The remaining five day-neutral genotypes (viz., AK-21, AK-42, AK-26, KS-2 and Maru Kulthi), were evaluated in both rabi and summer seasons. The evaluation was done in RBD with four replications. The data over the three years and two seasons were subjected to pooled analysis, following the procedure suggested by Cochran and Cox (1957).

The details of the genotypes used for varietal evaluation studies conducted in rabi and summer seasons of 1997, 1998 and 1999 are given in Table 12. The results of the evaluation are presented in Tables 13 – 20 and illustrated graphically in Fig. 8 to Fig.13.

4.2.1. Evaluation of five day-neutral genotypes in Rabi and summer.

4.2.1.1. Seed yield

The mean performance of the genotypes with respect to seed yield per plant are presented in Table 13. In the case of seed yield, the analysis of variance revealed that difference between the genotypes, seasons, years and their interactions were highly significant, except for variety x season interaction (Table 14).

TABLE 13. ANOVA FOR PERFORMANCE OF FIVE HORSEGRAM GENOTYPES IN RABI AND SUMMER SEASONS DURING 1997, 1998 AND 1999 WITH RESPECT TO SEED YIELD PER PLANT (g)

Source	d.f.	S.S.	M.S.S.	F Value
Replication	3	0.184	0.061	0.2157
Variety (A)	4	12.725	3.181	11.1731 **
Error	12	3.417	0.285	
Season (B)	1	17.705	17.705	66.0549 **
Variety x Season	4	2.009	0.502	1.8739
Error	15	1.021	0.268	
Year (C)	2	18.797	9.399	38.7357 **
Variety x Year	8	9.172	1.146	4.7251 **
Season x Year	2	12.647	6.324	26.0627 **
Variety x Season x Year	8	7.228	0.903	3.7236 **
Error	60	14.558	0.243	
Total	119	102.463		

** Significant at 0.01 level

TABLE 14. MEAN PERFORMANCE OF FIVE HORSEGRAM GENOTYPES IN RABI AND SUMMER SEASONS DURING 1997, 1998 AND 1999, WITH RESPECT TO SEED YIELD PER PLANT (g)

Genotypes	1997		1998		1999		Gen. Mean (Seasons)		Gen. Mean (Years)			Gen. Mean
	Rabi	Summer	Rabi	Summer	Rabi	Summer	Rabi	Summer	1997	1998	1999	(Genotypes)
1. AK-21	3.419	2.623	2.827	1.065	2.211	1.471	2.819	1.720	3.021	1.946	1.841	2.269
2. AK-42	4.086	3.616	4.094	2.182	2.534	3.244	3.572	3.013	3.850	3.138	2.889	3.292
3. AK-26	3.858	2.535	3.458	2.680	2.443	1.348	3.253	2.188	3.196	3.069	1.895	2.720
4. KS – 2	3.379	3.565	3.142	1.233	2.699	2.898	3.073	2.565	3.472	2.187	2.799	2.819
5.MaruKulthi	3.269	2.881	3.254	1.380	2.569	3.001	3.030	2.421	3.075	2.317	2785	2.726
Mean	3.602	3.043	3.355	1.708	2.491	2.392	3.149	2.381	3.323	2.531	2.441	2.765
	C. D. (0.05) (Genotypes) : 0.3358											
	C. D. (0.05) (Years) : 0.2205											
	C. V. (%) : 17.81											

TABLE 15. ANOVA FOR PERFORMANCE OF FIVE HORSEGRAM GENOTYPES IN RABI AND SUMMER SEASONS DURING 1997, 1998 AND 1999 WITH RESPECT TO POD YIELD

Source	d.f.	S.S.	M.S.S.	F Value
Replication	3	0.364	0.121	0.5929
Variety (A)	4	21.739	5.435	26.5811 **
Error	12	2.453	0.204	
Season (B)	1	13.471	13.471	22.6709 **
Variety x Season	4	6.819	1.705	2.8688
Error	15	8.913	0.594	
Year (C)	2	23.848	11.924	18.1586 **
Variety x Year	8	14.917	1.865	2.8396 **
Season x Year	2	20.473	10.236	15.5885 **
Variety x Season x Year	8	14.874	1.859	2.8314 **
Error	60	39.400	0.657	
Total	119	167.270		

** Significant at 0.01 level

TABLE 16. MEAN PERFORMANCE OF FIVE HORSEGRAM GENOTYPES IN RABI AND SUMMER SEASONS DURING 1997, 1998 AND 1999, WITH RESPECT TO POD YIELD PER PLANT (g)

Genotypes	1997		1998		1999		Gen. Mean (Seasons)		Gen. Mean (Years)			Gen. Mean
	Rabi	Summer	Rabi	Summer	Rabi	Summer	Rabi	Summer	1997	1998	1999	(Genotypes)
1. AK- 21	5.656	3.428	4.002	2.750	3.434	2.772	4.364	2.983	4.542	3.376	3.103	3.674
2. AK- 42	6.377	5.111	5.758	3.250	3.599	5.271	5.245	4.544	5.744	4.504	4.435	4.894
3. AK- 26	5.476	3.559	4.779	4.625	3.302	2.161	4.519	3.600	4.518	4.702	2.959	4.059
4. KS – 2	5.337	4.992	4.549	4.125	3.921	4.729	4.602	4.625	5.164	4.337	4.340	4.614
5.MaruKulthi	4.959	4.122	4.598	3.000	3.715	5.032	4.424	2.421	4.540	3.799	4.374	4.238
Mean	5.561	4.242	4.737	3.550	3.594	4.090	4.631	3.635	4.902	4.144	3.842	4.269
	C. D. (0.05) (Genotypes) : 0.2841											
	C. D. (0.05) (Years) : 0.3625											
	C. V. (%) : 18.86											

During 1997, rabi season AK-42 (4.086) and AK-26 (3.858 g) had mean yield above the seasonal mean of 3.602 and these two were statistically on par. In summer season, AK-42 (3.616 g) and KS-2 (3.565 g) had higher yield than the seasonal mean of 3.043 g. In the evaluation conducted during 1998 rabi season, AK-42 had significantly superior seed yield than others, followed by AK-26 (3.458 g). The seasonal mean was 3.043 g. In summer AK-26 had maximum seed yield (2.680 g), which was significantly superior to the next entry AK-42 (2.182 g). During 1999 rabi season, KS-2 had the maximum seed yield (2.699 g) which was on par with the performance of all other entries except AK-21. In summer AK-42 had the maximum seed yield of 3.244 g, which was on par with Maru Kulthi (3.001 g).

Mean performances of the genotypes were better in the rabi (traditional) season (3.149 g) than in summer (2.381 g). Among the three years, maximum mean yield was obtained in 1997 (3.323 g), followed by 1998 and 1999. In overall performance, the genotype AK-42 excelled others. The next best genotypes were KS-2, Maru Kulthi and AK-26, which were statistically on the par.

4.2.1.2. Pod yield

In the case of pod yield per plant also, a similar trend was observed. The mean values are presented in Table 15 and analysis of variance in Table 16. The grand mean value for pod yield was maximum for AK-42 (4.894 g), followed by KS-2 (4.614 g). These two genotypes were on par and significantly superior over others. The next best entries were Maru Kulthi and AK-26, and both these were statistically on par. During 1997 rabi and summer seasons, performance of AK-42 was superior over the others, the mean yield being 6.377 g and 5.111 g respectively. AK-42 was the top yielder in 1998 rabi season also (5.758 g). However during 1998 summer season, AK-26 with a mean pod yield of 4.625 g was superior over others. During 1999 rabi season, KS-2 produced maximum quantity of pods (3.921 g), followed by Maru Kulthi (3.715 g) which were statistically on par. AK-42 (3.599 g) was the next

best entry. In season-wise overall performance with respect to pod yield, AK-42 (5.245 g) was better in rabi season. In summer season, performance of KS-2 (4.625 g) and AK-42 (4.544 g) were statistically on par (Table 15.) and superior to others.

4.2.2. Evaluation of ten horsegram genotypes in rabi season

4.2.2.1. Seed yield

In this case, the photosensitive variety PHG-9 with a mean seed yield of 4.263 g was found to be better, in over all performance(Table 18). The day-neutral genotype AK-42 was the next best variety. It had a mean seed yield of 3.437 g. The analysis of variance for seed yield (Table 17) revealed that variety effect, year effect and interaction effect of variety x year, were all highly significant.

Among the three years in which the genotypes were evaluated (1997, 1998 and 1999), the performance of the genotypes in terms of seed yield was better in 1997 and significantly superior to other years. During 1997, seed yield was highest for the photosensitive genotype PHG-9 (4.346 g) that was statistically on par with AK-42 (3.963 g) and Muthalamada local (3.891 g). These were followed by KS-2 (3.416 g) , AK-26 (3.237 g), CO-1 (3.129 g), PHML-64 (3.102 g), Maru Kulthi (3.089 g) and AK- 21 (3.076 g). During 1998 also the genotype PHG-9 gave the highest yield of 4.373 g followed by PHML 64 (4.178 g), which were statistically on par. The next best entries were AK-42 (3.420 g) and AK 26 (3.038 g), which also were statistically on par. Seed yield was highest for PHG-9 (4.070 g) in 1999 also. This was statistically superior to that of KS-2 (2.949 g) and AK-42 (2.929 g) and MaruKulthi (2.572 g), which were on par.

TABLE 17. ANOVA FOR PERFORMANCE OF TEN HORSEGRAM GENOTYPES IN RABI SEASON DURING 1997, 1998 AND 1999 WITH RESPECT TO SEED YIELD PER PLANT (g)

Source	d.f.	S.S.	M.S.S.	F Value
Replication	3	1.712	0.571	1.8163
Variety (A)	9	32.977	3.664	11.6632 **
Year (B)	2	14.494	7.247	23.0685 **
Variety x Year	18	13.998	1.778	2.4754 **
Error	87	27.332	0.314	
Total	119	90.513		

** Significant at 0.01 level

TABLE 18. MEAN PERFORMANCE OF TEN HORSEGRAM GENOTYPES IN RABI SEASON DURING 1997, 1998 AND 1999 WITH RESPECT TO SEED YIELD PER PLANT (g)

Genotypes	1997	1998	1999	Mean
1. AK – 21	3.076	2.407	1.806	2.430
2. AK – 42	3.963	3.420	2.929	3.437
3. AK – 26	3.237	3.038	1.562	2.612
4. KS – 2	3.416	2.723	2.949	3.030
5. MaruKulthi	3.089	2.481	2.572	2.714
6. PHML – 64	3.102	4.178	2.336	3.205
7. DPI – 1574	2.488	2.504	2.427	2.473
8. PHG – 9	4.346	4.373	4.070	4.263
9.Muthalamada Local	3.891	2.481	2.248	2.874
10. CO – 1	3.129	2.685	2.373	2.729
Mean	3.374	3.029	2.527	2.977
CD (0.05) (Genotypes)		0.4671		
CD (0.05) (Years)		0.2506		
CV (%)		1 8.83		

TABLE 19. ANOVA FOR PERFORMANCE OF TEN HORSEGRAM GENOTYPES IN RABI SEASON DURING 1997, 1998 AND 1999 WITH RESPECT TO POD YIELD PER PLANT (g)

Source	d.f.	S.S.	M.S.S.	F Value
Replication	3	11.564	3.855	4.7970
Variety (A)	9	35.188	3.910	4.8657 **
Year (B)	2	46.738	23.369	29.0818 **
Variety x Year	18	33.978	1.888	2.3491 **
Error	87	69.909	0.804	
Total	119	197.377		

** Significant at 0.01 level

TABLE 20. MEAN PERFORMANCE OF TEN HORSEGRAM GENOTYPES IN RABI SEASON DURING 1997, 1998 AND 1999 WITH RESPECT TO POD YIELD PER PLANT (g)

	1997	1998	1999	Mean
1. AK – 21	4.128	3.398	3.052	3.526
2. AK – 42	5.721	4.457	4.269	4.816
3. AK – 26	4.721	4.669	2.538	3.976
4. KS – 2	5.243	4.380	4.405	4.676
5. Maru Kulthi	4.497	3.604	4.225	4.109
6. PHML - 64	4.502	5.321	3.122	4.315
7. DPI - 1574	6.134	3.134	3.156	4.142
8. PHG – 9	5.817	5.303	5.437	5.519
9.Muthalamada Local	5.388	3.260	3.074	3.907
10. CO – 1	5.224	3.449	3.193	3.955
Mean	5.138	4.098	3.647	4.294
CD (0.05)	(Genotypes)		0.7475	
CD (0.05)	(Years)		0.4010	
CV (%)			20.88	

4.2.2.2. Pod yield

Comparing the performance of the genotypes during the three years (Table 20) in which the genotypes were evaluated (1997, 1998 and 1999), it was better during 1997, followed by 1998 and 1999. Analysis of variance (Table 19) revealed that variance due to varieties; year and the interaction effects were all highly significant. PHG-9 had the highest overall mean for pod yield (5.519 g), which was statistically on par to that of AK-42 (4.816 g).

Pod yield per plant was maximum for genotype PHG 9 during 1997 (6.134 g), which was statistically on par with that of DPI- 1574 (5.817 g), AK-42 (5.721g) and Muthalamada local (5.388 g). During 1998, PHML-64 recorded the highest value for pod yield (5.321 g) that was on par with PHG-9 (5.303 g) and AK-26 (4.669 g). In 1999, pod yield was highest for the genotype PHG-9 (5.437 g).

4.3. Hybridisation Studies

The same genotypes that were selected for varietal evaluation studies (one each representing each of the ten clusters), were selected for hybridisation studies also. These genotypes are listed in Table 12.

4.3.1. Standardisation of techniques for selfing and crossing

Floral biology and anthesis: Flowers of horsegram are typically papilionaceous with standard, wing and keel petals. The anther and stigma remain enclosed within keel petals. It was observed that under Pattambi conditions, anther dehiscence occurs between 3 pm and 4 pm on the previous day of opening. Stigma becomes receptive after about one hour (around 4.30-5pm). Cleistogamy was observed to be the general rule.

4.3.2. Crossing

Though large numbers of crosses were attempted, the percentage of success obtained was very low. Since the flowers are tiny and flimsy, they get injured easily and drop while handling. Emasculation and pollination could be done only by looking through magnifying glass. Flower dropping and immature fruit dropping also reduced the percentage of success. On an average crossing was attempted in 80 – 120 flowers. The percentage of success in crossing ranged from 0 % – 2 %.

4.3.3. Diallel Analysis

A 6 x 6 diallel analysis as outlined by Griffing (1956) for Model-1 (test for fixed effects involving limited number of parents), Method-II (half diallel with parents and one set of F_1s, excluding reciprocals) was carried out, using the data collected for hybridization studies. The six parents designated as P1,P2, P3, P4, P5, P6 were:-

P1	-	PHML-64 ;	P4	-	AK-21 ;
P2	-	Muthalamada Local ;	P5	-	AK-42 ;
P3	-	Maru Kulthi ;	P6	-	AK-26.

Among these, two were photosensitive (viz. PHML-64 and Muthalamada Local) and four were day-neutral (viz. Maru Kulthi, AK-21, AK-42 and AK-26) genotypes. The resulting set of six parents and their fifteen direct crosses were evaluated in an RBD with three replications.

4.3.4.1. Mean performance of parents and hybrids:

The mean performance of the six parents and their fifteen direct cross hybrid progenies are presented trait-wise in Table 22. The analysis of variance is given in Table 21. Analysis of variance of the nine biometric traits studied viz. days to

TABLE 21. DIALLEL ANALYSIS – ANOVA FOR BIOMETRIC TRAITS

Sl. No.	Characters	Mean Squares		F Value Genotypes
		Error (d.f.: 40)	Genotypes (d.f.: 20)	
1	Days to flowering	4.5111	235.8302	52.2776 **
2	Plant height (cm)	3.7622	143.3902	38.1131 **
3	Number of branches	0.7611	7.0873	9.3118 **
4	Number of Pods	14.7659	1180.2873	79.9335 **
5	Seeds per pod	0.0470	1.8416	39.2225 **
6	100 seed weight (g)	0.0319	0.2020	6.3403 **
7	Pod yield (g)	1.0380	18.6190	17.9380 **
8	Pod length (cm)	0.0234	1.3279	56.7902 **
9	Seed yield (g)	0.4430	8.1029	18.2905 **

** Significant at 0.01 levels

TABLE 22. DIALLEL ANALYSIS – MEAN PERFORMANCE OF F_1's AND PARENTS

Parents / F_1s	Days to Flowering	Plant height (cm)	Number of branches	Number of Pods	Seeds per pod	100 seed weight (g)	Pod yield (g)	Pod length (cm)	Seed yield (g)
1.P1 x P1	50.33	55.29	6.33	34.33	5.21	3.12	6.78	5.39	3.83
2.P1 x P2	52.00	41.69	5.67	32.67	6.33	3.81	7.02	6.20	4.02
3.P1 x P3	31.00	32.67	6.67	42.33	6.17	3.80	8.49	6.17	5.37
4.P1 x P4	60.00	25.19	6.67	61.00	6.98	3.96	11.77	4.19	7.23
5.P1 x P5	31.33	33.94	7.67	82.67	8.28	3.98	12.71	5.43	8.85
6.P1 x P6	31.00	30.58	7.67	59.33	7.36	4.04	13.06	5.29	7.32
7.P2 x P2	39.33	37.45	7.33	45.00	5.44	3.73	8.97	6.16	5.73
8.P2 x P3	31.00	42.57	3.00	25.33	5.30	4.10	5.38	5.47	6.13
9.P2 x P4	29.00	28.81	6.00	44.67	5.34	4.12	8.63	4.28	3.32
10.P2 x P5	27.33	33.80	6.33	44.33	5.67	3.74	9.30	4.37	5.74
11.P2 x P6	29.00	45.80	8.33	52.67	5.65	3.86	10.52	4.39	7.41
12.P3 x P3	30.33	31.46	6.00	43.33	5.32	3.63	8.27	5.31	6.12
13.P3 x P4	29.67	42.51	4.67	31.33	5.24	3.70	6.04	5.37	4.07
14.P3 x P5	27.67	40.42	7.33	82.00	5.94	3.65	11.42	5.53	7.53
15.P3 x P6	31.33	39.43	6.00	71.33	6.11	4.02	10.82	5.12	6.49
16.P4 x P4	37.00	30.49	8.67	76.33	5.94	3.42	10.99	4.28	6.61
17.P4 x P5	28.00	42.60	4.33	27.67	6.30	4.26	5.66	5.39	3.48
18.P4 x P6	30.67	39.13	6.00	77.00	6.39	4.01	10.61	5.39	7.62
19.P5 x P5	30.67	30.58	9.00	77.00	5.24	3.65	11.78	4.34	7.49
20.P5 x P6	32.33	38.60	4.67	25.33	6.03	4.04	5.35	5.33	3.90
21.P6 x P6	32.67	37.76	8.33	67.00	6.44	3.75	11.43	4.25	7.39
Grand Mean	34.37	37.16	6.51	52.51	6.03	3.83	9.29	5.13	5.98
C.D. (0.05)	1.0803	1.2148	0.2351	2.1143	0.0551	0.0662	0.5516	0.0793	1.2195

flowering, plant height(cm.), number of branches, pods per plant, seeds per pod, pod length(cm.) and seed yield per plant(g.), revealed that the treatment differences among the parents and hybrids were highly significant for all nine traits.

Days to flowering

In case of days to flowering, parents P_3 and P_5 were on par and the earliest to flower, in 30.33 days and 30.67days respectively. Parent P_1 had the maximum values (50.33days). Among crosses, P_2 x P_5 took minimum days for flowering (27.33) and was on par with P_2 x P_5, P_3 x P_5 and P_4 x P_5. It was maximum for the cross P_1xP_4 (60 days). The grand mean for the trait was 34. 37days.

Plant height

The trait had a grand mean value of 37.16 cm. Among parents, P_4 had the least height (30.49 cm.), which was on par with P_3 (31.46 cm). P_1 with a mean height of 55.29 cm was the tallest. Among crosses, plant height ranged from 25.19 cm in P_1 x P_4 to 45.80 in P_2xP_6.

Number of branches

The number of branches ranged from 6.00 in P_3 to 9.00 in P_5 among parents. In crosses, P_2xP_3 had least no. of branches (3.00) and P_2xP_6 had the maximum no. of branches (8.33). The grand mean for the trait was 6.51.

Number of Pods

The maximum number of pods per plant was produced by the parent P_5 (77.00) and minimum by P_1 (34.33). General mean for the trait was 52.51. Among the crosses, The number of pods produced per plant was maximum in the cross P_1 x P_5 (82.67) followed by P_3 x P_5 (82.00), which were on par. Two crosses viz. P_2 x P_3 and P_5xP_6 had the least (25.33). The grand mean for the trait was 52.51.

Seeds per pod

This trait had a grand mean value of 6.03. Among the parents, P_6 had maximum number of seeds per pod (6.44) and P_1 had the minimum number (5.21). Number of seeds per pod among crosses ranged from 5.24 in P3xP4 to 8.28 in P_1xP_5.

Hundred seed weight

Values for this trait among parents ranged from 3.12 g. in P_1 to 3.75 g. in P_6. Among hybrids, hundred seed weight was least for P3xP5 (3.65 g.) and maximum for P_4 x P_5 (4.26 g.). Grand mean vale for the trait was 3.83.

Pod yield

P_1 was the parent having minimum pod yield (6.78 g) and P_5 had maximum value (11.78 g), among parents. The hybrids had values ranging from 5.35 g for P_5 x P_6 to 13.06 g for P_1 x P_6. The grand mean value was 9.29 g for the trait.

Pod length.

