GENETIC ANALYSIS OF PRODUCTIVITY PARAMETERS IN HORSEGRAM

BY

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THESIS

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Dedicated to my beloved Grandmother

DECLARATION

I hereby declare that this thesis entitled "Genetic analysis of productivity parameters in horsegram" 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 University or Society.

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Certified that this thesis entitled "Genetic analysis of productivity parameters in horsegram" is a record of research work done independently by Kumari ELIZABETH MATHEW, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

The grain legumes commonly known as pulses form an important and ancient component of Indian agricultural system. They are generally grown under rainfed and low input conditions. According to Aykroyd and Doughty (1964) a balanced diet should contain three ounces of pulses per day per adult to meet the protein requirement. India grows a variety of pulse crops but the unfortunate situation is that with the large acreage of about 22 to 24 million hectares, the production is only 9 to 12 million tonnes. The area and production of pulses in Kerala are only 25.7 thousand hectares and 18.6 thousand tonnes respectively (Anonymous, 1990). Day by day the demand for protein (pulses) is increasing and this emphasizes the necessity for increasing the production of pulses.

Horsegram (Macrotyloma uniflorum L. Verdic. Syn. Dolichos biflorus L.) occupies an area of 1200 ha. in Kerala (Directorate of Agriculture). It is considered to be the poor man's pulse crop in Southern India. Owing to an appreciable amount of hardiness and adaptability it stands out as an exception from other pulse crops. It fares well over a wide range of soils in the uplands during rabi and is capable of withstanding prolonged drought. It is an excellent source of protein (24%) and starch (57.3%). Horsegram is an inexpensive source of protein, fodder and manure. Only little attention has been given to its improvement by research workers.

Genetic variability is necessary in any crop improvement programme and information on its extent is therefore basic. The prime aim of breeding is for evolving high yielding varieties and the main job of the breeder is to identify the superior and the more desirable type in a community exhibiting variability. So selection for yield is the chief consideration in any crop breeding programme. However, yield itself is a very complex character depending upon numerous genetic factors interacting with environment. So any direct method of selection based only on yield becomes a difficult proposition due to its inter-relationships with the yield attributes. Efficiency of selection under such circumstances can be improved by determining the association existing between yield and other plant characters which would serve as simple guides for spotting out high yielders.

The present work was undertaken with the prime objective of identifying through biometrical tests the important yield components that would help in the selection of superior horsegram genotypes for yield and adaptability.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Variability, heritability, genetic advance, correlations and path analysis are the main parameters which help the selection of superior genotypes from genetically diverse population. A brief review of the work done on those aspects in relation to yield and its components in horsegram and other pulse crops relevant to the present study are summarized below:

I. Variability

Plant breeding in the true sense related to the efficient management and utilization of variability. Genetic variability in a crop forms the primary prerequisite for achieving genetic improvement. The most important genetic parameter which provides an efficient estimation of variability is the coefficient of variation.

Many workers studied the extent of variability in pulse crops by working out genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). But the extent of genetic variability is more important than the total variation since greater the genetic diversity, wider would be the scope for selection. Their findings are briefly reviewed below:

Joshi (1971) reported a wide range of phenotypic variability in yield and some yield contributing characters viz. number of pods, number of seeds, number of branches and 100 seed weight in Dolichos lablab var. lignosus.

Srivastava and Sachan (1974) studied 35 varieties of pea obtained from different parts of the country. Pods per plant showed the maximum and shelling percentage showed the minimum genotypic coefficient of variability.

Hira Chand et al. (1975) reported the highest gcv for seeds per plant and the lowest for seeds per pod in chickpea.

Singh and Singh (1975) reported high gcv values for primary branches, test weight and pods per cluster in lentil.

In horsegram, Aggarwal and Kang (1976) reported that the coefficient of genetic variation was the lowest (0.68) for days to maturity and highest (33.82) for yield per plant.

Ram et al. (1976) obtained the value of gcv for the characters grain yield and harvest index as 53.47 and 42.42 respectively in a study conducted with 18 genetically diverse strains of pigeonpea.

Shivashankar et al. (1977) observed that high genetic coefficient of variation was exhibited by number of secondary branches (79.27), whereas it was moderate for number of nodes per plant, primary branches, length of primary branches, 100-seed weight, days to 50 per cent flowering, yield and pods per plant in horsegram. It was found to be low for plant height (8.66) and seeds per pod (4.71).

According to Ramakrishnan *et al.* (1978) the coefficient of genotypic variations were the lowest (6.14) for pod length and highest (102.1) for plant height in horsegram.

In greengram, Rathnaswamy *et al.* (1978) reported high estimates of gcv for 100 seed weight followed by pods per plant.

Arunachala (1979) observed high genetic coefficient of variation for yield per plant, pod number and plant height in field bean.