Pod length of parents ranged from 4.28 cm in parent P_4 to 6.16 cm in P_2. Among crosses, P_1 x P_4 had the least pod length (4.19 cm) and P_1xP_2 had the longest pods (6.20 cm). General mean value for the trait was 5.13 cm.

Seed yield

Among parents, P_1 had the lowest yield (3.83 g) and P_5 had maximum yield (7.49 g). Grand mean value for the trait was 5.98 g. Seed yield was minimum in the cross P_2 x P_4 (3.48 g) and maximum in P1 x P5 (8.85 g).

4.3.4.2. Analysis of Combining Ability using Griffing's approach

In Griffing's numerical approach, the genetic analysis is done based on estimation of combining ability variances and effects. The total variation among the crosses can be partitioned into variation among half-sib families and full-sib families

obtained in the crosses. The variation among half -sib families is estimated by averaging the performance of all crosses having one parent in common. It gives an estimate of the general combining ability of that parent. The specific combining ability is estimated from the performance of full sib families resulting from each single cross.

a) Combining Ability Variances

Since the differences among the parents and crosses for the traits included in the study were highly significant, further analyses were carried out to assess the combining ability. The analysis of variance for combining ability (Table 23) showed that mean squares due to g.c.a. and s.c.a. effects were significant for all characters. The ratio of g.c.a. variance to s.c.a. variance was higher than one, for days to flowering (3.5205), seeds per pod (1.5370) and pod length (1.5385). For other traits, the ratio was lowest for plant height (0.4117), followed by hundred seed weight (0.5000), seed yield (0.5147), pod yield (0.5661), number of branches (0.5883) and number of pods (0.7882).

b) Combining Ability Effects

The g.c.a. effects of parents and s.c.a. effects of hybrids, for the nine characters are presented in Tables 24 and 25 respectively.

Days to flowering

The parent P_5 ranked first in negative significant g.c.a. (desirable), followed by P_3. The values of g.c.a. effects were – 4.07 and – 3.65 respectively. The highest value for gca effect was 8.18 of parent P_1. Parents P_3, P_5 and P_6 showed negative values of general combining ability effects for days to flowering and others viz. P_1, P_2 and P_4 had positive values (Table 24). Specific combining ability effects of

TABLE 23. DIALLEL ANALYSIS – ANOVA FOR COMBINING ABILITY

Source	df	MS	F	σ^2 GCA/ σ^2 SCA
1. Days to flowering				
gca	5	169.77	112.90 **	3.5205
sca	15	48.22	32.07 **	
Error	40	1.50		
2. Plant Height				
gca	5	21.62	17.23 **	0.4117
sca	15	56.52	45.06 **	
Error	40	1.25		
3. Number of branches				
gca	5	1.54	6.06 **	0.5833
sca	15	2.64	10.40 **	
Error	40	0.25		
4. Number of Pods				
gca	5	327.45	66.53 **	0.7882
sca	15	415.42	84.40 **	
Error	40	4.92		
5. Seeds per pod				
gca	5	0.83	59.98 **	1.5370
sca	15	0.54	34.63 **	
Error	40	0.02		
6. 100 seed weight				
gca	5	0.04	3.77 **	0.5000
sca	15	0.08	7.20 **	
Error	40	0.01		
7. Pod yield				
gca	5	3.94	11.40 **	0.5661
sca	15	6.96	20.12 **	
Error	40	0.35		
8. Pod length				
gca	5	0.60	76.55 **	1.5385
sca	15	0.39	50.20 **	
Error	40	0.01		
9. Seed yield				
gca	5	1.58	10.72 **	0.5147
sca	15	3.07	20.81 **	
Error	40	0.15		

** Significant at 0.01 levels

hybrids for days to flowering ranged from -8.93 of P_1 x P_6 to 16.11 of P_1 x P_4. Ten hybrids had negative values and only five had positive values (Table25.).

Plant height

In the case of plant height, the g.c.a. effects of parents ranged from –2.61 for P_4 to 1.77 for P_1. Three parents viz., P_1, P_2 and P_4 had positive values and others had negative values for combining ability. Among the hybrids eight had positive s.c.a. values and others had negative values. The s.c.a.values of hybrids ranged between – 11.13 of P_1 x P_4 to 9.25 of P_4 x P_5.

Number of branches

For this character, general combining ability effects of parents ranged from – 0.74 (P3) and 0.47 (P6). Out of six parents, three exhibited negative and rest had positive values. However the values were low as showed in Table 24. Out of fifteen hybrids, six had positive values and all others had negative values of s.c.a. effects.

Number of Pods

In the case of pods per plant, parents P_4, P_5 and P_6 exhibited positive values for general combining ability and others had negative values. The values for g.c.a. effects ranged from –9.74 showed by P_2 to 6.51 of Parent P_6. As presented in Table 25, the specific combining ability effects of hybrids ranged from –2.66 (P_5xP_6) 1.55(P_2xP_6). Out of the fifteen hybrids, six had positive values of specific combining ability effects.

Seed per pod

As shown in Table 24, general combining ability effects of parents for seeds per pod [illegible] positive values. [illegible] varied from –0.47 of P_3xP_4 to 1.73 of P_2xP_6. Ten hybrids had positive and five had negative values for specific combining ability.

TABLE 24. DIALLEL ANALYSIS - GENERAL COMBINING ABILITY EFFECTS OF PARENTS

Parents	Days to Flowering	Plant height (cm)	Number of branches	Number of Pods	Seeds per pod	100 seed weight (g)	Pod yield (g)	Pod length (cm)	Seed yield (g)
P1	8.18	1.77	0.18	- 2.61	0.41	- 0.12	0.20	0.27	- 0.18
P2	0.81	-0.93	- 0.19	- 9.74	- 0.38	0.04	- 0.78	0.14	- 0.48
P3	-3.65	0.01	- 0.74	- 3.57	- 0.35	- 0.03	- 0.79	0.30	- 0.36
P4	1.35	-2.61	- 0.07	3.35	- 0.01	0.01	- 0.04	- 0.34	- 0.02
P5	-4.07	-1.20	0.35	6.06	0.06	0.02	0.38	- 0.14	0.32
P6	-2.61	1.12	0.47	6.51	0.27	0.08	1.03	- 0.23	0.71
SE (G.I.)	0.3958	0.3615	0.1626	0.7160	0.0404	0.0332	0.1898	0.0285	0.1240
SE (G.I.-G.J.)	0.6131	0.5600	0.2518	1.1093	0.0626	0.0515	0.2941	0.0441	0.1921

Hundred seed weight

Two parents (P_1 and P_3) exhibited negative and the remaining four had positive values of gca effects for this trait. The values ranged between -0.12 of P_1 to 0.08 of P_6. Specific combining ability effects of hybrids ranged between –0.17 (P_3 x P_5) and 0.40 (P_4xP_5). Four hybrids had negative and eleven had positive values for specific combining ability effects.

Pod yield

Lowest g.c.a. effect was for parent P_3 and the value was –0.79. Parent P_6 had the highest value of 1.03. Three parents had negative and others had positive values of general combining ability effects. Out of fifteen hybrids, six had negative and the rest had positive values for specific combining ability effects.

Pod length

The gca effects of parents for pod length showed values ranging between – 0.34 of P_4 and 0.30 of P_3. Specific combining ability effects of hybrids for this trait varied from –0.87 of P_1 x P_4 and 0.83 of P_4xP_6. Nine hybrids had positive and others six had negative values. (Table 25)

Seed yield

In the case of seed yield per plant, general combining ability effects were positive for parents P_5 and P_6. The g.c.a. effects varied from -0.48 of P_2 to 0.71 of P_6. Out of fifteen hybrids, eight had positive and others had negative sca effects (Table 25). The lowest value of –3.12 was shown by the cross P_5 x P_6 and highest value of 2.72 by P_1 x P_5.

TABLE 25. DIALLEL ANALYSIS - SPECIFIC COMBINING ABILITY EFFECTS OF HYBRIDS

Crosses	Days to Flowering	Plant height (cm)	Number of branches	Number of Pods	Seedsper pod	100 seed weight (g)	Pod yield (g)	Pod length (cm)	Seed yield (g)
P1 x P2	8.65	1.83	- 0.83	- 7.49	0.27	0.07	- 1.69	0.66	- 1.31
P1 x P3	- 7.89	- 6.66	0.71	- 3.99	0.07	0.12	- 0.21	0.47	- 0.08
P1 x P4	16.11	-11.13	0.05	7.76	0.55	0.24	2.32	- 0.87	1.44
P1 x P5	- 7.12	- 3.78	0.63	26.71	1.78	0.25	2.85	0.17	2.72
P1 x P6	- 8.93	- 9.46	0.51	2.92	0.64	0.25	2.55	0.12	0.81
P2 x P3	- 0.52	4.48	- 2.58	-13.87	0.01	0.27	- 2.34	- 0.10	- 1.83
P2 x P4	- 7.52	- 6.67	- 0.22	- 1.44	- 0.29	0.24	0.16	- 0.65	0.64
P2 x P5	- 3.77	- 3.09	- 0.33	- 4.49	- 0.04	- 0.14	0.42	- 0.75	- 0.10
P2 x P6	- 3.56	6.59	1.55	3.38	- 0.27	- 0.09	0.98	- 0.64	1.20
P3 x P4	- 2.39	7.97	- 1.04	-20.95	- 0.42	- 0.10	- 2.42	0.28	- 1.53
P3 x P5	1.02	4.47	1.21	27.01	0.20	- 0.17	2.55	0.25	1.58
P3 x P6	3.22	1.15	- 0.24	15.88	0.16	0.14	1.29	- 0.08	0.16
P4 x P5	- 3.64	9.25	- 2.45	-34.24	0.22	0.40	- 3.96	0.75	- 2.81
P4 x P6	- 2.43	3.46	- 0.91	14.63	0.08	0.09	0.34	0.83	0.95
P5 x P6	4.65	1.52	- 2.66	-39.74	- 0.34	0.10	- 5.34	0.58	- 3.12
SE (S.I.I.)	0.8975	0.8197	0.3687	1.6238	0.0916	0.0754	0.4305	0.0646	0.2813
SE (S.I.J.)	11.0870	0.9927	0.4465	1.9665	0.1109	0.0913	0.5214	0.0783	0.3406

4.3.4.3.Estimation of components of variance and genetic parameters by Hayman's method:

The estimates of various genetic parameters are presented in Table 26. Studies of components of genetic variance by diallel analysis revealed that dominance variance was higher in horsegram than additive variance, for all the characters studied. Seeds per pod, hundred seed weight and pod length had low values for both types of genetic variance, whereas number of pods, plant height and days to flowering had high values (Table 26). Estimates for environmental variance were lowest for hundred seed weight and pod length (0.01 each). It was the highest (4.92) for number of pods.

Days to flowering

Additive genetic variance for days to flowering in horsegram was 117.50 and the dominance variance was 196.77. Mean degree of dominance for this trait was 1.29.

Plant height

Plant height showed additive variance of 32.39 and dominance variance of 201.73. Dominance effect of this character was 244.89. Mean degree of dominance for this trait was found to be 2.50 and the proportion of dominant and recessive genes in parents was 2.19. Numbers of factors controlling the character and exhibiting the dominance was observed to be 1.52

Number of branches

Additive variance for number of branches per plant was 1.21 and dominance variance 7.72. Branch number showed a dominance effect of 17.32. Mean degree of dominance for branch number was 2.52 and proportion of genes with positive and negative effects in parent was 0.24. Proportion of dominant and recessive genes in

parents was 1.05 and groups of genes controlling the character and exhibiting the dominance were 2.38.

Number of Pods

Number pods showed values of 17.17 and 30.31.10 as additive and dominance variances, respectively. Dominance effect for this trait was 4947.06 and the mean degree of dominance was 13.29. Proportion of genes with positive and negative effects in parents was 0.21. Value for proportion of dominant and recessive genes in parents was 0.79. Number of groups of genes controlling the character and exhibiting dominance was 1.96.

Seeds per pod

Additive and dominance variance for seeds per pod was calculated to be 0.88 and 1.46, respectively. Dominance effect for the trait was 0.47 and the mean degree of dominance was 2.29. Proportion of genes with positive and negative effects in parents was 0.21 and 0.57 was the estimated value for proportion of dominant and recessive genes in parents (Table) Number of groups of genes controlling the character and exhibiting dominance was 0.38. Seeds per pod exhibited a narrow-sense heritability value of 12.91.

Hundred seed weight

Additive variance for hundred seed weight was 0.15 and dominance variance 0.10. Dominance effect for this trait was –0.01. For hundred seed weight, mean degree of dominance was 0.80. Proportion of genes with positive and negative effect in parents and proportion of dominant and recessive genes in parents, were having values 0.17 and 2.53 respectively. Number of groups of genes controlling the character and exhibiting dominance was –0.08.

TABLE 26. DIALLEL ANALYSIS – ESTIMATES OF GENETIC COMPONENTS OF VARIANCE FOR DIFFERENT TRAITS BY HAYMAN'S APPROACH

Components	Days to Flower-ing	Plant height (g)	Number of branches	Number of pods	Seeds per Pod	100 Seed weight (g)	Pod yield (g)	Pod length (cm)	Seed yield (g)
1. Additive Variance (D)	55.71	88.67	1.32	338.71	0.23	0.05	3.68	0.61	1.67
2. Dominance Variance (H_1)	187.42	270.81	9.57	1740.97	2.39	0.22	29.51	1.71	12.81
3. H_2	180.98	175.53	8.08	1518.93	1.52	0.20	24.23	1.33	11.01
4. Dominance Effects (h^2)	29.41	- 0.70	6.48	115.43	1.01	0.41	0.76	0.15	0.16
5. Covariance of Additive and and Dominance effects (F)	- 33.31	175.90	1.98	402.31	0.41	0.06	6.41	0.70	2.60
6. Environmental Variance (E)	1.50	1.25	0.25	4.92	0.02	0.01	0.35	0.01	0.15
7. Mean Degree of Dominance $(H_1/D)^{1/2}$	1.83	1.75	2.69	2.27	3.26	2.18	2.83	1.67	2.77
8. Proportion of genes with positive and negative effect in parents $(H_2/4H_1)$	0.24	0.16	0.21	0.22	0.16	0.22	0.21	0.24	0.21
9. Proportion of dominant and recessive genes in parents (KD/KR)	0.72	3.63	1.77	1.71	1.77	1.85	1.89	2.05	1.78
10. No. of groups of genes controlling the character and exhibiting dominance (h^2 / H_2)	0.16	- 0.01	0.80	0.08	0.67	2.09	0.03	0.11	0.01
11. Heritability (Narrow sense)	19.72	47.02	13.31	19.96	9.92	18.73	13.07	37.04	13.42
12. t^2	17.57	1.32	0.26	0.01	25.96	0.16	1.09	1.26	0.55

Pod yield

Pod yield showed an additive variance of 0.16 and dominance variance of 131.86. Dominance effect of this particular trait was 169.66 and the estimated value for mean degree of dominance was11.16. The respective values for proportion of genes with positive and negative effect in parents and proportion of dominance and recessive genes in parents were 0.21 and 0.42. The estimated value for number of groups of genes controlling the character and exhibiting dominance was 1.56

Pod length

Additive variance for pod length was found to be 0.10 and 1.60 was the dominance variance. Dominance effect for the trait was calculated to be 0.87 and mean degree of dominance was 3.92. Proportion of genes with positive and negative effects in parents was 0.24. The proportion of dominant and recessive genes in parents was found to be 0.74. Number of groups of genes controlling the character and exhibiting dominance was estimated to be 0.56.

Seed yield

Seed yield per plant had an additive variance value of 0.11 and dominance variance value of 84.75. Dominance effect for the trait was estimated as 154.42. The mean degree f dominance was 27.49. Values for proportion of genes with positive and negative effects in parents and proportion of dominant and recessive genes in parents were obtained as0.21 and 0.65 respectively. Number of groups of genes controlling the character and exhibiting dominance was 2.15.

4.3.4.4. Heritability estimates (Narrow sense)

The values on narrow sense heritability for the different traits estimated using Hayman's method, are presented in Table 26. High values of heritability were showed by plant height followed by pod length. The values were 47.02 and 37.04, respectively. In the case of number of pods, the heritability estimate was 19.96. Days

to flowering had a narrow sense heritability estimate of 19.72. Hundred seed weight had a narrow sense heritability of 18.73. Number of branches showed the value as 13.31. For pod yield, the narrow sense heritability estimate was 13.07. Pods per plant showed a heritability value of 19.96. For seed yield per plant the value was 13.42. The lowest value for narrow sense heritability was for the character seeds per pod (9.92).

4.3.4.5. Heterosis

The heterotic expression of the hybrids in terms of relative heterosis over midparent values, heterobeltiosis over better parent values and standard heterosis over standard parent, were calculated with respect to the nine biometric traits and the results are presented in tables 27, 28 and 29 and described below.

Days to flowering

The percentage of relative heterosis for this trait ranged from –25.30 for the cross P_1 x P_6 to 37.40 for P_1 x P_4. Relative heterosis was significant and negative (desirable) for most of the crosses viz. P_1 x P_3, P_1 x P_5, P_1 x P_6, P_2 x P_3, P_2 x P_4, P_2 x P_5, P_2 x P_6, P_3 x P_4, P_4 x P_5 and P_4 x P_6. It was significant and positive for three crosses viz. P_1 x P_2, P_1 x P_4 and P_3 x P_4. Only in one cross viz., P_1 x P_4, flowering duration was relatively longer than both the parents. In other crosses, two had a low rate of increase and others flowered earlier than parents.

The percentage of heterobeltiosis for this trait ranged between –38.41 for the cross P_1 x P_3 and 19.21 for the cross P_1 x P_4. The values were negative and significant for crosses like P_1 x P_3, P_1 x P_5, P_2 x P_3 and P_2 x P_4. It was significant and positive for two crosses viz. P_1 x P_2 and P_1 x P_4.

Standard heterosis was computed based on Muthalamada Local as standard parent and the values ranged from –30.51% for the cross P_2 x P_5 to 52.56% for P_1 x P_4. The values were significant and negative for all crosses except for P_1 x P_2 and P_1 x P_4, which had significant positive values.

TABLE 27. PERCENTAGE OF HETEROBELTIOSIS

Crosses	Days to flowering	Plant height (cm)	Number of branches	Number of pods	Pod yield (g)	Pod length (cm)	Seeds per Pod	100 Seed weight (g)	Seed Yield (g)
P1 x P2	3.31**	- 24.60**	- 22.73*	- 27.41**	16.35*	2.05	- 21.74**	0.76	- 29.88**
P1 x P3	- 38.41	- 41.64**	5.26	- 2.31	15.84	4.69**	2.66**	14.34	- 12.21
P1 x P4	19.21**	- 54.45**	- 23.08**	- 20.09**	17.57	15.58**	7.03**	- 22.37**	9.43
P1 x P5	- 37.75	- 38.61**	- 14.81	7.36	57.98	9.05	7.89**	- 0.62*	18.15*
P1 x P6	- 38.41	- 44.69**	- 8.00	- 11.44*	14.28*	7.55	14.29**	- 1.98*	-0.99
P2 x P3	- 21.19	13.65**	- 50.00**	- 43.70**	- 2.57**	9.82**	- 40.02	- 11.21**	- 45.78
P2 x P4	- 26.27**	- 23.09**	- 30.77**	- 41.48**	- 9.99**	10.36**	- 21.50**	- 30.54**	- 7.26**
P2 x P5	- 30.51	- 9.75*	- 29.63**	- 42.42**	4.16**	0.27**	- 21.05	- 28.97**	- 23.44**
P2 x P6	- 26.27	21.29**	0.01	- 21.39**	- 12.26	2.84**	- 7.96	- 28.64	0.27
P3 x P4	- 19.82	35.15**	- 46.15**	- 58.95**	- 11.68**	2.11	- 45.06**	1.07	38.38**
P3 x P5	- 9.78	28.50**	- 18.52*	6.49	11.65	0.01	- 3.08**	4.08	0.44
P3 x P6	- 4.08	4.41	- 28.00**	6.47	- 5.12	7.02	- 5.37*	- 3.70*	- 12.22
P4 x P5	- 24.32	39.31**	- 51.85**	- 64.07**	6.18**	16.82**	- 51.94*	24.27**	- 53.56**
P4 x P6	- 17.12	3.62	- 30.77**	0.87	- 1.14	6.84**	- 7.17	25.93	3.07
P5 x P6	- 1.0	2.22	- 48.15**	- 67.10**	- 6.47**	7.55**	- 54.60**	22.81*	- 47.29**

* Significant at 0.05 level

** Significant at 0.01 level

TABLE 28. PERCENTAGE OF RELATIVE HETEROSIS

Crosses	Days to flowering	Plant height (cm)	Number of branches	Number of Pods	Pod yield (g)	Pod length (cm)	Seeds per Pod	100 Seed weight (g)	Seed Yield (g)
P1 x P2	15.99**	- 10.10**	- 17.07	- 17.65*	18.90	11.13**	- 10.84**	7.42**	15.93
P1 x P3	- 23.14**	- 25.61**	8.11	9.01	17.09	12.49**	12.85**	15.19**	7.98
P1 x P4	37.40**	- 41.28**	- 11.11	10.24*	25.24**	20.88**	32.43**	- 13.44**	38.57**
P1 x P5	- 22.63**	- 20.94**	0.01	48.50**	58.48**	17.48**	37.00**	11.51**	56.37**
P1 x P6	- 25.30**	- 34.27**	4.55	17.11**	26.37**	17.40	43.50**	9.61**	30.44**
P2 x P3	- 11.00*	23.54**	- 55.00**	- 42.64**	- 1.49**	11.41*	- 37.59	- 4.68**	- 44.02
P2 x P4	- 24.02**	- 15.20**	- 25.00**	- 26.37**	- 6.09	15.14**	- 13.54*	- 18.05**	- 0.68**
P2 x P5	- 21.90**	- 0.63	- 22.45**	- 27.32**	6.11	1.45**	- 10.34	- 16.67	- 13.26
P2 x P6	- 19.44**	21.79**	6.38	- 5.95	- 4.88	3.12**	3.14*	- 15.59	12.95
P3 x P4	11.88*	37.26**	- 36.36**	- 47.63**	- 6.87**	5.06**	- 37.29**	11.95	- 35.99**
P3 x P5	- 9.29	30.33**	2.22	36.29**	12.49*	0.27**	13.90**	14.57	10.60
P3 x P6	- 0.53	13.92**	- 16.28	29.31**	3.91	8.85**	9.81	6.97*	- 3.92**
P4 x P5	- 17.24**	39.51**	- 50.94**	- 63.91**	12.76**	20.51**	- 50.27**	25.14**	- 50.65**
P4 x P6	- 11.96*	14.66**	- 29.41**	7.44	2.91	11.75**	- 5.37	26.33*	8.83
P5 x P6	2.11	12.96**	- 46.15**	- 64.81**	3.14**	9.10**	- 53.91	24.05*	- 47.65**

* Significant at 0.05 level

** Significant at 0.01 level

TABLE 29. PERRCENTAGE OF STANDARD HETEROSIS

Crosses	Days to flowering	Plant height (cm)	Number of branches	Number of Pods	Pod yield (g)	Pod length (cm)	Seeds per Pod	100 Seed weight (g)	Seed Yield (g)
P1 x P2	32.21**	11.32*	- 22.65*	- 27.40**	- 21.74**	0.65**	16.36**	2.14**	- 29.84**
P1 x P3	- 21.18**	- 12.76**	- 9.00	- 5.93	- 5.35**	0.16**	13.42**	1.88**	- 6.28
P1 x P4	52.56**	- 32.74**	- 9.00	35.56**	31.22*	- 31.98**	28.31**	6.17**	26.18**
P1 x P5	- 20.34**	- 9.37*	4.64	83.71**	41.69	- 11.85**	52.21**	6.70**	54.45**
P1 x P6	- 21.18**	- 18.34**	4.64	31.84**	45.60*	- 14.12**	35.29**	8.32**	27.75**
P2 x P3	- 21.18**	13.67**	- 59.07**	- 43.71**	-40.02**	- 11.20**	- 2.57	9.92**	6.98
P2 x P4	- 26.26**	- 23.07**	- 18.14	- 0.73	-3.79**	- 30.52**	- 1.83**	10.46**	- 42.06**
P2 x P5	- 30.51**	- 9.75*	- 13.64	- 1.49	3.68**	- 29.06**	4.23**	0.27**	0.17
P2 x P6	- 26.26**	22.30**	13.64	17.04*	17.28**	- 28.73**	3.86**	3.49**	29.32**
P3 x P4	- 24.56**	13.51**	- 36.29**	- 30.38**	- 32.66**	- 12.82**	- 3.68**	- 0.80**	- 28.97**
P3 x P5	- 29.65**	8.01	0.00	82.22**	27.31**	- 10.23**	9.19**	- 2.14**	31.41**
P3 x P6	- 20.34**	5.29	- 18.14	58.51**	20.62**	- 16.88**	12.32**	7.77**	13.26
P4 x P5	- 28.81**	13.75*	- 40.93**	- 38.51**	-36.90**	- 12.50**	15.81	14.21**	- 39.27**
P4 x P6	- 22.02**	4.49	- 18.14	71.11**	18.28**	- 12.50**	17.46**	7.51**	32.98**
P5 x P6	- 17.80**	3.07	- 36.29**	- 43.71**	-40.36**	- 13.47**	10.84	8.31**	- 31.94**

* Significant at 0.05 level

** Significant at 0.01 level

Plant height

The values for relative heterosis for plant height ranged from –41.28 % in the cross P_1 x P_4 and 39.51% in P_4 x P_5. It was significant and negative for six crosses - viz. all five crosses involving P_1 and one cross involving P_2 with P_4. Significant positive heterosis were observed for all the remaining crosses except P_2 x P_5. The percentage of heterobeltiosis also showed almost a similar trend.

Values for standard heterosis were positive and significant in four crosses viz. P_1 x P_2, P_2 x P_3, P_2 x P_6 and P_3 x P_4. Maximum positive standard heterosis was observed for the cross P_2 x P_6 and negative standard heterosis was maximum for P_1 x P_4. Altogether five crosses had significant negative heterosis and another five had significant positive heterosis

Number of branches

The percentage of relative heterosis for this trait ranged between –55.00 of the cross P_2 x P_3 to 8.11 for P_1 x P_3. Negative heterosis values of nine crosses alone were significant.

The range for heterobeltiosis was –51.85 (P_4 x P_5) to 5.26 (P_2 x P_3). Eleven crosses showed significant negative heterosis. Heterobeltiosis of other crosses were not significant.

Standard heterosis for number of branches ranged from –59.07% for the cross P_2 x P_3 to 13.64% of P_2 x P_6. However the negative standard heterosis of five crosses alone were significant.

Number of pods

The values of relative heterosis for this trait ranged from –64.81of P_5 x P_6 and 48.50 of P_1 x P_5. Significant negative heterosis was observed for seven crosses and three crosses had significant positive heterosis.

Heterobeltiosis also showed a similar trend. The values varied between – 67.10% of P_5 x P_6 and 7.36% of P_1 x P_5.

Percentage of standard heterosis was maximum for P_1 x P_5 (83.75), followed by P_3 x P_5 (82.22). Positively significant standard heterosis values were observed in seven crosses.

Pod yield

Relative heterosis expressed as percentage, ranged from –6.87 of P_3 x P_4 to 58.48 of P_1 x P_5. Significant and positive relative heterosis was observed in six crosses viz. P_1 x P_4, P_1 x P_5, P_1 x P_6, P_3 x P_5, P_3 x P_5, P_4 x P_5 and P_5 x P_6.

Heterobeltiosis for this trait varied from –12.26% of P_2 x P_6 to 57.98% of P_1 x P_5. The values were significant and positive in four of the crosses viz. P_1 x P_2, P_2 x P_5 and P_4 x P_5.

In comparison with the standard parent, percentage of heterosis was maximum for the cross P_1 x P_6 (45.60). Seven crosses showed significant and positive standard heterosis values.

Pod length

In this case, all crosses showed positive relative heterosis values which ranged between 1.45% (P_2 x P_5) and 20.88% (P_1 x P_4). Relative heterosis for all crosses except P_1 x P_6 were statistically significant.

Heterobeltiosis, ranging between 16.82% in P_4 x P_5 and 0.01% in P_3 x P_5, also were positive in all crosses. However the values were significant for nine crosses only.

Standard heterosis values for pod length ranged between –31.98% for the cross P_1 x P_4 and 0.65% for P_1 x P_2. It was negative for all crosses except and P_1 x P_3.

Seeds per pod

Highest value of relative heterosis for seeds per pod was exhibited in the cross P_1 x P_6 and the value was 43.50%. Lowest value of –56.91% was observed in

P_5 x P_6. Positive relative heterosis values of five crosses and negative values of four crosses were statistically significant.

Values of heterobeltiosis ranged from –54.60% (P_5 x P_6) to 14.29% (P_1 x P_6). Seven hybrids had significant negative values and four others had significant positive values.

Standard heterosis values ranged from –3.68% in P_3 x P_4 to 52.21% in P_1 x P_5. Positive and significant values were recorded in ten crosses and significant negative values were observed in two crosses.

Hundred seed weight

For this trait, the lowest value of relative heterosis (–18.05%) was observed for the cross P_2 x P_4 and highest value for P_4 x P_6 (26.33%). Three hybrids had significant negative values and five had significant positive values.

Seven hybrids showed significant negative values of heterobeltiosis whereas two hybrids had significant positive values. The percentage of heterobeltiosis varied between –30.54 of P_2 x P_4 and 25.93 of P_4 x P_6.

Standard heterosis computed based on Muthalamada Local as standard parent ranged between –2.14% in the cross P_3 x P_5 and 14.21% in P_4 x P_5. Values were significant for all crosses. Standard heterosis values were positive for thirteen crosses and negative for the remaining three crosses.

Seed yield

Relative heterosis for seed yield ranged between -50.65% of the cross P_4 x P_5 to 56.37% of P_1 x P_5. Significant positive heterosis was observed only in three crosses involving P_1 viz. P_1 x P_4, P_1 x P_5 and P_1 x P_6. It was significant and negative for five crosses viz. P_2 x P_4, P_3 x P_4, P_3 x P_6, P_4 x P_5 and P_5 x P_6.

Heterobeltiosis values ranged from –53.56% (P_4 x P_5) and 38.38% (P_3 x P_4). Significant positive values were observed for two crosses only viz. P_3 x P_4 and P_1 x P_5. Negative heterobeltiosis of five crosses also were statistically significant.

Percentage of standard heterosis values ranged from –50.65 for the cross P_4 x P_5 to 56.37 in P_1 x P_5. Six crosses showed significant positive heterosis and five had significant negative values.

DISCUSSION

DISCUSSION

5.1. Genetic Evaluation of germplasm accessions

The basic information, which a breeder usually requires as a pre-requisite to any breeding programme of a particular crop species, is the quantum and nature of variability present in the available germplasm. The variability once assessed is to be partitioned into heritable and non-heritable components with the help of parameters like coefficient of variability, heritability and genetic advance. Information on heritability and estimates of that could be obtained in the next cycle of selection are of vital importance to the breeder in deciding the appropriate method of breeding.

Correlation studies reveal the association between yield and other biometric traits. Knowledge on the degree of association among the quantitative and qualitative characters would help the breeder to pin point a character or character set based on which selection of genotypes would result in over all progress of the selected genotypes over the base material with reference to the character or characters. The association analysis based on correlation coefficient of components with yield, however will not give a true picture of the relative merits/demerits of each of the component to final yield, which is a complex character. Hence an assessment of the merit of each character by examining the direct and indirect effect of the same towards final yield is of immense value for final selection. Path analysis, which permits partitioning of the correlation coefficients into components of direct and indirect effects, is an efficient tool for this purpose.

Since variability is the outcome of the divergence in a population, it is always better to study the variability along with genetic diversity. Many workers have emphasized the importance of genetic diversity of parents in hybridization programme. The more diverse the parents within a reasonable range, more would be the chances of improving the characters in question. Mahalanobis D^2 statistics has

been found to be a powerful tool in the hands of plant breeder to assess the degree of dissimilarity among the genotypes and to group them based on this phenotypic expression.

For selecting suitable genotypes from a highly heterogeneous mass population, selection should always be based on minimum number of characters. An estimation of discriminant function based on such reliable and effective characters is a valuable tool for pulse breeders. This discriminant function would ensure a maximum concentration of the desired genes in the plants selected.

Information as to the above nature is very limited in horsegram, compared to other pulses. Horsegram is the poor mans' pulse crop and India is the only country growing this pulse crop on a large scale. In Kerala it is traditionally grown during rabi season in the paddy nursery fields and terraced uplands (Palliyals). In southern districts of Kerala State, there is a practice of raising horsegram along with tapioca. Almost all the traditional varieties of the state are season bound (short day) plants and hence not suited for cultivation in other seasons. The productivity of present cultivars also is very low.

Horsegram is a short duration crop showing appreciable amount of hardiness to withstand prolonged drought and adaptability to a wide range of soils. Also, it is comparatively free from incidence of pests/diseases. As such, horsegram does not require much care and management for its cultivation. A potential area for expansion of cultivation of pulse crops in the State is the summer rice fallow. But the photosensitive nature of traditional horsegram cultivars makes it unsuitable for cultivation in summer season. Hence it will be a high reward to the farmers of Kerala for evolving day neutral short duration high yielding varieties of horsegram suitable to this specific cropping situation. It will also be very helpful for pulse breeders to derive the background genetic information for further improvements in this crop.

Accordingly, the objectives of the present investigation were fixed and methodologies formulated to take up variability studies, genetic analysis, varietal evaluation and hybridization in horsegram. The results obtained are discussed in the following pages:

5.1.1. Variability

The variability expressed in a population can be studied by means of range and dispersion. This apparent variability may be due to genetic or environmental factors, along with their interaction effects. The influence of genetic and environmental factors on expressed variability can be studied by determining the magnitude of phenotypic and genotypic coefficients of variability. The 115 horsegram genotypes used for the present investigation showed significant differences for all the thirteen biometric traits studied (Table 2). Wide range of variability had also been reported in horsegram by various workers like Sreekantaradhya *et al.*(1975), Aggarwal and Kang (1976), Shivashankar *et al.*(1977), Ramakrishnan *et al.*(1978), Balan (1980), Ganeshaiah *et al.*(1982), Suraiya *et al.* (1988), Singh (1990), Balan *et al.* (1991), Dobhal and Rana (1994), Rao and Nanda (1994), Sood *et al.* (1994), Savithramma *et al.* (1996), Nagaraja *et al.*(1997), Samal and Senapati (1997) and Lad *et al.* (1998).

Among the various estimates of quantitative variability, range and coefficient of variation are the basic ones. Success in genetic improvement of a crop to a large extent depends upon a wide genetic base, resulting in a wider genetic variability. As shown in Table 2, the percentage of magnitude of range over mean, was high for traits viz. number of branches (398.31), number of pods (355.01), seed yield (229.05), pod yield (222.34), haulms yield (204.37), plant height (174.82), harvest index (131.67) and hundred seed weight (119.28). This also indicated the presence of

Fig.1. Scatter diagrams depicting variability for twelve biometric traits in 115 horsegram genotypes

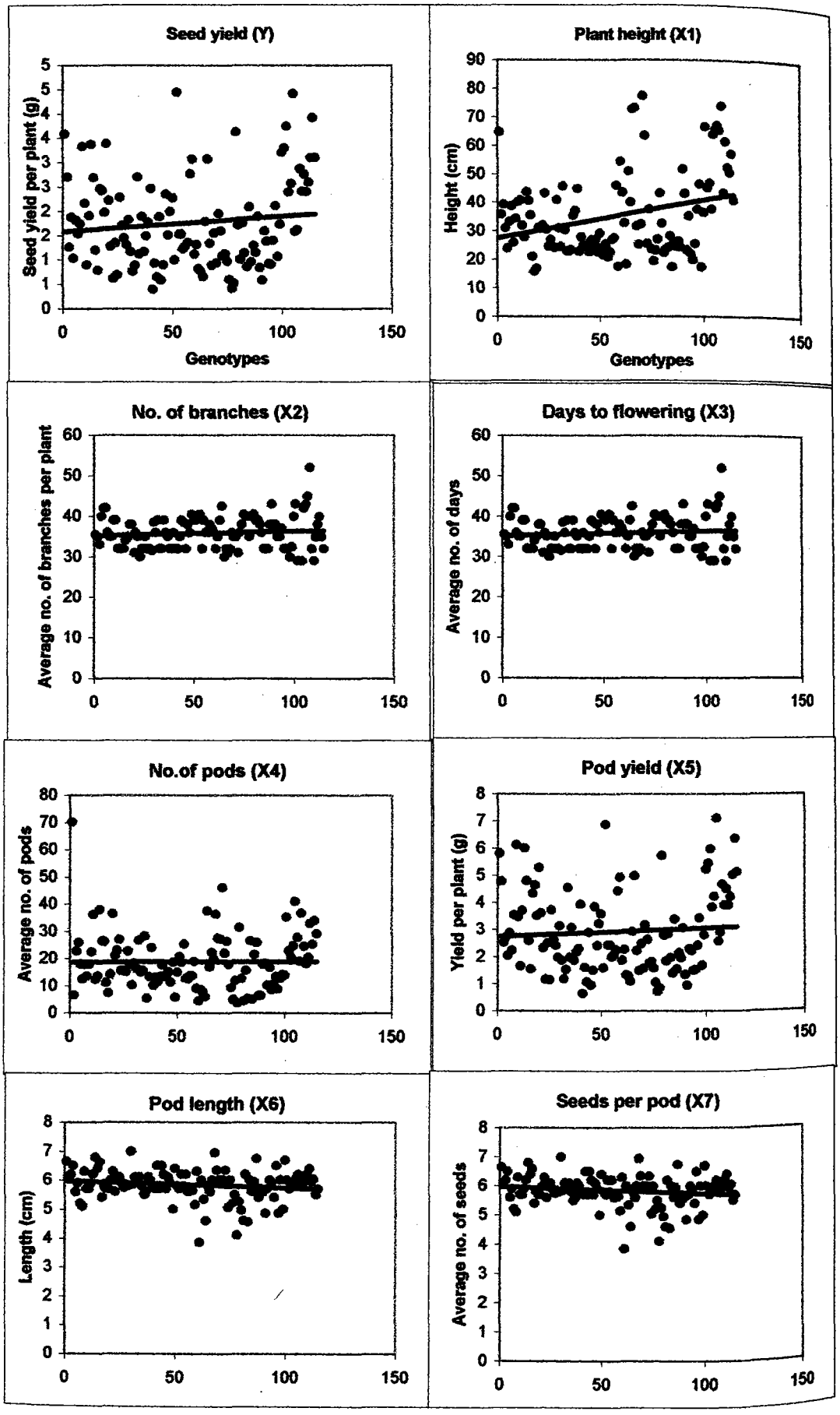
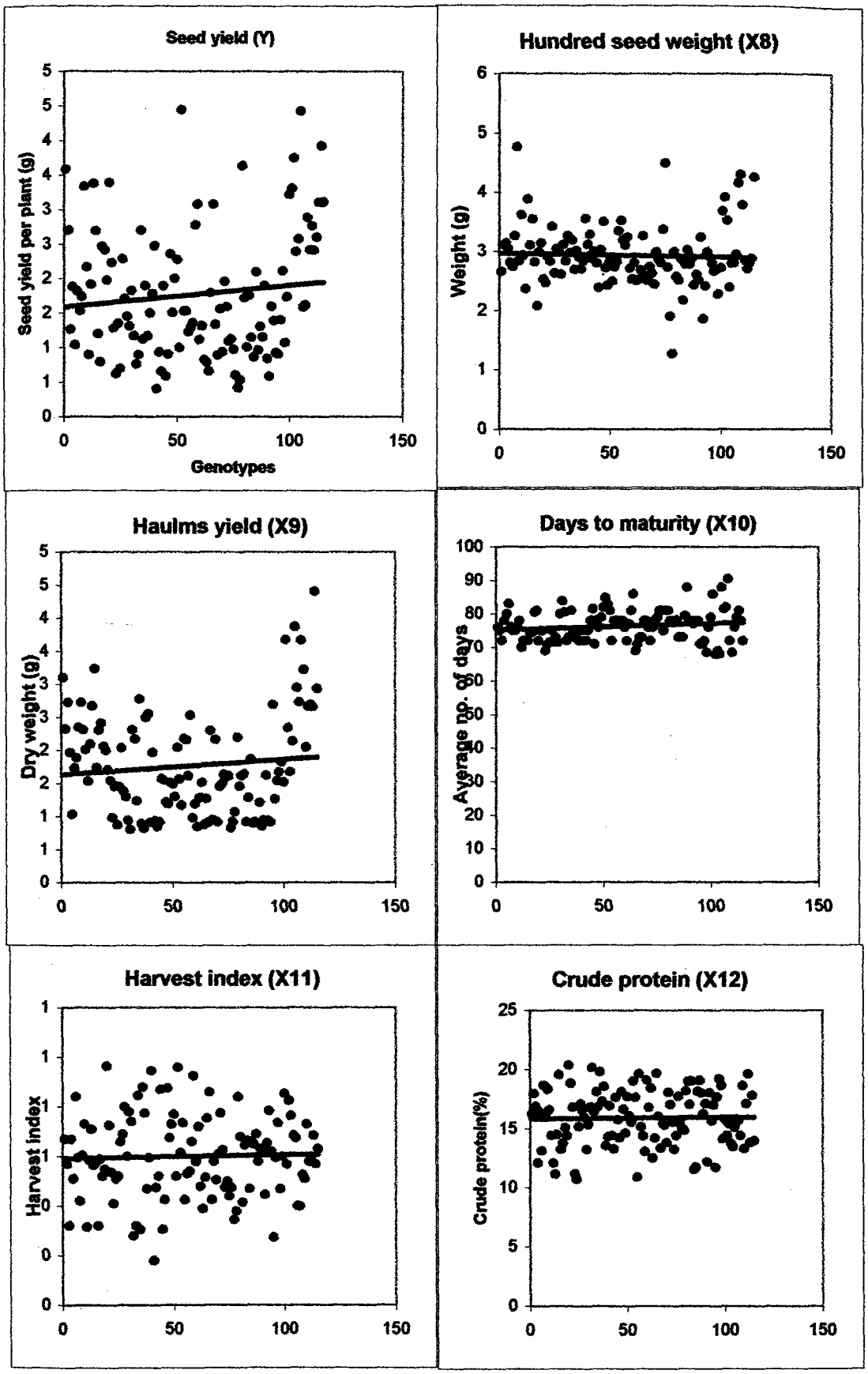


Fig.1. Scatter diagrams depicting variability for twelve biometric traits in 115 horsegram genotypes



enough variability in the population under study, suggesting the possibility for exploitation of the same through selection and other methods of crop improvement.