Ganeshaiah (1980) reported that in general the variability was more in the characters associated with post flowering period in horsegram. The highest genotypic and phenotypic variability was observed for the character number of secondary branches.

In pigeonpea, Godawat (1980) reported high values for gcv for the characters grain yield per plant and number of primary branches per plant.

Medhi *et al.* (1980) stated that significant variation was observed for all the yield components studied except days to flowering and days to maturity in 12 selections of *Vigna radiata*.

Pandita *et al.* (1980) found that the coefficient of genetic variation was the lowest (11.44) for days to flowering and highest (44.88 and 42.78) for number of flowers and yield respectively in field bean.

Suraiya (1980) obtained the highest genotypic and phenotypic variances for duration, plant height and days to 50 per cent flowering in a study conducted with 15 genotypes of horsegram. Days to 50 per cent flowering showed the highest and 100-seed weight showed the lowest genotypic and phenotypic coefficients of variation also.

Bainiwal *et al.* (1981) observed maximum variability for secondary branches followed by primary branches and seed yield in 29 genotypes of pigeonpea.

Kumar *et al.* (1981) found that in chickpea coefficients of variations were high for biological yield, grain yield per plant and the number of pods per plant and low for days to flowering, height, pod length and breadth and number of seeds per pod.

Ganeshiah *et al.* (1982) obtained the lowest values for gcv and pcv for seeds per pod, days to maturity, threshing percentage, 100-seed weight, days to flower and number of pods per plant in horsegram.

Kumar and Reddy (1982) reported that in pigeonpea seeds per pod exhibited low value for coefficient of variation.

Patel and Shah (1982) found that pod length and plant height showed high values of gcv in 20 strains of blackgram.

Radhakrishnan and Jebaraj (1982) observed high genotypic coefficient of variation for number of pods per plant in a study with 16 varieties of cowpea.

Rashid and Islam (1982) obtained high gcv for branches per plant, plant height, pods per plant and yield per plant in 15 varieties of soyabean.

In chickpea Mandal and Bahl (1983) reported that biological yield showed the highest phenotypic and genotypic coefficients of variability and low for harvest index.

Shoram (1983) evaluated 100 genotypes of *Cajanus cajan* in 5 environments over 2 years. High estimates of gcv were obtained for pods per plant, days to maturity, plant height and days to flowering in all environments.

Variability studies undertaken on forty genotypes of cowpea by Dharmalingam and Kadambavanasundaram (1984) had shown that there existed greater variability for the traits harvest index, number of pods and seed yield. The least contribution to genetic variability was by number of seeds per pod.

Liu *et al*. (1984) recorded high genetic coefficients of variation for seed weight per plant and pod number per plant in greengram.

Primary and secondary branch number, pod number per plant, 100-seed weight and yield per plot gave high estimates of pcv and gcv in a study of eight traits in 29 genotypes of pigeonpea (Balyan and Sudhakar, 1985).

Rao and Sharma (1985) reported that in 28 genotypes of soyabean substantial genetic variability was observed for days to 50 per cent flowering, pod yield per plant, number of seeds per plant and 100-seed weight.

Singh (1985) reported high degree of genetic variability for grain yield, plant height, number of pods per plant and number of branches per plant in pea.

Genotypic and phenotypic variability studies were conducted by Gupta *et al*. (1986) in nine parents and their 36 f_1's in peas. The maximum genetic coefficient of variation was observed in case of 100-seed weight followed by branches per plant, pods per plant, seed yield per plant and length of fruiting zone.

In horsegram Birari *et al.* (1987) reported a maximum genotypic coefficient of variation in case of number of seeds per pod (26.96) followed by that for seed yield per hectare (20.37). Low gcv was obtained for the character number of days to first pod maturity.

Geetha Philip (1987) studied fifty varieties of blackgram under partial shade. The highest genotypic coefficient of variation was observed for Cercospora leaf spot disease rating (46.69) and the lowest for days to pod harvest initiation (3.52).

Twenty one diverse varieties of gram were analysed by Maloo and Sharma (1987). The estimates of genotypic coefficient of variation ranged from 1.58 for days to maturity to 40.26 for grain yield per plant.

Patil and Baviskar (1987) recorded the highest estimates of gcv and pcv for pod clusters per plant, pods per plant, seed yield per plant and 100-seed weight in cowpea.

Sudha Rani (1989) obtained the lowest estimate of gcv for the character days to flowering (2.05) in a study with twenty genotypes of blackgram. The value of gcv for root/shoot ratio was 21.22.

II. Correlation studies

Correlation studies provide estimates of the degree of association of a character with its components and also among the components. In a programme of breeding for improving the yield potential of a crop, information of the interrelationship of yield with other traits is of immense value. This will facilitate selection of high yielding plants through other related components.

Correlation studies conducted by various workers in different pulses are reviewed below:

A. Association between yield and its components

Singh and Dixit (1970) found that yield was phenotypically associated with number of primary branches and secondary branches. Yield was found to be genotypically associated with the number of primary branches, number of secondary branches and negatively associated with number of seeds per pod in lentil.

In field bean Joshi (1971) found strong and positive association of yield with number of pods, number of seeds and number of branches per plant.

Joshi (1973) reported significant and positive correlation of seed yield with the number of pods and number of branches in pigeonpea. The number of seeds per pod was apparently negatively associated with the seed yield.

Singh and Malhotra (1973) observed significant and positive association of yield with pods per plant and secondary branches in pigeonpea.

Veeraswamy et al. (1973) reported that in pigeonpea grain yield was positively and significantly related to number of pods, number of branches per plant, plant height and days to flower.

Singh et al. (1975) observed that in blackgram primary yield components viz. primary branches, plant height and test weight showed a positive and significant association with yield both at genotypic as well as phenotypic levels.

In horsegram Aggarwal and Kang (1976) observed significant positive correlation of grain yield with pods per plant, seed size (100-grain weight), pod length, number of branches and plant height. Days to flowering and days to maturity showed a significant negative correlation with yield.

Ram et al. (1976) reported that grain yield had positive and significant genotypic association with number of primary branches and harvest index in pigeonpea.

In soyabean Srivastava et al. (1976) found that seed yield exhibited positive and highly significant genotypic association with days to flower and seeds per pod.

Days to maturity, plant height and pods per plant did not show association with seed yield.

Gautam and Singh (1977) recorded that in soyabean yield was positively correlated phenotypically and genotypically with days to maturity, days to flowering, height, number of branches and pods per plant.

In pea Malik and Hafeez (1977) found that seed yield per plant was correlated with mean number of pods per plant and mean number of seeds per plant.

Shivashankar et al. (1977) reported positive correlation of yield with height of the plant, number of pods per plant, number of seeds per pod and number of nodes per plant in horsegram.

Correlation studies of six characters in lentil revealed positive association of harvest index with grain yield. Pod number, plant height and primary and secondary branches showed positive correlation with grain yield. But 100-seed weight was negatively correlated (Singh, 1977).

In Lathyrus Singh et al. (1977) reported that grain yield per plant showed highly significant association with days to maturity and plant height. There was absence of association of grain yield per plant with days to flower, 100-grain weight and number of primary branches per plant.

In pea seed yield was positively correlated with number of pods per peduncle, pod length and seed size (Tikka and Assawa, 1977).

Tikka et al. (1977) found that number of pods per plant was positively correlated with yield in moth bean.

Das (1978) reported that in blackgram number of branches per plant and number of pods per plant were positively correlated with seed yield per plant.

Narsinghani et al. (1978) reported positive association of seed yield per plant with the number of days to flowering, maturity period, height, number of branches, number of pods per plant and number of seeds per plant in pea.

In chickpea Raju et al. (1978) obtained positive genotypic correlations between seed yield per unit area on the one hand and days to flowering, number of pods per unit area, number of seeds per unit area and number of seeds per pod on the other hand. Seed yield was negatively correlated with 100-seed weight.

Rathnaswamy et al. (1978) reported that pods per plant had highly significant positive correlation with seed yield per plant in greengram. The 100-seed weight was negatively correlated with seed yield.

Sandhu et al. (1978) found positive association of grain yield with pods per plant, pod length and seeds per pod in blackgram.

In soyabean Shettar et al. (1978) obtained positive association of yield per plant with number of nodes, branches and pods per plant.

Singh et al. (1978) reported that in chickpea seed yield exhibited significant and positive association with pod number, the number of primary branches and the number of secondary branches. However, 100-seed weight, exhibited negative association and seeds per pod had no significant association with yield.

In 196 selections of Dolichos lablab L. pod yield was positively correlated with number of pods, height, pod length and width and seed length and width (Arunachala, 1979).

In pigeonpea Dani (1979) found that seed yield was correlated with number of pods and number of seeds per plant.

Sandhu et al. (1979) observed positive association of yield with clusters and pods per plant, pod length, seeds per pod and 100-seed weight in greengram.

The correlation study conducted by Ganeshiah (1980) in horsegram showed that the pod weight, number of pods, days to maturity, secondary branches, number of fruiting nodes and number of nodes were highly positively associated with yield.

Godawat (1980) obtained positive significant correlation of grain yield with number of primary branches per plant, 100-grain weight, number of pods per plant and pod length in pigeonpea.

Natarajan and Arumugam (1980) reported that in pea first flower node, plant height, number of pods per plant, length and breadth of pod and number and weight of seeds per pod showed highly significant positive correlations with yield of pods.