More than the total observed variation, it is the nature of variation that is more important. The total variation can be divided into heritable and non-heritable components. Variance estimates in the present study have indicated the influence of both genetic and environmental factors. The phenotypic and genotypic variabilities expressed as percentage over mean i.e. phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) are independent of units of measurements and hence are more useful to compare the quantum of variability of different traits, than the corresponding variance values. High magnitude of PCV and GCV for quantitative characters viz. number of branches (93.44, 92.08), number of pods (58.19, 50.95), seed yield (52.80, 50.92), pod yield (52.24, 50.41), haulms yield (44.15, 42.52) and plant height (41.86, 41.07) indicate the existence of large variability and scope for genetic improvement of these traits through selection (Table 4). Similar high estimates of PCV and GCV for number of branches have been reported by earlier workers in horsegram (Sreekantaradhya *et al.*, 1975; Shivashankar *et al.*, 1977; Ganeshaiah *et al.*, 1982 and Samal and Senapaty, 1997), in blackgram (Guptha and Singh, 1970; Singh *et al.*, 1972; Veeraswamy *et al.*, 1973 b. and Soundarapandyan *et al.*, 1975) and in cowpea (Trehan *et al.*, 1970; Hachinal *et al.*, 1981; Vaid and Singh1983 and Vijayakumar 1989).

High PCV and GCV values for number of pods as observed the present study has also been reported in horsegram by Aggarwal and Kang (1976), (Sreekantaradhya *et al.* (1975), Balan *et al.* (1991), Dobhal and Rana (1994) and Lad *et al.* 1998. Moderate to high variability estimates for seed yield and pod yield had been reported by (Sreekantaradhya *et al.* (1975), Ganeshaiah *et al.* (1982), Balan *et al.* (1991), Dobhal and Rana (1994), Samal and Senapaty (1997) and Lad *et al.* (1998).

Fig. 2. PHENOTYPIC GENOTYPIC AND ENVIRONMENTAL COEFFICIENTS OF VARIATION IN 115 HORSEGRAM GENOTYPES

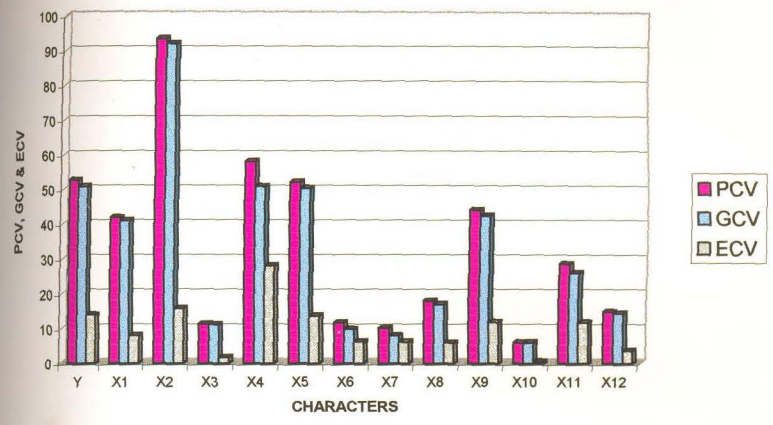
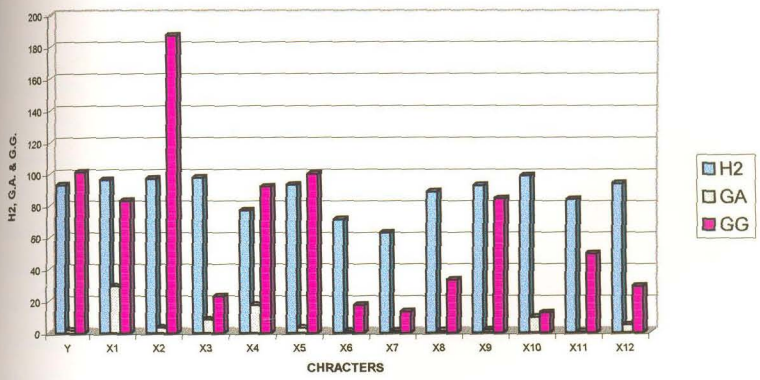


Fig. 3. HERITABILITY, GENETIC ADVANCE AND GENETIC GAIN IN 115 HORSEGRAM GENOTYPES



The estimated GCV and PCV values for the above traits followed a similar trend, indicating that influence of environment is low on expression of these traits. This is in agreement with the findings of Balan *et al.* (1991) and Sood *et al.* (1994), in horsegram.

The difference between PCV and GCV was low for days to maturity, days to flowering, and crude protein percentage. This also indicates that the variation manifested in these traits is mainly due to genetic factors. However this is to be further confirmed by studying heritability and genetic advance. Dobhal and Rana (1994) and Savithramma et al. (1996) also had obtained similar results in horsegram.

Moderate to low GCV and PCV estimates were recorded in the present study for days to maturity, seeds per pod, pod length, days to flowering and hundred seed weight. Reports of Sreekantaradhya *et al.* (1975), Shivashankar *et al.* (1977), Borole (1984), Suraiya *et al.*, 1988, Savithramma et al. (1996), Samal and Senapaty, 1997 and Lad *et al.* 1998, also supports this observation.

5.1.2. Heritability

The progress in a breeding programme depends on the extent to which the desired traits are heritable. In the present study, heritability estimates in broad sense (Table 4), were the highest for days to maturity (99.03) followed by days to flowering (97.73) and number of branches(97.14). Other traits like seed yield, pod yield, haulms yield, plant height and crude protein percentage also recorded high heritability in broad sense. Johnson *et al.* (1955) suggested that high heritability indicated the effectiveness of selection based on phenotypic performance and importance of genetic factors in expression of such traits. High heritability estimates for these traits had also been reported in horsegram by Sreekantaradhya *et al.* (1975), Shivashankar *et al.* (1977), Suraiya *et al.* (1988), Balan *et al.* (1991), Dobhal and Rana (1994), Sood *et al.* (1994), Savithramma *et al.* (1996), Nagaraja *et al.* (1997) and Samal and Senapaty (1997). However, Aggarwal and Kang (1976), Rao and

Nanda (1994) and Singh (1990) had reported low heritability estimates for traits like plant height, number of branches and seed yield.

Moderate heritability estimates were recorded for hundred seed weight and harvest index, indicating that selection may improve these traits also to some extent. This was in conformity with the findings of Balan *et al.* (1991) and Rao and Nanda (1994). Heritability estimates were low in the case of number of pods and pod length, suggesting that selection would be ineffective in such cases. Low heritability estimate for number of pods was also reported by Shivashankar *et al.* (1977), Rao and Nanda (1994) and Savithramma *et al.* (1996) in horsegram.

5.1.3. Genetic advance and genetic gain

Heritability only denotes the percentage of effectiveness with which the selection can be based on the phenotypic performance. In order to assess the genetic progress, genetic gain should be measured along with heritability. Genetic gain as percentage over mean was calculated for all the thirteen characters and it was observed that seed yield, number of branches and pod yield recorded high genetic advance (Table 4). High expected genetic advance for these characters suggest that they can be improved genetically by selection from divergent genotypes or from the segregating population. Similar results were reported in horsegram by Shivashankar *et al.* (1977), Balan *et al.* (1991), Rao and Nanda (1994) and Samal and Senapaty (1997). Moderate values were observed for plant height, number of pods and haulms yield. Hence these characters will have moderate level of improvement on selection. traits. Sreekantaradhya *et al.* (1975), Shivashankar *et al.* (1977) and Samal and Senapaty (1997) reported moderate genetic advance values for pod yield, number of pods and seed yield. The remaining traits had low genetic advance.

For a more reliable conclusion, estimates of heritability and genetic advance should be considered together which is more useful than heritability alone (Singh

and Narayanan, 1993). Expected genetic advance will be high if the heritability is due to additive gene effects. When non-additive gene effects govern heritability, expected genetic advance will be low. The characters under present investigation which were found to have high broad sense heritability and high genetic advance expressed as percentage of mean, include seed yield, pod yield and number of branches. High heritability coupled with moderate genetic advance was exhibited by plant height, and haulms yield. Hence it can be concluded that additive genes govern these five characters and direct selection will be effective for their improvement. Similar results have been reported in horsegram for traits like number of branches, days to flowering and hundred seed weight (Shivashankar *et al.* , 1977); number of branches, days to flowering, days to maturity and plant height (Ganeshaiah *et al.*, 1982); days to flowering (Suraiya *et al.*, 1988); plant height, number of branches, number of pods, seed yield and pod yield (Balan *et al.*, 1991); seed yield and days to flowering (Dobhal and Rana, 1994) and days to flowering and days to maturity (Savithramma *et al.*, 1996); number of branches (Nagaraja *et al.*, 1997); seed yield (Samal and Senapaty, 1997) and days to flowering, days to maturity, plant height and seed yield (Lad *et al.*, 1998).

In the present investigation, days to flowering, days to maturity and crude protein percentage exhibited high heritability coupled with low genetic advance. This is indicative of non-additive genes governing these traits. The high heritability values may be due to favourable influence of environment rather than genotypic effects and selection may not be much rewarding in such cases. Similar observations have been made by Savithramma *et al.* (1996) for crude protein content and Lad *et al.* (1998) for number of branches, pod length and seed yield, in the same crop.

Low heritability and moderate expected genetic advance were observed for number of pods. Additive genes may be governing this trait, and low heritability may be due to environmental influence. Selection may improve this trait to some extent. The present investigation revealed that both heritability as well as expected genetic

advance were low for pod length indicating high influence of environmental factors in its expression. This is in consonance with the reports of Lad *et al.* (1998).

In general, present investigation revealed that for crop improvement in horsegram, seed yield, pod yield and number of branches provide great help in direct selection based on phenotypic performance.

5.1.4. Correlation Studies

For a complex character like yield, simultaneous selection for more than one character becomes necessary in genetic improvement programmes since many such traits influence one another in the final phenotypic expression. Simple correlation analysis will be inadequate to measure the association between yield and other associated traits, since the influence of environment will vary depending on the genotype. Study based on the heritable values of correlation or genotypic correlation coefficients will serve as a more efficient tool than simple correlations. For this reason, the correlation between seed yield and other associated characters, as well as the inter-correlations among the characters were estimated (Table 5).

A comparison of phenotypic and genotypic correlation coefficients revealed that genotypic correlation coefficient values were higher than corresponding phenotypic values, in most cases. This may be due to the masking effect of environment modifying total expression of the genotype, resulting in reduced phenotypic expression (Johnson *et al.*, 1955). Earlier workers like Balan (1980), Dobhal and Rana (1994) and Samal and Senapaty (1997) also had found similar trends.

Seed yield had positive association with all the thirteen traits, except the genotypic correlation with crude protein percentage, which was negative but non-significant. The association was positive and significant with pod yield, harvest

Fig. 4. PENOTYPIC AND GENOTYPIC CORRELATION COEFFICIENTS BETWEEN SEED YIELD AND TWELVE BIOMETRIC TRAITS IN 115 HORSEGRAM GENOTYPES

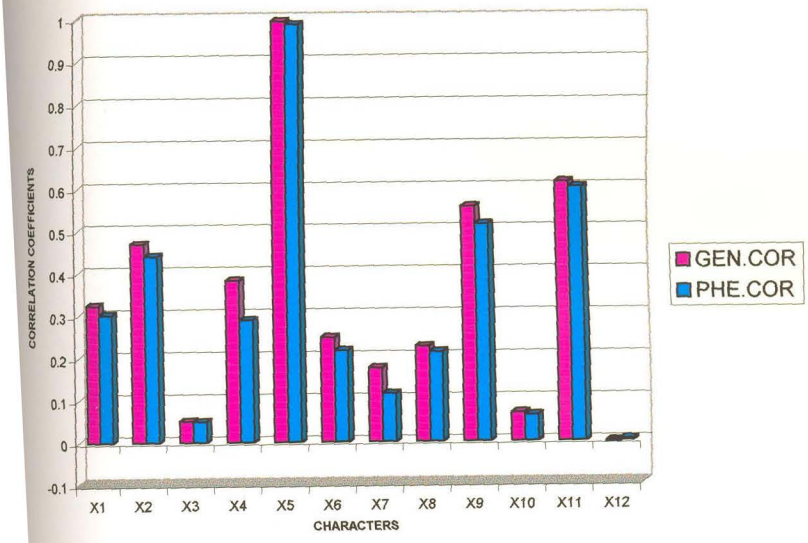
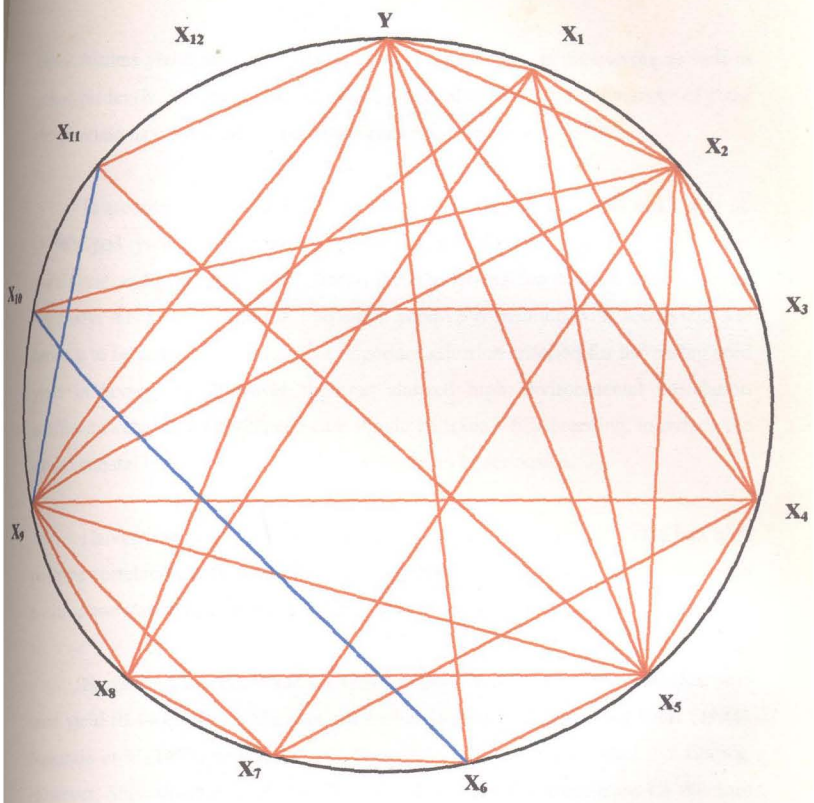


Fig. 5. Genotypic correlation Diagram



Y – Seed yield

X1 – Plant height		X2 – Number of branches	
X3 – Days to flowering		X4 – Number of pods	
X5 – Pod yield		X6 – Pod length	
X7 – Seeds per pos		X8 – 100 seed weight	
X9 – Haulms yield		X10 – Days to maturity	
X11 – Harvest Index		X12 – Crude protein %	

— Significant + ive Correlation — Significant − ive Correlation

index, haulms yield, number of branches and plant height, at phenotypic as well as genotypic levels. In the case of pod length, hundred seed weight and number of pods, the correlations were positive, but significant at genotypic level only.

In accordance with the earlier reports by Nagaraja *et al.* (1997) and Lad *et al.* (1998), pod yield showed strong positive correlation with seed yield both at phenotypic and genotypic levels (0.987, 0.994). Among the thirteen traits used for the study, this trait showed the maximum positive correlation with seed yield and hence is to be considered as the most important selection criterion for increasing seed yield in horsegram. However the trait showed high environmental correlation coefficient value also (0.899) and care should be taken while breeding, to reduce the environmental influence to the minimum, to obtain better results.

Harvest index (0.601, 0.613) and haulms yield (0.513, 0.555) also had high positive correlation with seed yield. Rao and Nanda (1994) also have reported high positive correlation of harvest index with seed yield.

Number of branches was the trait that had the next highest correlation with seed yield (0.440, 0.469). Many of the earlier reports by Dobhal and Rana (1994), Nagaraja *et al.*(1997) and Samal and Senapaty (1997) also supported this finding. However, Shivashankar *et al.* (1977) obtained low positive correlation for this trait with seed yield. Plant height also showed significant positive correlation with seed yield (0.302, 0.324), which is in tune with the earlier reports in horsegram by Aggarwal and Kang (1976) and Shivashankar *et al.* (1977).

Phenotypic and genotypic associations of days to flowering with seed yield (0.050, 0.051) were positive but not significant in the present study. Reports of Shivashankar *et al.* (1977) supports this observation. However, many other workers like Ghorpade (1985), Rao and Nanda (1994), Sood *et al.* (1994), Savithramma *et al.* (1996) and Samal and Senapaty (1997) obtained negative correlations, indicating the

possibility for simultaneous selection for high yield and earliness. The weak positive correlations obtained in the present study may be due to the favourable photoperiod in rabi season in which the genotypes were evaluated. The day-neutral entries flowered in about 30 days and most of the remaining entries also flowered in around 35-40 days on obtaining favourable photoperiod. Hence variability expressed was low for the trait. A better comparison of the influence of extended/long pre-flowering phase of photosensitive entries and fixed pre-flowering phase of day-neutral genotypes on seed yield, can be made only during other seasons.

Number of pods showed significant positive association with seed yield at genotypic level only. Shivashankar *et al.*(1977), Dobhal and Rana (1994), Samal and Senapaty (1997) and Lad *et al.* (1998) also reported significant positive association of this trait with seed yield. Pod length also showed significant positive association with seed yield, at genotypic level only. This is in conformity with the reports of Swapna (1993), Dobhal and Rana (1994) and Lad *et al.* (1998).

Seeds per pod recorded weak positive correlation with seed yield. Shivashankar *et al.*(1977), Dobhal and Rana (1994), Nagaraja *et al.*(1997), Samal and Senapaty (1997) and Lad *et al.* (1998) however reported strong positive correlations.

In the case of hundred seed weight, the association with seed yield was significant at genotypic level only. Shivashankar *et al.*(1977) reported weak positive correlations for this trait with seed yield, whereas Sood *et al.* (1994), Samal and Senapaty (1997) and Lad *et al.* (1998) reported significant negative correlations.

The positive association of days to maturity with grain yield was not significant in the present study. But, Sood *et al.* (1994) reported significant negative correlations for the trait with seed yield.

5.1.5. Path Analysis

The true picture on the influence of the various component traits on final yield, will not be revealed through correlation analysis alone. High positive influence of certain components may not represent its actual contribution, if it had a negative indirect influence through some other trait. Similarly, a character with low direct effect may have high indirect effect through other characters. These traits in addition to their relationship with yield, also exhibit different degrees of inter-relationships among themselves. A change in one character may bring about change in its relationship with other associated characters that may finally reflect on yield. In order to have an insight into these chain relations, the cause – effect relationships between seed yield and eight traits that had significant genotypic correlation with yield were investigated using path coefficient analysis.

As per the present investigation, pod yield was found to contribute maximum to seed yield in horsegram (Table 6). This trait had a total correlation of 0.9940 with seed yield and the major part of this was through direct effect to the tune of 0.8842. The indirect effects of this trait were low, thus predicting the significance of this trait in determining the yield. Other traits included in the present study exerted their influence indirectly through this trait. According to Aggarwal and Kang (1976), pod yield per plant and seed size were the main traits having high direct influence on seed yield. Studies by Ganeshaiah (1980) and Singh (1990) revealed that number of pods, pod yield per plant and hundred seed weight contributed maximum direct influence on seed yield. However, in the present study, number of pods and hundred seed weight had only lesser influence, compared to pod yield. Their direct effects were negligible or negative and influence was mostly indirect, through pod yield.

As per the present study, harvest index, haulms yield and number of branches showed genotypic correlation coefficient values of 0.6125, 0.5550 and 0.4686, respectively. Indirect effects of these traits through pod yield per plant also were

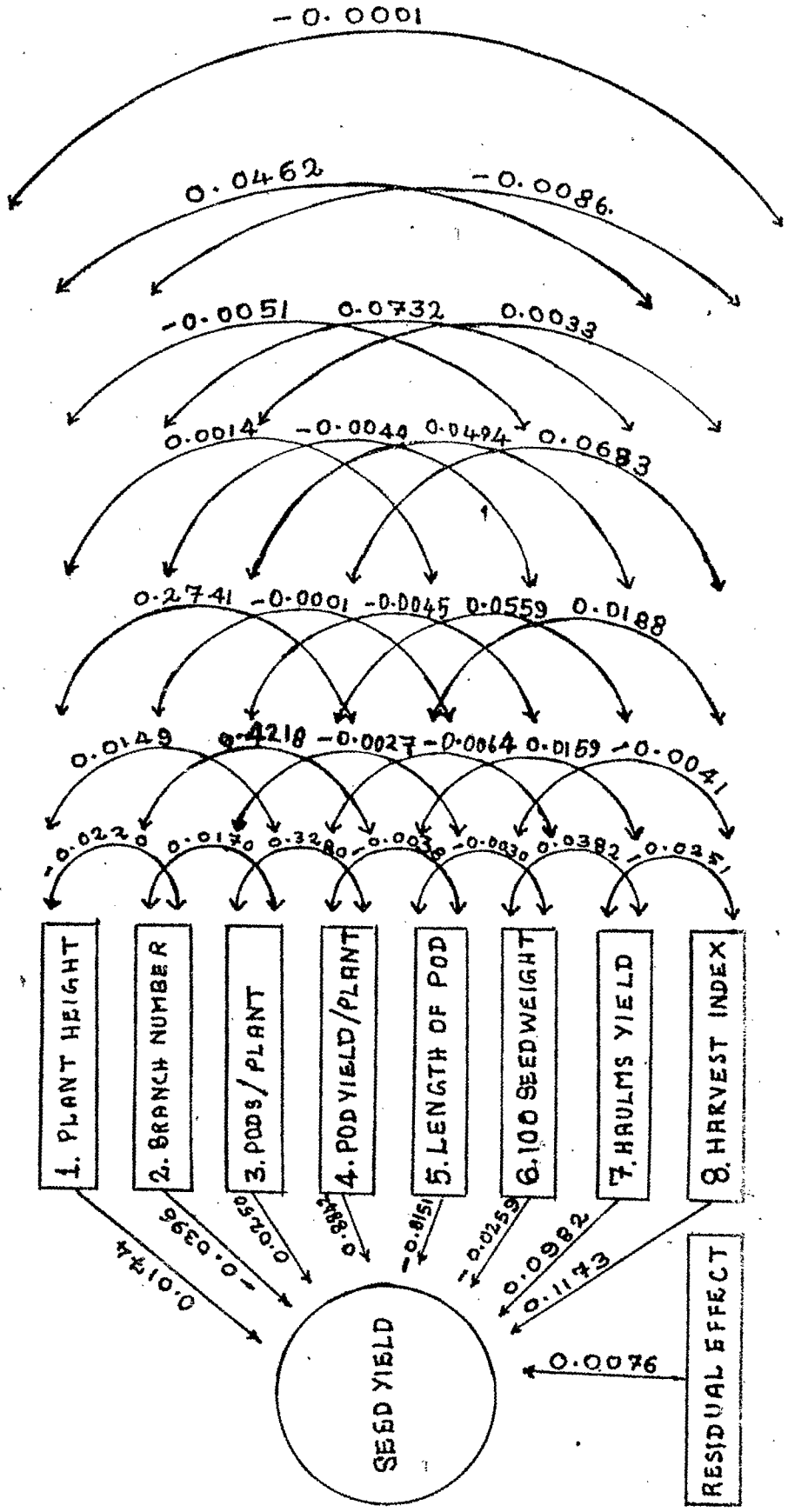


Fig. 6. Path Diagram

considerable. According to Sood *et al.* (1994), hundred seed weight had negative direct effect on seed yield. In the present study also the trait showed low negative direct effect on seed yield. However this negative direct effect was masked by its indirect positive effect through pod yield per plant. Sood *et al.* (1994) also have made similar observations in horsegram.

Plant height and number of pods had low direct effect and their influence was indirectly through pod yield. The direct effect of pod length was negative, in agreement with the earlier observations by Aggarwal and Kang (1976). Pod length also had indirect influence through pod yield.

The residual effect observed in the study was 0.0076 only. This indicated that most of the important traits have been included in the model.

From the results it is clear that selection to improve seed yield in horsegram should be mainly based on pod yield as it had high direct effect and all other traits used in the study had indirect effects via this character. The indirect effect of this trait was negligible. It also had high positive association with seed yield, both at phenotypic and genotypic levels. In addition to this, this trait also recorded high values of heritability, genetic advance and genetic gain. So, direct selection based on pod yield will directly improve seed yield in horsegram.

5.1.6. D^2 Analysis

It is well established that exploitation of hybrid vigour and success in getting desirable segregants in horsegram breeding programme as in other pulse crops, depends to a large extent on the degree of genetic divergence between parents chosen. A quantitative assessment of genetic divergence among the genotypes and association between genetic and geographical diversities are essential information required for the breeders. Evolution of variability among indigenous cultivars is the outcome of prolonged natural and artificial selection. D^2 analysis permits precise

comparison among all possible pairs of genotypes, which helps a lot in proper selection of parents in modeling the crossing programme.

In the present investigation D^2 analysis was utilized to assess the genetic distance between the genotypes and classify them into clusters based on their genetic divergence. The analysis of variance (Table 3.) for the thirteen biometric traits revealed that significant differences existed among the genotypes in respect of all the traits. Wilk's lambda criterion also revealed that significant diversity existed among the lines. The diversity among the genotypes was further confirmed through D^2 analysis wherein the 115 genotypes formed as many as ten clusters (Table 7). This large number of clusters formed indicated that horsegram is a crop marked by considerable genetic diversity.

A perusal of the genotypes that fall into various clusters reveal that the genetic diversity does not relate to geographical diversity. Genotypes having different geographical origin fell into same cluster and different lines collected from same centre were found scattered in different clusters. For example cluster I had genotypes collected from Madhya Pradesh, Tamil Nadu, Orissa, Rajasthan and Andhra Pradesh. Cluster VI had one exotic collection from Australia, along with other entries from Madhya Pradesh, Maharashtra, Karnataka and Manipur. Cluster VIII also had an exotic collection from Nepal, along with other genotypes from Tamil Nadu, Maharashtra, Madhya Pradesh, Andhra Pradesh and Gujarat. This might be due to similar selection pressure that existed in these places of origin. Almost similar observations have been reported in horsegram by Ramakrishnan *et al.* (1979), Balan (1980), Ganeshaiah (1984) and Swapna (1993); in cowpea by Mehndiratta and Singh (1971); in greengram by Guptha and Singh (1970) and in blackgram by Malhothra and Singh (1971).

In contrast to this, different lines collected from same centre were found scattered in different clusters. For example, out of the total 29 genotypes collected

from Tamil Nadu, eight belonged to cluster VII, seven to cluster IX, five to cluster V, four to cluster X, two each to cluster II and cluster VIII and one to cluster I. Fourteen genotypes from Madhya Pradesh were found scattered in as many as six clusters. Seven types from Himachal Pradesh belonged to six different clusters. Such diversity within a zone may be due to different selection forces acting in same zone itself or may be due to genetic drift (Sagar *et al.*, 1976). Cluster III contained only one entry (PHML-64), which was from Karnataka. This can be attributed to the marked superior or inferior nature of that genotype in respect of one or more traits.

Intra and inter-cluster distances

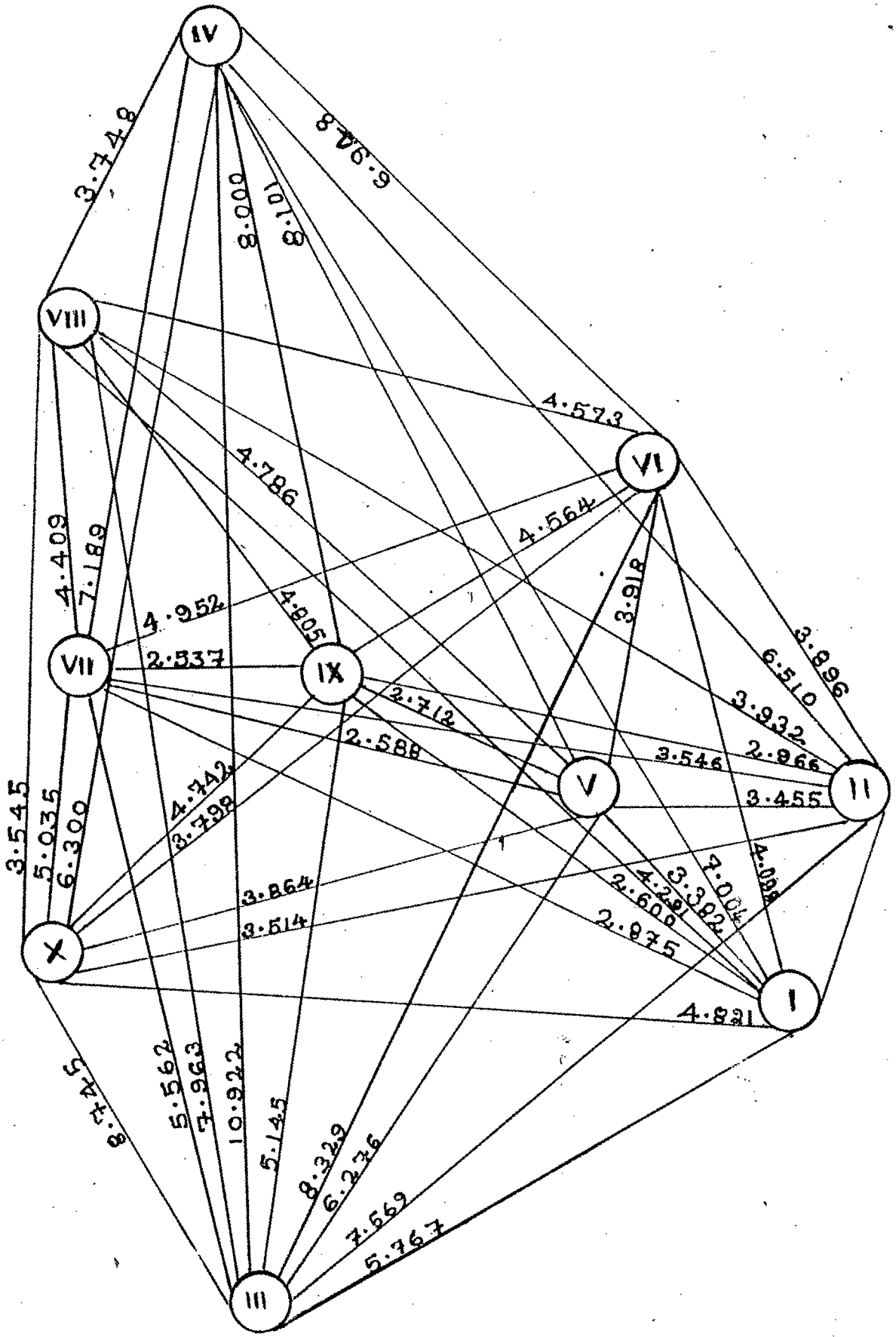
Intra-cluster distance values provide a measure of the diversity available within a cluster, attributable to the genotypes included therein. In the present study, cluster X had the maximum intra-cluster distance (3.359). It was minimum for cluster IV which included three genotypes obtained from three different regions (Andhra Pradesh, Madhya Pradesh and Karnataka). This low intra-cluster distance may be due to the coherent polygenic or pleitropic genetic mechanism (Singh and Gupta, 1968).

Inter-cluster distance was maximum between cluster III and cluster IV (10.922) and minimum between cluster I and cluster II (2.431). In general, it can be inferred that selection of parents belonging to cluster III for crossing with parents selected from cluster IV will be more fruitful, since genetic diversity is considered as one of the most important criterion in selecting genotypes for hybridisation.

Cluster mean values

Different clusters showed superiority for different traits (Table 9.). Cluster IV showed superiority for grain yield. Cluster IV contained genotypes with highest values for most of the traits like plant height, number of branches, days to flowering,

Fig. 7. Cluster Diagram



number of pods, pod yield, hundred seed weight, haulms yield, and days to maturity. In the case of seeds per pod and harvest index, cluster II showed superiority. Cluster IX had superior genotypes for crude protein percentage.

In the case of traits where minimum values are desirable, like dwarfness, earliness, compact growth habit etc., desirable genotypes were present in cluster I for plant height; cluster III for number of branches; cluster III for early flowering and cluster III for early maturity, can be chosen.

Inter-crossing of genotypes selected from these clusters might be effective in improvement of traits desirable. Pod yield, harvest index, haulms yield and number of branches were the traits having high positive correlation and maximum positive direct effect on seed yield. Genotypes superior for these features are available in cluster II for harvest index and cluster IV for other traits. Cluster V and X had genotypes that showed earliness for flowering and maturity. In the case of crude protein content, cluster IX had desirable types. Thus, genotypes can be selected from the above-mentioned clusters for utilisation in hybridization programmes to evolve superior lines having high yield potential, earliness and high protein content.

5.1.8. Selection Index using discriminant function analysis

In order to assess the efficiency of simultaneous selection based on several characters over based on yield alone, the discriminant function analysis was carried out. The pattern of ranking of genotypes based on selection index and that based on yield alone varied. Based on selection index, the best ten genotypes were identified. However these ten were also identified based on yield alone. But the ranking were different. This may be because the two traits - viz. pod yield and harvest index - included in the selection index, had maximum correlation and positive direct effect on seed yield.

5.2. Varietal Evaluation Studies

To study the stability in performance of selected horsegram genotypes in different seasons (rabi and summer) over years, ten genotypes were evaluated during the years 1997, 1998 and 1999. Out of these ten genotypes, five (viz., PHML-64, DPI-1574, PHG-9, Muthalamada Local and CO-1) were season bound (photosensitive) genotypes and they did not flower or set pods properly during summer season. Hence these were not considered for evaluation conducted during summer season. The other five (viz., AK-21, AK-42, AK-26, KS-2 and Maru Kulthi) were day-neutral genotypes and these were evaluated in both rabi and summer. The evaluation was done based on two most reliable characters viz. seed yield and pod yield, as identified in the preliminary genetic evaluation studies.

5.2.1. Evaluation of five day-neutral genotypes in rabi and summer.

The study revealed that performance of the genotypes both in terms of seed yield as well as pod yield differed significantly over the seasons and over the years. However the difference in performance of the varieties during same season for these three years were not significant, indicating that performance of the varieties is stable both in rabi and summer.

Mean performances of the varieties were better in rabi (traditional) season compared with that in summer. This may be because of the natural adaptability of the cultivars or due to the favourable influence of environmental factors like soil moisture, temperature during rabi. In overall performance, the genotype AK-42 excelled other entries; both for seed yield as well as pod yield. Hence this genotype can be recommended for cultivation in summer rice fallows as well as in traditional season.

Fig. 8. MEAN SEED YIELD OF FIVE HORSEGRAM GENOTYPES IN RABI AND SUMMER SEASONS DURING 1997. 1998 & 1999

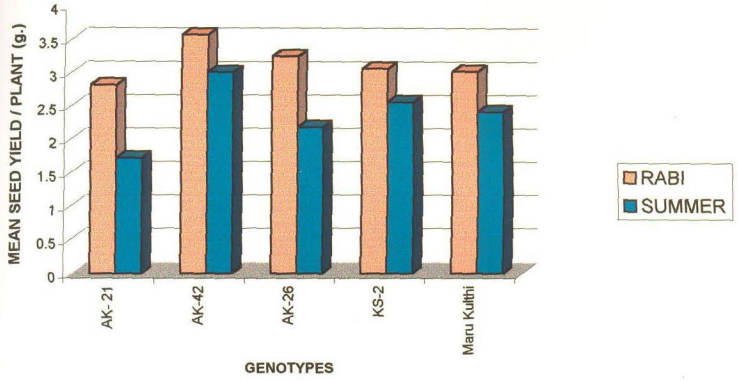


Fig. 9. MEAN POD YIELD OF FIVE HORSEGRAM GENOTYPES IN RABI AND SUMMER SEASONS DURING 1997, 1998 &1999

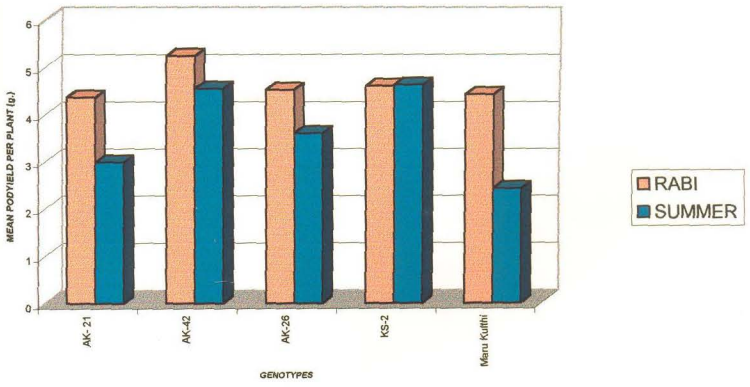


Fig. 10. MEAN SEED YIELD OF FIVE HORSEGRAM GENOTYPES DURING 1997, 1998 & 1999

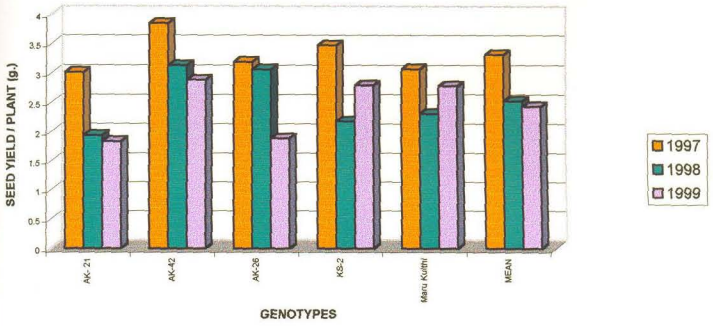


Fig. 11. MEAN POD YIELD OF FIVE HORSEGRAM GENOTYPES DURNG 1997, 1998 & 1999

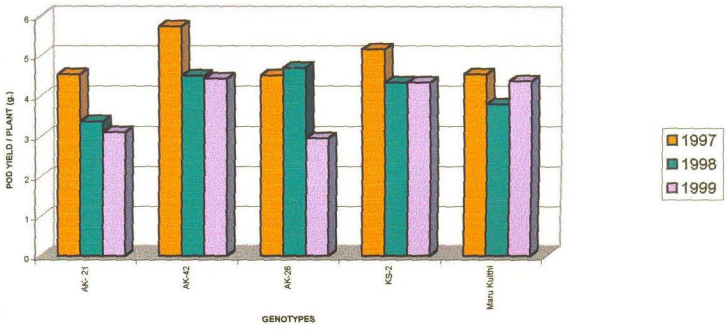


Fig. 12. MEAN SEED YIELD OF TEN HORSEGRAM GENOTYPES DURING 1997, 1998 & 1999

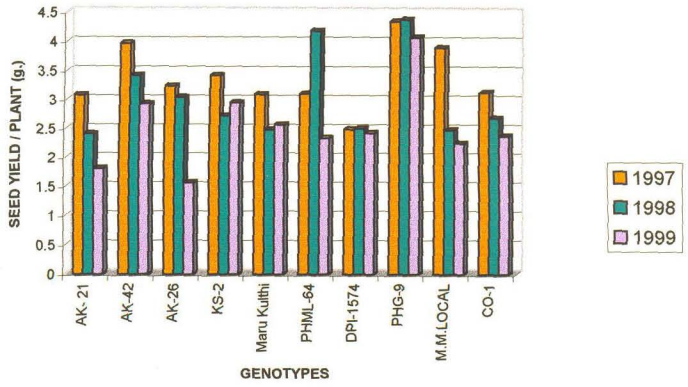
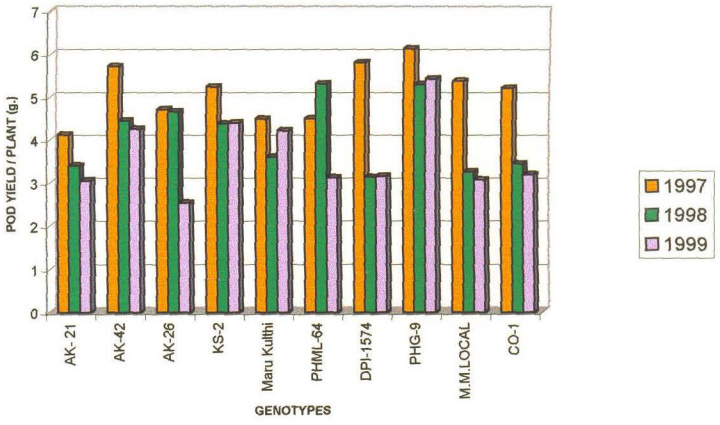


Fig. 13. MEAN POD YIELD OF TEN HORSEGRAM GENOTYPES DURING 1997, 1998 & 1999



5.2.2. Evaluation of ten horsegram genotypes in rabi season

When photosensitive and day-neutral genotypes were evaluated together in the rabi (traditional) season over three years, the best and stable performance was shown by the photosensitive variety PHG-9. This variety had brown coloured seeds that have got consumer preference.

Earlier reports on co-ordinated varietal evaluation trials conducted by ICAR also confirms that PHG-9 and AK-42 are stable over years and locations and these were included as check varieties in the yield trials on a National basis (ICAR, 1999 and 2000). However, in order to make specific recommendations, the promising cultivars must be subjected to further evaluation.

5.3. Hybridisation Studies

Studies on anthesis, pollen maturity and stigma receptivity revealed that anthesis and pollination occurs in horsegram between 3 pm and 5 pm on the previous day of flower opening and cleistogamy was the general rule in horsegram. This is in agreement with the reports by Sundararaj and Thulasidas (1976) in horsegram. According to various workers like Sen and Jana (1963) and Nainar Mohammed (1991) in blackgram and by Sen and Ghosh (1959), Boiling et al. (1961) and Jiji Joseph (1998) in greengram, cleistogamous condition is present in other pulses also.

5.3.1. Standardisation of techniques for selfing and crossing

It was observed from the present study that emasculation can be done by cutting open the flower bud and the ideal time for pollination to obtain successful crosses in horsegram to be between 3 pm – 5 pm on previous day of flower opening. Similar methods have been proposed other leguminous crops such as in blackgram (Sen and Jana, 1963 and Nainar Mohammed, 1991); in greengram (Sen and Ghosh,

1959; Boiling et al., 1961 and Jiji Joseph, 1998) and in groundnut (Achamma Oommen, 1990).

5.3.2. Crossing

The ideal time for pollination to obtain successful crosses in horsegram was observed to be between 4 pm and 6 pm on the previous day of flower opening. The percentage of success obtained was very low. The flower buds are tiny and flimsy and easily get injured while handling. Flower dropping, immature fruit dropping etc. also substtially reduce successful pod setting.

5.3.3. Diallel Analysis

Diallel analysis is an efficient tool for the plant breeder, to estimate the genetic components of variation and combining ability of the selected lines in a series of crosses. In addition to this, it is also useful for the estimation of heterosis, heritability and genetic advance. Thus it helps in selection of parents for hybridisation programme as well as in deciding appropriate breeding procedure for the genetic improvement of various quantitative traits.

The combining ability analysis provides an understanding of genetic architecture of traits and would be useful in handling the segregating material. The ability of parents to combine well depends on various complex gene interactions, which cannot be fully judged from phenotypic values.

5.3.4.2. Analysis of Combining Ability using Griffing's approach

In this method, the genetic components of variance are computed through estimates of general combining ability (gca) and specific combining ability (sca) variances and effects. The gca variance is basically due to additive gene action, and

Plate 7. Emasculation – Step 1.

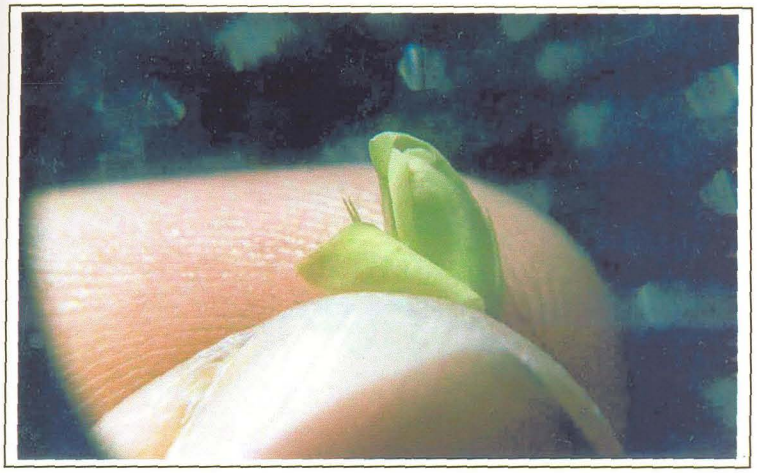


Plate 8. Emasculation – Step 2.

Plate 9. Emasculation – Step 3.

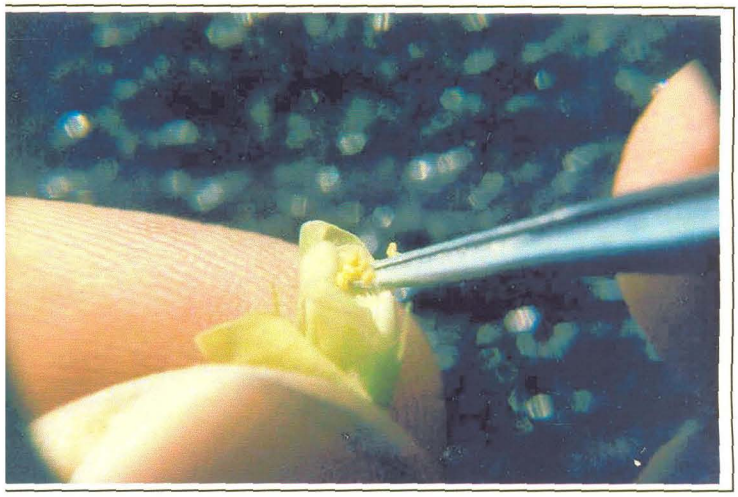


Plate 10. Pollination

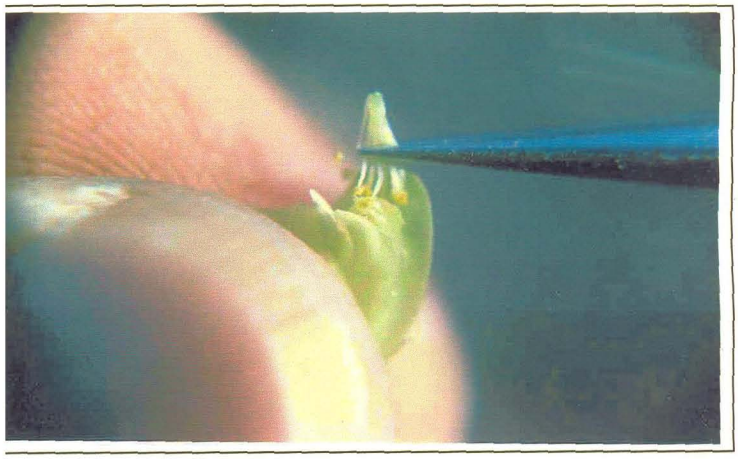


Plate 11. Protection of crossed flower

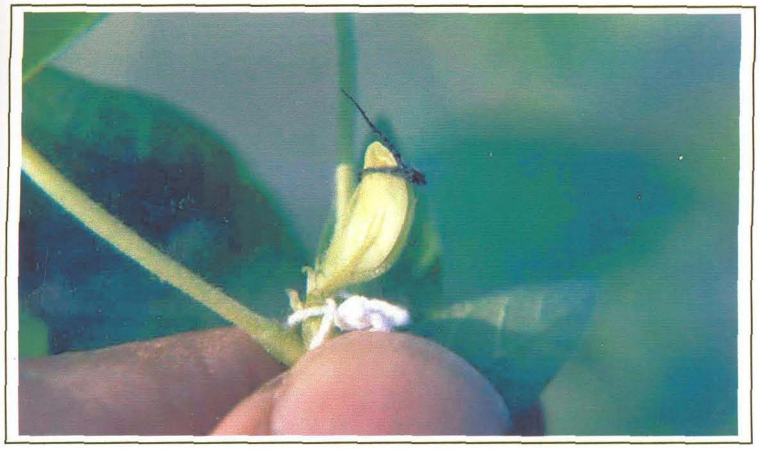


Plate 12. F_1 pod in young stage

Plate 13. F1 plants obtained from various crosses

Plate 14. F_1 plant of the cross PHML-64 x AK-26

Plate 15. F_1 plant of the cross PHML-64 x AK-42

Plate 16. F1 plant of the cross PHML-64 x AK-21

Plate 17. F1 plant of the cross Maru Kulthi x PHML-64

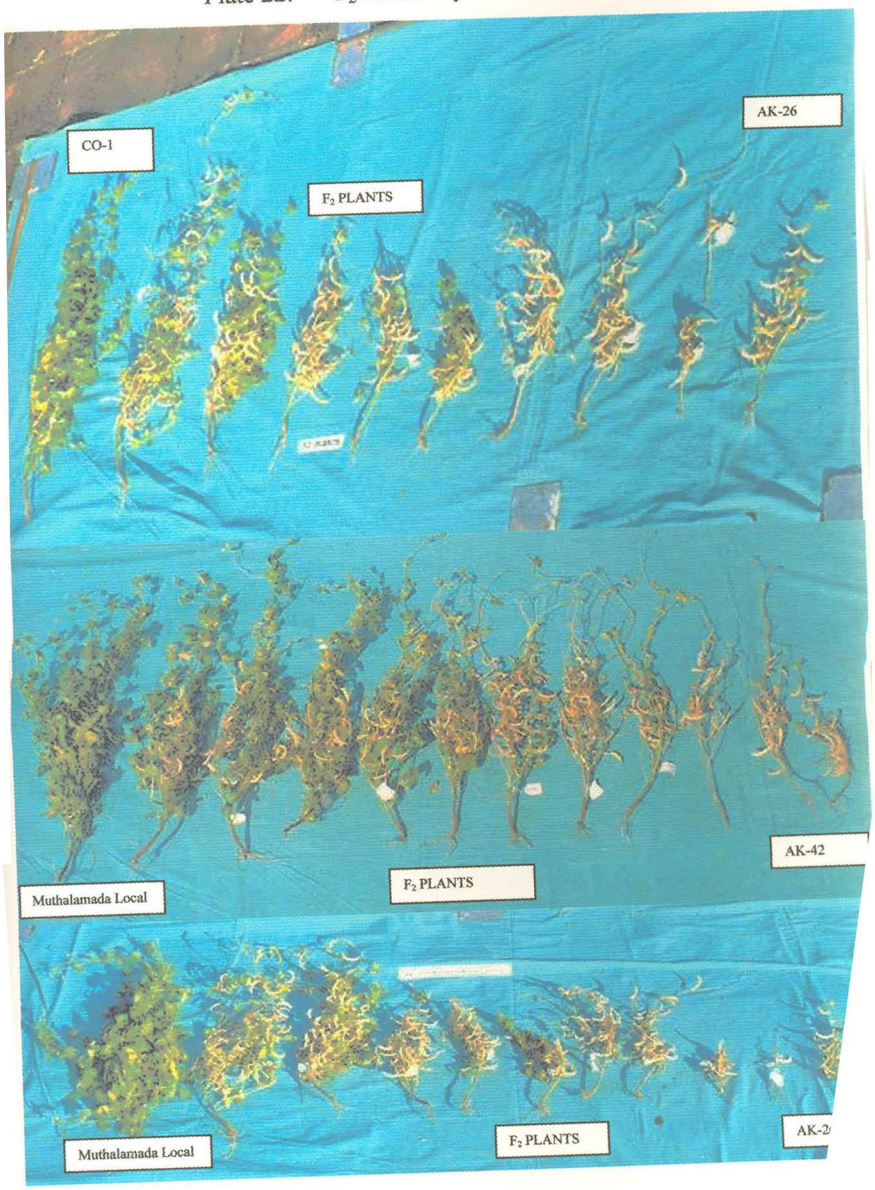
Plate 18. F_2 Variability in the cross PHML-64 x AK-21

Plate 19. F_2 Variability in the cross Maru Kulthi x PHML-64

Plate 20. F_2Variability in the cross AK-42 x PHML-64

Plate 21. F_2Variability in the cross PHML-64 x AK-21

Plate 22. F_2 Variability in various crosses



is equal to twice gca variance. However, if epistasis is present, gca variance will include additive x additive component also. The sca variance that deals with non-additivity of genes and is mainly attributable to dominance variance. But may also include all the three types of epistatic interactions, viz. additive x additive, additive x dominance and dominance x dominance, if epistasis is present.

a) Combining Ability Variances

In the present study, analysis of variance for combining ability (Table 23) showed that mean squares due to g.c.a. and s.c.a. effects were significant for all characters, thereby indicating the importance of both additive and non-additive gene effects. The ratio of g.c.a. variance to s.c.a. variance was higher than one, for days to flowering (3.5205), seeds per pod (1.5370) and pod length (1.5385) pointing out the predominance of additive as well as additive x additive gene action in the expression of these traits. Hence progeny selection or pedigree breeding will be effective for the genetic improvement of the traits if they are positively associated with seed yield. (Singh and Choudhary, 1977)

For other traits, viz. plant height (0.4117), hundred seed weight (0.5000), seed yield (0.5147), pod yield (0.5661), number of branches (0.5883) and number of pods (0.7882) the ratio was less than one, showing that these traits are under the influence of non-additive gene action (dominance and epistasis). Hence, in order to harness both types of gene actions, resorting to recurrent selection seems to be more rewarding in horsegram.

Significant gca variances for most of the traits studied had also been reported in blackgram by Singh and Singh (1971), Prem Sagar and Chandra (1977), Lal and Waldia (1980), Phudan Singh and Srivastava (1982), Waldia and Dahiya (1982), Malhotra (1983) Baruah and Panday (1983) Sharma et al. (1987) Dasgupta and Das (1987) and Haque et al. (1988).

b) Combining Ability Effects

Estimates of combining ability effects assists in efficient selection of parents for breeding, once the breeding strategy is decided based on the information on gene action gathered from the study on combining ability variances. The effects consists of gca effects (i.e. the contribution of the two parents) and sca effects (i.e. the excess over and above the two gca effects.), as stated by Singh and Narayanan (1993)

The present study revealed that out of the six parents, three (P_3, P_5 and P_6) had significant negative (desirable) gca effects for days to flowering and these parents can be considered useful for incorporating earliness. Among crosses, P1 x P6 exhibited maximum negative sca effect for the trait. In the case of plant height, wide range of variation was observed for gca effects (-2.61 for P4 to 1.77 for P1) as well as for sca effects (-11.13 for P1 x P4 to 9.25 for P4 x P5). Since plant height shows significant positive correlation as well as direct effect with seed yield in horsegram, the cross between P4 and P5 may yield good recombinants. For number of branches, P6 had maximum positive gca effect and the cross P2 x P6 exhibited maximum positive sca effect. Since this trait also had significant positive association with seed yield, the above cross combination can be considered as desirable.

5.3.4.3. Analysis of Genetic components of variance, by Hayman's approach

The three traits that exhibited high values for additive as well as dominance variance as computed by Hayman's approach were number of pods, plant height and days to flowering, indicating that both additive as well as dominance gene actions govern these traits. In the case of pod yield per plant, dominance variance component was higher compared to additive component. Hence this trait is primarily having dominance gene action.

Mean degree of dominance estimated was more than unity for all the traits studied, indicating overdominance for these traits (Singh and Narayanan, 1993). The estimates on ratio of dominant and recessive genes in parents indicate that, except for the trait days to flowering, the parents exhibit excess of dominant genes compared to recessive genes. Number of groups of genes controlling traits like was more than one in the case of only one trait viz. hundred seed weight. Estimates of proportion of genes with positive and negative effects in parents indicated that there was a symmetrical distribution of positive and negative alleles among the parents except for the traits plant height and seeds per pod. Heritability (narrow sense) estimates were high for traits like plant height and pod length indicating that these traits are largely governed by additive genes and selection can improvement such traits. Low estimates of narrow sense heritability was recorded for seeds per pod indicating that there is a preponderance of non-additive gene action and heterosis breeding may prove useful to improve this trait.

5.3.4. Evaluation of parents, F_1 and F_2 to study the inheritance pattern of photoperiodic response and seed colour

Olegogenes determine expression of qualitative traits. Gene action and number of genes controlling such traits can be studied by observing the inheritance pattern of the traits in the parents and offsprings. Hybridisation was carried out between selected parents and inheritance pattern of photoperiodic response and seed colour was studied based on information obtained from the parents and their progenies. The F_2 segregation ratios of different crosses for photoperiodic response are discussed below:

i) In the cross between the photosensitive variety PHML – 64 and the day-neutral genotype AK – 42, F_1 were day-neutral and the F_2 segregated in the ratio 33 Day-neutral : 27 Photosensitive. From the results, it can be inferred that day-neutral

flowering habit is dominant over photosensitive (short-day) flowering habit. Many of the earlier reports like that of Sen and Bhowal (1959) and Sundararaj and Thulasidas (1976) also supports this view. The χ^2 goodness of fit test indicated that this observed ratio agrees with the 9 : 7 F_2 segregation ratio for complementary gene inter-action (Singh, 1983) involving two genes. Two dominant genes (A and B) are necessary to produce the 'day-neutral' flowering habit (A- B-). Nine out of 16 progenies will have this genotype and they will be day-neutral. When one or both genes are recessive, the phenotype in F_2 is expressed as 'photosensitive' (i.e genotypes A- bb; aa B- and aabb, which are obtained in the ratio 3 : 3 : 1 respectively, totaling seven).

The genotypic constitution and corresponding phenotypes can be represented as below:

i) Parents PHML – 64 x AK - 42

(aa bb)(Photosensitive) ↓ AA BB(Day-neutral)

F_1

(Aa Bb - All Day-neutral)

↓

F_2

33 (Day-neutral) : 27

(Photosensitive)

Genotypes (Numbers):		Phenotype (Numbers):	
A- B-	(nine)	Day- neutral	(nine)
A- bb	(three)		
aa B -	(three)	Photosensitive	(seven)
aa bb	(one)		

ii) In another cross between PHML- 64 and another day-neutral genotype AK – 26 all F_1 were day-neutral and F_2 segregated as 40 day-neutral and 27 photosensitive)

In this case also, the χ^2 goodness of fit test indicated that this observed ratio agrees with the 9 : 7 F_2 segregation ratio for complementary gene inter-action, as discussed above.

The F_2 segregation ratios for seed colour as observed in the following crosses are discussed below:

i) Parents PHML - 64 (Black seeds) x AK- 42 (Brown seeds)

↓

F1

(All had Black seeds)

↓

F_2 → 34 (Black seeds) : 23 (Grey seeds) : 3 (Brown seeds)

From the results, it can be inferred that black seed colour is dominant over brown. This is in agreement with earlier reports by Ayyangar (1934), Sen and Bhowal (1959) and Sundararaj and Thulasidas (1976). However, the F_2 in the present study segregated into three classes, indicating that at least two genes are involved in controlling this trait. The χ^2 goodness of fit test suggested that the ratio observed in this case, agrees with the 9 : 6 : 1 F_2 segregation ratio for polymeric gene inter-action (Singh, 1983). Two dominant genes B_1 and B_2 produce identical effects individually, but their effect is increased when both the dominant genes are present together. The double-recessive genotype will have another phenotype (brown, in this case), as illustrated below:

		Genotypes		Phenotype	
Parents:	PHML-64	$B_1B_1\ B_2B_2$		Black seeded	
	AK-42	$b_1b_1\ b_2b_2$		Brown seeded	
F_1		$B_1b_1\ B_2b_2$		Black seeded	
F_2	B_1 - B_2 -	(nine)		Black	(nine)
	B_1 - b_2b_2	(three)	}	Grey	(Six)
	b_1b_1 B_2 -	(three)			
	b_1b_1 b_2b_2	(one)		Brown	(one)

ii) Parents PHML-64 (Black seeds) x AK-26 (brown seeds)

↓

F_1

(All had black seeds)

↓

F2 →	39	:	24	:	4	
	(Black seeds)		(Grey seeds)		(Brown seeds)	

Here also, the χ^2 goodness of fit test suggested that this observed ratio is in agreement with the 9 : 6 : 1 F_2 segregation ratio for polymeric gene inter-action, as discussed above.

The major objectives envisaged in the programme had been achieved more or less satisfactorily. The detailed genetic analysis of biometric traits among 115 widely divergent horsegram genotypes, had brought out valuable background information

on genetic variability and genetic parameters suitable for utilization in selection and other breeding procedures in the crop. The varietal evaluation enabled to identify promising cultivars suitable for traditional (rabi) season and those offer potential for cultivation in summer rice fallows. The efforts on hybridization in the crop had yielded useful material and reliable data for immediate as well as future crop improvements in horsegram.

SUMMARY

SUMMARY

The present study entitled "Genetic analysis in horsegram (*Dolichos biflorus* Linn.) with special reference to photoperiodic response" was undertaken in the Department of Plant Breeding & Genetics of College of Horticulture, Vellanikkara, during 1993-2000 to identify stable, high-yielding, day-neutral horsegram genotypes suitable for year-round cultivation and to understand the nature of gene action involved in the inheritance of photoperiodic response in the crop. The field experiments were laid out at the Regional Agricultural Research Station, Pattambi of Kerala Agricultural University.

The material consisted of 115 horsegram genotypes obtained from NBPGR regional stations at Vellanikkara and Akola, and entries supplied under AICRP (Arid Legumes) scheme of ICAR. The whole investigation was carried out as three parts. In first part, the 115 germplasm accessions were evaluated in rabi (traditional season of horsegram cultivation in Kerala) and summer, in RBD with two replications. Since most of the entries were photosensitive, only five genotypes (viz. Maru Kulthi, AK- 21, AK-26, AK-42 and KS-2) flowered in summer season. Hence detailed genetic evaluation was conducted using rabi data involving all the 115 entries. Observations were recorded on seed yield and twelve other biometric traits viz. plant height, number of branches, days to flowering, number of pods, pod yield, pod length, seeds per pod, hundred seed weight, haulms yield, days to maturity, harvest index and crude protein percentage. The data were subjected to statistical analysis including analysis of variance (ANOVA), association analysis and path analysis. The genotypes were clustered using Mahalanobis D^2 statistics. The results obtained are summarised below:

- Evaluation of genotypes indicated that enough variability exists among the genotypes with respect to seed yield and yield attributes.

- Studies on correlation and cause-effect relations among seed yield and yield attributes revealed that pod yield, harvest index and haulms yield were the traits having maximum positive association and positive direct effect on seed yield. Duration to flowering or maturity did not have significant correlation with seed yield. Hence it is possible to have varieties that combine high yield and early maturity.

- Based on genetic diversity, the 115 genotypes were grouped into ten clusters, using Mahalanobis D^2 statistics. It was found that genetic diversity existing among genotypes is not associated with their geographical origin.

- A selection index constructed based on seed yield, pod yield and harvest index was found to give 79.47 per cent gain in efficiency over selection based on yield alone.

In the second part of investigation, genotypes selected on the basis of the preliminary evaluation were further tested over two seasons (rabi and summer) and three years (1977,1998 and 1999) in a comparative yield trial, to select best genotypes suitable for each seasons. The materials were chosen in such a way that the best genotypes based on the ranking according to selection index, giving representation to all the ten clusters arrived at through D^2 analysis conducted in first experiment. The selected genotypes included five day-neutral types (AK-21, AK- 26, AK-42, Maru Kulthi and KS-2) and five photosensitive (short-day) types (PHML-64, DPI-1574, PHG-9, CO-1 and Muthalamada Local) The photosensitive genotypes did not flower or set pods properly during summer season, since short-days required for flowering initiation in such types are not available during summer. Hence these could be evaluated only during rabi season. The remaining five day-neutral genotypes were evaluated in both rabi and summer seasons. The evaluation was done in RBD with four replications. The study revealed that the day-neutral genotype AK-42 is ideal for year-round cultivation. However, for cultivation during

rabi, the photosensitive variety PHG-9 was found to be better. In general, performance of genotypes was better during rabi than in summer.

In the third part of the investigation, which was taken up simultaneous with the second one, the same genotypes were used to undertake hybridisation between day-neutral and photosensitive types. The objective was to study the combining ability and gene action involved and estimation of heterosis. The diallel analysis involving six parents (viz. four day-neutral types AK-21, AK-26, AK-42 and Maru Kulthi and two photosensitive types viz. PHML-64 and Muthalamada Local) revealed that the parents AK-42 and AK-26 (both day-neutral types) had maximum positive general combining ability for seed yield. Highest specific combining ability for the trait was observed for the cross PHML-64 x AK-42. Relative heterosis also was observed to maximum for the same cross. Higher gca expressed by traits like days to flowering, seeds per pod and pod length indicated that these traits are controlled by additive gene action. Higher sca was observed for plant height, hundred seed weight, seed yield and pod yield, indicating that non-additive gene action play a major role in expression of these traits. The results of F2 evaluation revealed that photoperiodic response in horsegram is probably a qualitative trait, controlled by at least two genes, either in complimentary gene action or inhibitory gene action. In the case of inheritance of seed colour, the black seed colour was observed to be dominant over brown. Two genes in polymeric gene action, were found to control seed colour.

Based on the study, the following future line of research can be recommended:

1) Isolation of superior recombinants from further seggregating generations, that combine high yield, high protein content and day-neutral flowering habit

2) Standardisation of the photoperiodic requirements of short-day types

REFERENCES

REFERENCES

Achamma Oommen. 1990. Genetic analysis in redgram (*Cajanus cajan* L.). Ph.D. Thesis, Kerala Agricultural University, Vellanikkara. 39-41.

Aggarwal,V.D. and Kang, M.S. 1976. Genetic variability, correlation and path analysis studies in horsegram (*Dolichos biflorus* L.). *Tropical Agriculture.* **53**(4): 335-340.

Aksel, R. and Johnson, L.P.V. 1962. Analysis of diallel cross, a worked example. *Adv.Fron.Pl.Sci.*, **2**: 37-54.

Alagaraswamy, G. 1981. Some aspects of production physiology of pearl millet. *Lecture delivered at the Summer Institute on Production physiology of dry land crops* held at APAU, Hyderabad: 1-12.

Allard, R.W. 1970. *Principles of Plant Breeding.* John Wiley and Sons. Inc., New York 263-275.

Angadi, S.P. 1976. Correlation studies and D^2 analysis in cowpea (*Vigna sinensis* L. SAVI.). M.Sc.(Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore.

Arunachalam, V. 1976. Evaluation of diallel crosses by graphical and combining ability methods. *Indian J. Genet.* **36**: 358-366.

Aryeety, A.N. and Laing, E. 1973. Inheritance of yield components and their correlation with yield in cowpea (*Vigna unguiculata*(L)Walp.). *Indian J.Genet.* **43**:710-715.

Asthana, A.N. 2000. Pulses – Now in the limelight. *The Hindu survey of Indian Agriculture 2000.* National Press, Kasturi Buildings, Chennai. p. 57-60.

Ayyangar, C.N.R., Rao, P.K. and Sarma, P.S. 1934. Preliminary studies in horsegram (*Dolichos biflorus* L.) *Madras Agric. J.*, **22**(6): 200-204.

Balakrishnan, G. 1978. Studies on pattern of variability and genetic diversity in cowpea (*Vigna sinensis* (L.) SAVI.). M.Sc.(Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore.

Balan, A. 1980. Biometrical studies in horsegram (*Dolichos biflorus* L.). M.Sc.(Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Balan, A., Guruswamy, V.D., Raja and Vivekanandan, P. 1991. Direct selection parameters in horsegram (*Dolichos biflorus* L.). *Legume Research.* **14**(2): 103-104.

Balasubramanian, V. 1985. *Horsegram.* Central Research Institute for Dryland Agriculture. Hyderabad, Andhra Pradesh. India. 183-187.

Banerjee, S.P., Majumdar, N.K., Chatterjee, S.D. and Bhattacharya, R. 1976. Application of path analysis and discriminant function for selection in blackgram(*Phaseolus mungo* L.). *Acta Agronomica*(Hungary). **25**(3-4): 423-431.

Bapna, C.S. and Joshi, S.N. 1973. A study on variability following hybridization in *Vigna sinensis* (L.) SAVI. *Madras Agric. J.* **60**(9 - 12): 1369-1372.

Baruah, D.K. and Panday, M.P. 1983. Combining ability analysis for seed yield and its components in blackgram. *Crop Improv.*, **10**(1): 26-30.

Bhaskariah, K.B., Shivashankar, G. and Virupakshappa, K. 1980. Heterosis and combining ability in cowpea. *Indian J. Genet. Pl. Breed.* **40**: 336-339.

Bastian, D.(1996). Heterosis and combining ability in cowpea (Vigna unguiculata (L) Walp). M.Sc.(Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Biradar, B.D., Goud, J.K. and Patil, S.S. 1991. A study on character association and path coefficient in cowpea. *J. Maharashtra Agric. Univ.* **16** (1): 27-29.

Birari, S.P., Deorukgakar, N.V. and Jamadagni, B.M. 1987. Genetic parameters and character association in horsegram. *Indian J. Agric. Res.* **21**: 55-58.

Black, B.J. and Weiss, K.W. 1956. *Amino Acid Hand Book.* Thomas Spring Field, Illinois.

Boiling, M., Sander, D.A. and Matlock, S. 1961. Mungbean hybridisation technique. *Agron. J.* **53**: 54-55.

Borah,H.K. and Hazarika,M.H.. 1995. Genetic variability and character association in some exotic collections of green gram. *Madras Agric. J.* **82**(4): 268-271.

Borole, D.S. 1984. Genetic variability and correlation studies in horsegram. M.Sc.(Ag.) Thesis. Konkan Krishi Vidyapeeth, Dapoli.

Briggle, L.W. 1963. Heterosis in wheat. *Crop Sci.* **3**: 407-412.

Burton, G.W. 1952. Quantitative inheritance in grasses. *Proc. 6th Int. Grassia. Cong.* **1:** 277-283.

Byregowda, M., Chandraprakash, J. Jagadeeshbabu, C.S. and Rudraswamy 1997. Genetic variability and inter-relationship among yield and yield components in greengram.(*Vigna radiata* L.). *Crop Res.***13**(2): 361-368.

Cassie, R.M. 1963. Multivariate analysis in the interpretation of numerical plankton data. *New Zeland J. Sci.* **6**: 39-59.

Chandel, K.P.S., Joshi, B.S. and Pant, K.C. 1973. Yield in mung bean and its components. *Indian J. Genet. Pl. Breed.*, **33**(2): 271-276.

Chandrasekharaiah, S.R., Murthy, B.R. and Arunachalam, V. 1969. Multivariate analysis of genetic divergence in Eu-sorghum. *Proc. Nat. Inst. Sci.* **35**: 172-195.

Chouhan, G.S. and Joshi, R.K. 1981. A note on combining ability in cowpea. *Legume Research* **4**: 112-114.

Chowdhury, J.B., Chowdhury, R.K and Kaker, S.N. 1971. Studies on genetic variability in moong. *Indian J. Agric. Sci.* **8**: 169-172.

Cochran, G.W. and Cox, M.G. 1957. *Experimental Design.* John Wiley and Sons Inc., London.

Crumpacker, D.W. and Allard, R.W.1962. A diallel cross analysis of heading date in wheat. *Hilgardia*, **32**: 275-318.

Dana. 1976. Origin, evolution and distribution of some grain legumes. *Indian J. Genet.* **36**: 143-145.

Dasguptha, T. and Das, P.K. 1987. Genetics of yield in blackgram. *Indian J.Genet.* **47**(3): 265-270.

Dewey, D.R, and Lu. K.H. 1959. A correlation and path coefficient analysis of components of crested grass seed production. *Agron. J.*, **51**: 515-518.

Dobhal, V.K. and Rana, J.C. 1994. Genetic analysis for yield and its components in horsegram (*Macrotyloma uniflorum*). *Legume Research.* **17**(3): 179-182.

Doku, E.V. 1970. Variability in local and exotic varieties of cowpea(*Vigna unguiculata* (L) Walp.) in Ghana. *J. Agric. Sci.* **3**: 139-143.

Dumbre, A. O., Deshmukh, R.B. and Padhye, A.P. 1983. Variability in cowpea. *J. Maharashtra Agric. Univ.* **8**: 85-86.

Falconer, D.S. 1989. *Introduction to quantitative genetics*. Eastern Language Book Society Ltd. Hong Kong.

Fisher, R. A. 1936. The use of multiple measurement in taxonomic problems. *Ann. Eug.* **7**: 179-188.

Fisher, R.A. and Yates, F. 1963. *Statistical tables for biological, agricultural and medical research (6th Edn)*. Oliver and Boyd Ltd. Edinburgh.

Ganeshaiah, K.N. 1980. Multivariate analysis for yield and its contributing characters in horsegram (*Dolichos biflorus* Ln.). *Mysore J. Agric. Sci.* **14**: 519-523.

Ganeshaiah, K.N., Shivashankar, G. and Hiremath, S.R. 1982. Genetic variability for yield and other characters in the germplasm of horsegram (*Dolichos biflorus* Linn.). *Mysore J. Agric. Sci.* **16**(4): 400-403.

Garner, W.W., and Allard, H.A. 1920. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. *J. Agric. Res.* **18**: 553-606.

Ghorpade,D.S. 1985. Metroglyph analysis of morphological variation in horsegram (*Dolichos biflorus* L.). *Current Research Report.* **1**: 56-60.

Gill, J.S., Verma, M.M., Gumber,R.K. and Singh, B. 1995. Character association in mungbean lines derived from three intervarietal crosses in mungbean. *Crop Improvement.* **22**: 255-260.

Giriraj, K. and Vijayakumar, S. 1974. Path coefficient analysis of yield attributes in mung bean. *Indian J. Genet.* **34:** 27-30.

Gohokar, R.T. 1983. Important diseases of horsegram in Vidarbha region. *Proc. of first ICAR group meeting of horsegram research workers.* Dryland Project, Hyderabad.

Gopalsingh, B., Rajareddy, C, and Krishnaiah,V.V. 1977. Studies on heritability, genetic advance and character association in cowpea. (*Vigna unguiculata* L.) *Andhra Agric. J.* **24**: (5-6). 209-212.

Goud, J.V., Vikramath, B.C. and Lakshmi, P.V. 1977. Variability and correlation studies in blackgram (*Phaseolus mungo* L.) *Mysore J. Agric. Sci.* **11**: 322-325.

Gowda, T.H. 1984. Comparison of three selection criteria in segregating populations of cowpea. *Mysore J. Agric. Sci.* **8**: 1-10.

Griffing, B. 1956(a). Concept of general and specific combining ability in relation to diallel crossing systems. *Aust. J. Biol. Sci.* **9**: 465-493.

Griffing, B. 1956(b). A generalised treatment of the diallel cross in quantitative inheritance. *Heredity.* **10**: 31-50.

Gupta, M.P. and Singh, R.B., 1969. Variability and correlation studies in greengram. *Indian J. Agric. Sci.* **39**: 482-493.

Gupta, M.P and Singh, R.B. 1970. Genetic divergence for yield and its components in greengram. *Indian J. Genet.* **30**: 212-221.

Hanchinal, R.R., 1978. Variability studies on cowpea (*Vigna unguiculata*(L.)Walp.). *Mysore J. Agic. Sci.* **12**: 349-352.

Hanchinal, R.R., Habib, A.F. and Goud, J.V. 1981. Variability in cowpea. *Mysore J. Agric. Sci.*, **15**: 371-375.

Hanson, C.H., Robinson, H.F. and Comstock,R.E. 1956. Biometrical studies of yield in segregating populations of Korean Lespedeza. *Agron J.* **48**: 268-272.

Haque, M.F. Ganguli, D.K. and Misra, A.K. 1988. Combining ability and heterosis in urdbean. *Indian J. Pulses Res.* **1**(1): 6-11.

Hathcock, B.R. and Mc Daniel. 1973. Yield and yield component heterosis in *Avena* hybrids. *Crop Sci.* **13**: 8-18.

Hayes, H.K., Immer, F.R. and Smith, D.C. 1955. *Methods of plant breeding.* McGraw Hill Book Co. Inc., NewnYork.

Hayman, B.I. 1954 a. The theory and analysis of diallel crosses. *Genetics.* **39**: 789-809.

Hayman, B.I. 1954 b. The analysis of variance and diallel tables. *Biometrics.* **10**: 235-244.

Hazel. L.N. 1943. The genetic basis for construction of selection index. *Genetics.* **28**: 476-490.

Hebbal, S.N. 1988. Genetic analysis of yield and yield components in cowpea. *Mysore J. Agric. Sci.* **22**(1): 151-153.

I.C.A.R. 1999. *Annual Progress Report, 1998-99.* All India Co-ordinated Research Project on Arid legumes. RAU, Beechwal, Bikaner. 63-70.

I.C.A.R. 2000. *Annual Progress Report, 1999-2000.* All India Co-ordinated Research Project on Arid legumes. CAZRI, Jodhpur, Rajasthan. 57-65.

Jackson, M.L. 1973. *Soil Chemical Analysis.* Prentice Hall of India Ltd. New Delhi. 2nd Edition. 498-499.

Jagadishmurthy. 1984. Path analysis and selection indices in three F2 population of cowpea. *Mysore J. Agric. Sci.* **18**: 322-323.

Janoria, M.P. and Ali, M.A. 1970. Correlation and regression in cowpea. *JNKUV. Res.J.* **4**: 15-19.

Jatasra, 1980. Combining ability for grain weight in cowpea. *Indian J. Genet.* **40**: 330-333.

Jayaprakash, T.L., Sashidhar, V.R., Prasad, T.G. and Udayakumar, M. 1992. Photoperiodic response of advanced breeding lines and cultivars of finger millet under irrigated and rain fed conditions. *Plant Physiol. & Biochem.* **19**(1): 49-54.

Jhorar, B.S. and Jatasra, D.S. 1990. Line x Tester analysis for grain and fodder yield and its components in cowpea (*Vigna unguiculata* (L) Walp.). *Forage Res.* **16**(1): 13-19.

Jiji Joseph. 1998. Genetic analysis in greengram (*Vigna radiata* (L) Wilczek) for yield and yield components. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore.

Jiji Joseph and Santhoshkumar, A.V. 1999. Character association and cause effect analysis in some F_2 population of greengram (*Vigna radiata* (L) Wilczek). *Legume Research.* **22**(2): 99-103.

Jinks, J.L. 1954. The analysis of continuous variations in diallel cross of *Nicotiana rustica* varieties. *Genetics.* **39**: 767-788.

Jinks, J.L. and Hayman, B.I. 1953. The analysis of diallel crosses. *Maize Genetics Coop. News Letter.* **27**: 48-54.

Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1955. Estimates of genetic and environmental variability in soyabean. *Agron. J.* **47**: 314-318.

Joshi, S.N. and Kabaria, M.M. 1973. Inter-relationships between yield and yield components in *Phaseolus aureus. Madras Agric. J.* **60**(9-12): 1331-1334.

Kabir, J. and Sen, S., 1987. Studies on genetic variability and heritability in dolichos bean. *Ann. Agric. Res.* **8**(1): 141-144.

Kabir, J. and Sen, S., 1989. Correlation and Path analysis in *Lablab niger* Medik. and *Dolichos uniflorus* Lam., *Tropical Agriculture (Trinidad).* **66**: 281-283.

Kabir, J. and Sen, S., 1990. Diallel analysis for combining ability in *Dolichos* bean (*Lablab niger* Medik. and *Dolichos biflorus* Lam. *Tropical Agriculture (Trinidad).* **67**(2): 123-126.

Katiyar, R.P. 1984. 'Kulthi'- a promising pulse crop for Himachal hills. *Indian Farming.* **34**(9): 31-35.

Kerala Agricultural University. 1999. Research Report 1996-'97. Directorate of Research, Vellanikkara – 680 656. pp.70.

Khan, I.A. 1985. Correlation and path coefficient analysis of yield components in mung bean (*Phaseous aureus.* Roxb.). *Botanical Bulletin Academia Sinica.***26**: 13-20.

Khan, K.A. and Ahamed, R. 1989. Relationship of yield and its component characters in mung bean(*Vigna radiata*(L.)Wilczek). *Legume Research.* **12**(4): 173-176.

Kheradnam, M and Niknejad, 1973. Heritability estimates and correlation of agronomic characters in cowpea (*Vigna sinensis* L.). *J. Agric. Sci. Camb.* **82**: 207-208.

Khorgade, P.W. 1995. Genetic parameters and regression analysis in greengram. *Indian J. Agric. Res.* **29**(4): 232-236.

Kumar, S.S., Sudharsan, A., Kumar, S.V. and Reddy,V.N. 1995. Correlation and path coefficient analysis in greengram (*Vigna radiata*). *Madras Agric. J.* **82**(3) 160-162.

Lad, D.B., Chavan, S.A. and Dumbre, A.D. 1998. Genetic variability and correlation studies in horsegram. *J. Maharashtra Agric. Univ.* **23**(3): 268- 271.

Lakshmi, P.V. and Goud, J.V. 1977. Variability in cowpea. (*Vigna sinensis* (L.). *Mysore J. Agric. Sci.* **11**: 144-147.

Lal, S., Singh, M. and Pathak, M.M. 1975. Combining ability in cowpea. *Indian J. Genet.* **35**(3): 375-378.

Lal, S. and Waldia, R.S. 1980. Combining ability in urdbean. *Indian J.Genet.* **40**(1): 295-299.

Lee, J. and Kaltsikes, P.J., 1973. The application of Mahalanobis's generalized distance to measure genetic divergence in durum wheat. *Euphytica.* **22**: 124-131.

Lush, J.L. 1940. Intra-sire correlation and regression of offspring on dams as a method of estimating heritability of characters. *Proc. Amer. Soc. Animal Production.* **33**: 293-301.

Luthra, O.P., Arora, N.D. Singh, R.K. and Choudhary, B.D. 1974. Genetic analysis for metric traits in mung bean. (*Vigna radiata*(L)Wilczek). *Haryana. Agric. Univ. J. Res.* 7: 200-205.

Mahalanobis, P.C. 1936. On the generalised distance in statistics. *Proc. Nat. Acad. Sci. (India)*. **12**: 49-55.

Mahalingam, G. 1991. Genetic variability analysis in greengram (Vigna radiata (L.) Wilczek). M.Sc.(Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore.

Mak, C. and Yap, T.C. 1980. Inheritance of seed protein content and other agronomic characters in longbean (*Vigna sesquipedalis* L.). *Theoretical and Applied Genet.* **56**(5): 233-236.

Malhotra, R.S. 1973. Genetic variability and discriminant function in soyabean (*Glycine max* (L.) Merr.). *Madras Agric. J.* **60**: 225-228.

Malhotra, R.S. 1983. Combining ability in urdbean. *Indian J. Genet.* **43**(3): 324-327.

Malhotra, R.S., and Singh, K.B. 1971. Multivariate analysis in blackgram (*Phaseolus mungo* Roxb.). *Indian J. Agric. Sci.* **41**(99): 757 – 760.

Malhotra, V.V., Sukhdev Singh and Singh, K.B. 1974. Relation between geographic diversity and genetic diversity and the relative role of each character towards maximizing divergence in greengram. *Indian J. Agric. Sci.* **44**(12): 811-815.

Malik, B.P.S., Singh,V. P. and Singh, M. 1983. Correlation, correlated response and relative selection efficiency in greengram. *Indian J. Agric. Res.* **53**: 101-105.

Manivannan, N. and Nadarajan, N. 1996. Character association and component analysis in greengram. *Madras Agric. J.* **83**(12): 784-786.

Mehndiratta, P.D. and Singh, K.H. 1971. Genetic diversity in respect of grain yield and its components in cowpea germplasm from Punjab. *Indian J. Genet.* **31**: 388-392.

Mishra, S.N., Varma, J.S. and Rastogi, R. 1987. Combining ability for flowering and seed yield in cowpea. *Ann. Agric. Res.* **8**: 268-272.

Mishra, A.K. and Yadav, R.K. 1992. Path analysis of component factors influencing economic yield , harvest index and biological yield of mung bean. *Adv. Pl. Sci.* **5**(2): 578-584.

Mishra, A.K., Yadav, L.N. and Reghu, J.S. 1995. Variability of metric traits and character association in (*Vigna radiata). Agric. Sci. Digest* (Karnal).**15**: 518-537.

Murthy, B.K., Patel, G.J. and Jaisani, B.G. 1976. Gene action and heritability estimates of some quantitative traits in mung. *Gujarat Res. J.* **2**: 1-4.

Muthiah, A.R. and Sivasubramanian, V. 1981. Genotypic correlations and path coefficient analysis in blackgram. *Vigna mungo* (L.) Hepper. *Madras Agric. J.* **68** (2): 105-109.

Murty, R.B., Mathur, J. B. L. and Arunachalam, V. 1965. Self incompatability and genetic divergence in *Brsssica campestris* var. Brown Sarson. *Sankhya* (Series B.) **27**: 271-273.

Nagaraja, N., Manjunath, A. and Gopalkrishna Rao, M. 1997. Genetic variability studies in horsegram (*Macrotyloma uniflorum* (Lam.) Verdec.). *Mysore J. Agric. Sci.* **31**: 326-330.

Naidu, N.V. 1993. Inter-relationships between yield and yield components in greengram (*Vigna radiata*(L)Wilczek). *Ann.Pl.Physiol.* **7**(1): 119-122.

Naidu, N.V. and Rosaiah, G. 1993. Association analysis in segregating and non-segregating populations of mungbean (*Vigna radiata*(L)Wilczek). *Ann. Agric. Res.* **14**(1): 25-29.

Naidu, N.V. and Satyanarayana, A. 1993. Heterosis for yield and its components in mungbean (*Vigna radiata*(L)Wilczek). *Indian J. Pulses Res.* **6**(1): 102-105.

Naidu, N.V., Satyanarayana, A. and Rajeswari, V.R. 1994. Path analysis of yield and yield attributes in different environments in mungbean (*Vigna radiata*(L) Wilczek). Ind. J. *Agric. Res.* **28**(1): 74-78.

Nainar Mohammed. 1991. Genetic analysis in blackgram (*Vigna mungo*(L.) Hepper. M.Sc.(Ag.) Thesis. Tamil Nadu Agricultural University. Coimbatore.

Narayanan, A. and Balasubramanian, M. 1991. Survey on status of horsegram in Tamil Nadu. Regional Research Station, (Tamil Nadu Agricultural University), Paiyur.

Natarajan, C., Thiyagarajan, K. and Rathnaswamy, R. 1988. Association and genetic diversity studies in mung bean (*Vigna radiata*(L)Wilczek). *Madras Agric. J.* **75**: 238-245.

Ogunbodede, B.A. 1986. Quantitative studies of some cowpea traits. *E. African Agri. For. J.* **50**: 89-100.

Pandita, M.L., Vashitha, R.N. and Bhutani, R.D. 1982. Genetic variability studies in cowpea. *Haryana Agric. Univ. J. of Res.* **12:** 241-245.

Panse, V.G. and Sukhatme, P.V. 1961. *Statistical methods for agricultural workers*. 2nd Edn. I.C.A.R., New Delhi. p.381.

Panwar, K.S., Kapila, R.K. and Mittal, R.K. 1995. Variability and character associations in mung bean. *Indian J. Pulses Res.* **8**(1): 78-79.

Paramasivan, J. 1979. Analysis of variability, genetic diversity and correlation in greengram (*Vigna radiata* (L.) wilczek). M.Sc. (Ag.) thesis. Tamil Nadu Agricultural University, Coimbatore.

Patel, A.B. and Shete, M.M. 1987. Heterosis in crosses of seven genotypes of cowpea.. *J. Maharashtra Agric. Univ.* **12:** 51- 54.

Patel, B.C. 1990. Heterosis and combining ability in cowpea. *Thesis Abstract, H.A.U., Hisar*. **16**(1): pp.50.

Patel, D.P., Dabas, B.S. Sapra, R.L. and Mandal, S. 1995. Evaluation of horsegram (*Macrotyloma uniflorum* Lam.) germplasm. N.B.P.G.R., New Delhi. 1-5.

Patel, S.T. and Shah, R.M. 1982. Genetic parameters, associations and path analysis in blackgram (*Vigna mungo* (L.) Hepper). *Madras Agric. J.* **69**(8): 535-539.

Patil, H.S. and Deshmukh, R.K. 1988. Correlation and path coefficient analysis in mungbean. *J. Maharashtra Agric. Univ.* **13**(2): 183- 185.

Patil, H.S. and Narkhede, B.N. 1987. Variability, associations and path analysis in blackgram. *J. Maharashtra Agric. Univ.* **12**(3): 289- 292.

Patil, H.S. and Narkhede, B.N. 1989. Association and path analysis of yield attributes in mungbean. *J. Maharashtra Agric. Univ.* **14** (2): 240-241.

Patil, H.S. and Shinde, Y.M. 1995. Genetic variability in greengram. *Madras Agric. J.* **82** : 490-491.

Patil, J.V. and Deshmukh, R.B. 1982. Genetic variability in horsegram. *J. Maharashtra Agric. Univ.* 7(2): 139-140.

Patil, R.B. and Bhapkar, D.G. 1986. Combining ability in cowpea. *J. Maharashtra Agric. Univ.* **11**: 303-306.

Patil, S.B. and Patil, R.B., 1987. Genetics of some quantitative traits in cowpea. *Current Res. Reporter*, Mahatma Phule Agric Univ. **3**: 5-10.

Phundan Singh and Srivastava, A.N. 1982. Combining ability for yield components in blackgram. *Science and Culture*. **48**(5): 185-186.

Prabhakar, G. 1995. Biometrical studies in blackgram (*Vigna mungo*(L)Hepper) through diallel analysis. M.Sc.(Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore .

Prem Narain, Bhatia, V.K. and Malhotra, P.K. 1979. *Handbook of Statistical Genetics*. Indian Agricultural Statistical Research Institute (I.C.A.R.), New Delhi. 252-253.

Pundir, S.R., Gupta, K.R. and Singh, V.P. 1992. Studies on correlation co-efficients and path co-efficient analysis in mung bean (*Vigna radiata*(L)Wilczek). *Haryana Agric. Univ. J. Res.* **22**(4): 256-258.

Premsagar and Chandra,S. 1977. Heterosis and combining ability in urd bean. Indian J. Genet. 37(3): 420-424.

Ramakrishnan, A., Marappan, P.V., and Sivasamy, N. 1979. Genetic divergence in horsegram. *Indian J. Agric. Sci.* **49**: 719-723.

Ramakrishnan, A., Muthukrishnan, P, Ranganathan, C.R. and Sivasamy, N. 1978. Genetic variability in horsegram (*Dolichos biflorus* L.). *Madras Agric. J.* **65** (5): 281-283.

Rang, A., Sandhu, T.S. and Bhullar, B.S. 1980. Variability and correlation studies on yield components and protein content and their implication in selection in cowpea. *J. Res. Punjab Agric. Univ.* **17**: 345-349.

Ranganayaki, K. and Sreerangasamy, S.R. 1993. Path co-efficient analysis in greengram. *Madras Agric.* J. **2**: 7-12 .

Rangareddy, S and Krishnaiah, V.V. 1977. Study of yield components and their inter-relationship in greengram. *Andhra Agric. J.* **24** (3): 69-73.

Rasupandi, M. 1979. Biometrical studies in blackgram (*Vigna mungo*). M.Sc.(Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore.

Rao, C.R. 1952. *Advanced statistical methods in biometrical research.* 1st Edn. John Wiley and Sons, New York. pp. 39.

Rao, C.R. 1960. Multivariate analysis – an indispensable statistical aid in applied research. *Sankhya.* **22**: 317-318.

Rao, S.S. and Nanda, H.C. 1994. Genetic variability and correlation studies for grain yield and its components in horsegram. *Indian J. Pulses Res.* **7** (1): 59-61.

Rathinaswamy, R., Krishnaswamy, S., Iyyamperumal, S. and Marappan, P.V. 1978. Estimates of correlation co-efficient and Path co-efficient analysis in greengram (*Vigna radiata*(L)Wilczek). *Madras Agric.* J. **65**: 188-190.

Reddy, C.R. Sekhar, M.R. and Reddy, K.R. 1994. Character association and Path co-efficient analysis in greengram. (*Vigna radiata*(L)Wilczek). *Ann. Agric. Res.* **15**(4): 423-427.

Reddy, P.R. and Sreeramulu, C. 1982. Heterosis and combining ability for yield and its components in greengram (*Vigna radiata* L.). Genetica Agraria. **36**(3-4): 297-307.

Sagar, P., Chandra, S. and Arora, N.D. 1976. Analysis of diversity in some urd bean (*Phaseolus mungo* L.) cultivars. *Indian J. Agric. Res.* **10** (2): 73-78.

Samal, K.M. and Senapati, N. 1997. Genetic variability performance correlation and coheritability of horsegram (*Macrotyloma uniflorum* Lam. Verd.) mutant lines. *Legume Research.* **20**(314): 207-211.

Savithramma, D.L., Nagaraja, T.E., Viswanatha, K.P. and Sambulingappa, K.G. 1996. Studies on genetic variability in horsegram. *Indian J. Pulses Res.* **9**(2): 127-131.

Sekhar, R.M., Reddy K.R. and Reddy C.R. 1994 Heterosis for yield and yield components in greengram (*Vigna radiata*(L)Wilczek). *Indian. J. Gen. Res.* **15**(4): 423-427.

Selvaraj, U. 1984. Stability and combining ability analysis in diallel crosses of cowpea. (*Vigna unguiculata* (L) Walp.). Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore.

Selvaraj, U. and Annappan, R.S. 1983. A study of heterosis in cowpea (*Vigna unguiculata* (L.) Walp.). *Pre-congress Scientific Meeting on Genetics and Improvement of Heterosis System*, Tamil Nadu Agricultural University, Coimbatore.

Sen, N.K. and Bhowal, J.G. 1959. Genetic studies in horsegram. *Indian J. Gen. & Pl. Br.* **19**(2): 228-233.

Sen, N.K. and Bhowal, J.G. 1960. Cyto-taxonomic studies on *Vigna*. *Cytologia*. 25: 195-207.

Sen, N.K. and Ghosh, A.K. 1959. Genetic studies in greengram. *Indian J. Genet. Pl. Breed.* **19**(2): 210-227.

Sen, N.K. and Jana, M.K. 1963. Genetics of blackgram (*Phaseolus mungo* L.). *Genetica*. **34**: 46-57.

Sharma, P., Lal, S., Singh, I.B. and Katiyar, R.P. 1987. Genetics of seed weight in blackgram. *Farm Sci. J.* **2**(1): 22-28.

Sharma, D.J. and Yadav, R.K. 1993. Heterosis and inbreeding depression in mungbean. *Indian J. Pulses Research*. **6**(2): 191-193.

Shivashankar, G., Jalikot, S.H., Chikkadeviah and Shettar, B.I. 1977. Heritability and correlation studies in horsegram. (*Macrotyloma uniflorum.* syn. *Dolichos biflorus*) *Mysore J. Agric. Sci.* **11**: 211-214.

Singh, B.D. 1983. *Plant Breeding – Principles and methods*. Kalyani publishers, New Delhi. 78-80.

Singh, D.N. 1990. Genetic variability, correlation and path analysis for grain yield and its components in horsegram. *Indian J. Pulses Res.*, **3**(1): 25-30 .

Singh, I.B., Singh, H.G., Singh, U. and Singh, P. 1987. Combining ability for yield and its components in blackgram. *Indian J. Genetic.* **47**(1): 99-103.

Singh, K.B., Bullar,G.S., Malhotra, R.S. and Singh, J.K. 1972. Estimates of genetic variability, correlation and path coefficient in urd and their importance in selection. *J. Res. PAU.* **9**: 410-414.

Singh, K.B. and Jain,R.P. 1972. Heterosis and combining ability in cowpea. *Indian J. Genet.* **32**: 62-66.

Singh, K.B. and Malhotra, R.S. 1970. Estimation of genetic and environmental variability in mung (*Phaseolus aureus* Roxb.). *Madras Agric. J.* **57**(3):155-159.

Singh, K.B. and Mehndiratta, P.D. 1969. Genetic variability and correlation studies in cowpea. *Indian J. Genet.* **29**: 104-109.

Singh, K.B. and Mehndiratta, P.D. 1970. Path analysis and selection indices in cowpea. *Indian J. Genet.* **30**: 471-475.

Singh, P. and Narayanan, S.S. 1993. *Biometrical techniques in plant breeding.* Kalyani publishers, Ludhiana. 31-160.

Singh, R. and Dabas, B.S. 1986. Inheritance of yield and its components in cowpea. (*Vigna unguiculata* (L) Walp.). *Intern. J. Trop. Agric.*, **4**: 85-87.

Singh, R., Singh, S. and Paroda, R.S. 1985. Line x Tester analysis in cowpea. *Forage Res.* **11**: 101-106.

Singh, R.B. and Gupta, M.P. 1968. Multivariate analysis of divergence in upland cotton (*Gossypium hirsutum* L.). *Indian J. Genet.*, **28**: 151-157.

Singh, R.K. and Chaudhary, B.D. 1977. *Biometrical methods in quantitative genetic analysis*. Kalyani Publishers, New Delhi.

Singh, R.P. 1982. Heterosis in cowpea. *Madras Agric. J.* **70**: 15-18.

Singh, R.P., Singh, H.L., Singh, U. and Singh, I.P. 1977. Path analysis in greengram. *Madras Agric. J.* **64** (9): 596-597.

Singh, R.P. and Pathak, M.M. 1993. Correlation studies in mung bean. *Indian J. Pul. Res.* **6**(1): 35-37.

Singh, T.P. and Singh, K.B. 1973. Association of grain yield and its components in segregating populations of greengram. *Indian J. Genet.* **33**: 112-117.

Singh, U.P., Singh, U. and Singh, P. 1975. Estimates of genetic variability, heritability and correlation for yield and its components in urd (*Phaseolus mungo* L.) *Madras Agric. J.* **62** (2): 71-72.

Smith, H. M. 1939. A descriminant function for plant selection. *Ann. Eugen.* **7**: 240-250.

Snedecor,G.W. 1961. *Statistical methods*. The Iowa State University Press, Ames., Iowa, USA. P.388.

Sokal, R.R. 1965. Statistical analysis in systematics. *Biol. Rev.* **40**: 337-391.

Sood, B.C., Gartan, S.L. and Kalia, N.R. 1994. Variability correlation and path studies in horsegram. *Indian J. Pulses Res.* **7** (1): 68-69.

Soundarapandian, G., Nagarajan, R., Mahudeswaran, K. and Marappan, P.V. 1975. Genotypic and phenotypic correlations and path analysis in blackgram.(*Vigna mungo)* (L.). *Madras Agric. J.* **63** (3): 141-147.

Sreekantaradhya, R., Shettar, B.I., Chandrappa, H.M. and Shivashankar, G. 1975. Genetic variability in horsegram. *Mysore J. Agric. Sci.* **9** (3) : 361-363.

Sreekumar, S.G. and Abraham, A.T. 1978. Heterosis in greengram. *Agric. Res. J. Kerala.* **16**(2): 142-147.

Srikanthan, N. 1976. Biometrical evaluation of the quantitative attributes in three duration groups of green gram (*Vigna radiata* (L) Wilczek) M. Sc.(Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore.

Stiles, W. 1969. *An introduction to the principles of plant physiology.* Methuen and Co. Ltd., London. 416-421.

Subhash Jain, Lodhi, G.P. and Boora, K.S. 1981. Combining ability analysis for forage characters in cowpea. *Forage Res.* 7: 131-137.

Sulaiman, M.S. 1976. Studies on variability, correlation and path coefficient analysis in greengram (*Vigna radiata* (L.). M.Sc.(Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore.

Sundararaj, D. and Thulasidas, G. 1976. *Botany of field crops*. Pub. S.G. Masani, Macmillan Co., India Ltd., Delhi. 145-156.

Suraiya, D., Mercy, S.T., Chandramony, D and Nayar, N.K. 1988. Genetic variability of yield and its components in horsegram (*Macrotyloma uniflorum*) *Ind. J. Agric. Sci.* **58**(10): 798-799.

Swapna, M. 1993. Germplasm evaluation in horsegram (*Dolichos biflorus* L.). M.Sc.(Ag.) Thesis. Kerala Agricultural University, Vellanikara.

Tandon, J.P., Joshi, A.B. and Jain, K.B.L. 1970. Comparison of graphic and combining ability analysis of diallel crosses of wheat. *Indian J. Genet.* **30**: 91-105.

Tewari, A.K., Gaurtam, N.C., Singh, R.D. and Shukla, A.K. 1988. Genetic variability and correlation in cowpea. (*Vigna unguiculata* (L) Walp.). *Narendra Deva J. of Agri. Res.* **4**: 183-187.

Thimmappa, A.S. 1987. Genetic analysis of quantitative traits in greengram (*Vigna radiata* (L) Wilczek). *Mysore J. Agric Sci.* **21**(4): 94-95.

Thiyagarajan, K. and Rajasekharan, S. 1989. Studies on character association and path co-efficient analysis in cowpea. *Madras Agric. J.* **76:** 10-14.

Thiyagarajan, K., Natarajan,C. and Rathinasamy, R. 1990. Combining ability and inheritance studies in cowpea (*Vigna unguiculata* (L. Walp.). *Madras Agric. J.* **77:** 305-309.

Tikka, S.B.S., Sharma, R.K. and Mather. 1976. Genetic analysis of flower initiation in cowpea. (*Vigna unguiculata* (L. Walp.). *Indian J. Agric. Sci.* **47:** 23-29.

Tomar, G.S., Aswa, B.M. and Tiwari, A.S. 1977. Path coefficient anlysis of growth and yield components in greengram. *JNKVV. Res. J.* **6**: 61-63.

Trehan, K.B., Bagrecha, L.R. and Srivastava, V.K. 1970. Genetic variability and correlation in cowpea (*Vigna sinensis* (L) Savi.) under rainfed conditions. *Indian J. Herd.* **2:** 30-34.

Usharani, Y., Sakharao, J. 1981. Path analysis of yield components in blackgram. *Indian J. Agric. Sci.* **51**(6): 378-381.

Vaid, I.K. and Singh, K.B. 1983. Genetic variability in F3 and F4 populations of a cross in cowpea (*Vigna sinensis* (L.) Savi.). *Madras Agric. J.* **70**: 281-283.

Vavilov, N.I., 1951. The origin, variation, immunity and breeding of cultivated plants. *Selected writings of Vavilov.* The Ronald Press Co., New York. 26-27.

Veeraswamy, R., Rathnaswamy, R. and Palaniswamy, G.A. 1973 a. Genetic variability in some quantitative characters of *Phaseolus aureus* (Roxb.). *Madras Agric. J.* **60** (9 - 12): 1320-1322.

Veeraswamy, R., Palaniswamy, G.A. and Rathnaswamy, R. 1973 b. Yield attributes and heritability in some varieties of *Phaseolus mungo* (L.). *Madras Agric. J.* **60** (9-12): 1834-1835.

Veeraswamy, R., Palaniswamy, G.A. and Rathnaswamy, R. 1973 c. Genetic variability in some quantitative characters of *Vigna sinensis* (L.) Savi. *Madras Agric. J.*, **60** (9-12): 1359-1360.

Veerabbadhiran, P. and Jehangir, K.S. 1995. Genetic variability, correlation and path analysis in green gam. *Madras Agric. J.* **82**: 365-367.

Verma, S.N.P. and Dubey, C.S. 1970. Correlation studies in blackgram (*Phaseolus mungo* L.). *Allahabad Farmer*. **44**: 417-419.

Vijayakumar, G. 1989. Study of heterosis and combining ability for yield and ield components in cowpea (*Vigna unquiculata* (L.) Walp.). M.Sc. (Ag.) Thesis, TNAU, Coimbatore.

Waldia, R.S. and Dahiya, B.S. 1982. Genetic components and combining ability effects in urdbean (*Vigna mungo* (L) Hepper). *Haryana Agric. Univ. J. Res.* **12**(3): 471-474.

Wani, S.A., Zargar, G.H. and Ahanger, H.O. 1992. Path co-efficient analysis in mung bean (*Vigna radiata*(L)Wilczek). *Adv. in Pl. Sci.* **5**(2): 554-558.

West Phal. 1974. *Pulses in Ethiopia, their taxonomy and agricultural significance.* Centre for agricultural publishing and documentation. Wangeningen.

Wright, S. 1934. The method of Path coefficient analysis. *Ann. Math. Statistics*. **5**: 161-215.

Wynne, J.C. Emery, D.A. and Rice, P.W. 1970. Combining ability estimates in *Arachis hypogaea* L. II. Field performance of F_1 hybrids. *Crop. Sci.* **10**: 713-715.

Yap, T.C. and Mak, C. 1982. Genetic studies and breeding of long beans. Malaysian Applied Biology. **6:** 155-162.

Yellappa, S.G. 1983. Agronomic investigations on varietal, spacing and manurial aspects of horsegram (Macrotyloma uniflorum(Linn.) Verde.). M.Sc.(Ag.) Thesis, U.A.S., Bangalore.

Zaveri, P.P., Patel, P.K. and Yadavendra, J.P. 1980. Diallel analysis of flowering and maturity in cowpea. *Indian J. Agric. Sci.* **50:** 807-810.

Zaveri, P.P., Patel, P.K., Yadavendra, J.P. and Shah, R.M. 1983. Heterosis and combining ability in cowpea. *Indian J. Agric. Sci.* **53** 793-796.

Zohary, O., Hopf, M. 1973. Domestication of pulses in the old world. *Science.* (New York.). **182**: 887-894.

GENETIC ANALYSIS IN HORSEGRAM (*Dolichos biflorus* Linn.) WITH SPECIAL REFERENCE TO PHOTOPERIODIC RESPONSE

By

SREENIVASAN, E.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding and Genetics
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2001

ABSTRACT

A study was undertaken in the Department of Plant Breeding & Genetics of College of Horticulture, Vellanikkara, during 1993-2000 entitled "Genetic analysis in horsegram (*Dolichos biflorus* Lin.) with special reference to photoperiodic response" The main objectives were to identify stable, high-yielding, day-neutral horsegram genotypes suitable for year-round cultivation and to understand the nature of gene action involved in the inheritance of photoperiodic response in the crop.

The material consisted of 115 horsegram genotypes. Evaluation of the genotypes during rabi (traditional)indicated that enough variability exists among the genotypes with respect to seed yield and yield attributes. Studies on correlation and cause-effect relations among seed yield and yield attributes revealed that pod yield, harvest index and haulms yield were the traits having maximum positive association and positive direct effect on seed yield. Duration to flowering or maturity did not have significant correlation with seed yield. Hence it is possible to have varieties that combine high yield and early maturity. Based on genetic diversity, the 115 genotypes were grouped into ten clusters, using Mahalanobis D^2 statistics. It was found that genetic diversity existing among genotypes is not associated with their geographical origin. A selection index constructed based on seed yield, pod yield and harvest index was found to give 79.47 per cent gain in efficiency over selection based on yield alone.

Genotypes selected on the basis of the preliminary evaluation were further tested over two seasons (rabi and summer) for three years (1997,1998 and 1999) in a comparative yield trial, to select best genotypes suitable for each seasons. The study revealed that the day-neutral genotype AK-42, is ideal for year-round cultivation. However, for cultivation during rabi, the photosensitive variety PHG-9 was found to

be better. In general, performance of genotypes was better during rabi than in summer.

Hybridisation studies between day-neutral and photosensitive types, also was taken up in order to assess the combining ability and gene action involved and for estimation of heterosis. The diallel analysis revealed that the parents AK-42 and AK-26 (both day-neutral types) had maximum positive general combining ability for seed yield. Highest specific combining ability for the trait was observed for the cross PHML-64 x AK-42. Relative heterosis also was observed to maximum for the same cross. Higher gca expressed by traits like days to flowering, seeds per pod and pod length indicated that these traits are controlled by additive gene action. Higher sca was observed for plant height, hundred seed weight, seed yield and pod yield, indicating that non-additive gene action play a major role in expression of these traits.

The results of F2 evaluation revealed that photoperiodic response in horsegram is probably a qualitative trait, controlled by at least two genes, either in complimentary gene action or inhibitory gene action. In the case of inheritance of seed colour, the black seed colour was observed to be dominant over brown. Two genes in polymeric gene action, were found to control seed colour.