Pandey *et al.* (1980) obtained high positive correlation between yield and leaflet area, days to flowering, 100-seed weight, pod width and protein content in field bean.

Pandita *et al.* (1980) observed that days to flowering was negatively correlated with yield in *Dolichos lablab* L.

Suraiya (1980) reported that pod length exhibited maximum genotypic correlation with seed yield in 15 varieties of horsegram.

In pigeonpea Assawa *et al.* (1981) found that yield was positively correlated with secondary branches, pods per plant, seeds per plant and days to maturity.

Analysis of data on six yield contributing characters in 16 varieties of soyabean revealed that only number of days to maturity was significantly and positively correlated with yield (Barbind *et al.*, 1981).

Boomikumaran and Rathinam (1981) found that in greengram the characters except pod length and 100-seed weight were significantly and positively correlated with grain yield.

Tikka and Assawa (1981) reported that in cowpea yield was correlated with height, primary branches and pods per plant.

In chickpea Adhikari and Pandey (1982) found that seed yield was positively correlated with primary branches per plant, secondary branches per plant and pods per plant.

Malik *et al.* (1982) recorded significant positive correlation of seed weight, pods per plant and days to maturity with seed yield in greengram.

In blackgram Patel and Shah (1982) found positive significant correlation of grain yield per plant with number of branches, pods and clusters per plant.

Rashid and Islam (1982) obtained high genotypic and phenotypic correlation between plant height and yield per plant in soyabean.

Singh *et al*. (1982) observed that in cowpea, height, pods per plant and seeds per pod were significantly and positively correlated with seed yield.

Tyagi *et al*. (1982) observed that grain yield per plant was significantly positively correlated with pods per plant, secondary branches and 100-seed weight in gram.

Bainiwal and Jatasra (1983) observed that in redgram seed yield was positively and significantly correlated with days to flowering, plant height and primary branch number per plant.

In horsegram Patil and Deshmukh (1983) found that seed yield was positively correlated with number of pods per plant, number of secondary branches and 100-seed weight.

Zhou (1983) reported that in soyabean seed weight per plant was closely correlated with height, number of internodes on the mainstem, pod number per plant and seed number per plant.

Dixit and Patil (1984) found that number of pods per plant, number of branches per plant, number of seeds per plant and 1000-seed weight were most closely correlated with yield in soyabean.

Islam *et al.* (1984) reported that yield per plant was highly and positively correlated with pods per plant and number of secondary branches in bengalgram.

Jindal and Gupta (1984) found that in cowpea plant height, inflorescence per plant, bunches of pods per plant, pods per plant, pod length and seeds per pod were significantly and positively associated with seed yield.

Sarker *et al.* (1984) obtained positive and significant correlation of yield with pods per plant and 100-seed weight in blackgram.

Shahi *et al.* (1984) recorded that in bengalgram components like primary branches, secondary branches, pods per plant and 100-seed weight showed high positive association with yield.

In horsegram Ghorpade (1985) obtained negative association between seed yield and days to 50 per cent flowering.

The estimation of phenotypic correlation of yield and yield components in ten cowpea genotypes revealed that grain yield had strong association with pod weight per plant, number of pods per plant, pod cluster per plant and plant height (Natarajaratnam *et al.*, 1985).

Rao and Sharma (1985) observed significant negative correlation of pod yield per plant with number of seeds per plant in soyabean.

In greengram Singh and Malik (1985) obtained a positive significant association of harvest index with seed yield.

Balyan and Singh (1986) reported that in lentil plant height, number of pods per plant, 100-seed weight, time to maturity and number of pods per peduncle were the characters with the strongest positive association with yield.

Gupta _et al_. (1986) observed positive correlation between seed yield and pods per plant in pea.

Tong (1986) reported that in soyabean positive correlations were detected between seed yield per plant and number of productive branches per plant, pods per plant, seeds per plant, 100-seed weight, aerial plant mass and harvest index. Seed yield per plant was negatively correlated with height and internodes per mainstem.

Studies on 21 varieties of horsegram revealed a strong positive correlation of yield with number of days to first pod maturity, number of pods per plant and number of seeds per pod (Birari _et al_., 1987).

Maloo and Sharma (1987) indicated that grain yield had significant positive association with number of pods per plant, number of primary branches and 100-seed weight at both genotypic as well as phenotypic levels in chickpea.

Patil and Bhapker (1987) found that in cowpea seed yield was positively and significantly correlated with pods per plant and seeds per pod in cowpea.

The correlation studies in pigeonpea indicated positive association of seed yield with number of pods, days to maturity, plant height and number of branches (Prem Sagar et al., 1987).

Rajesh Mishra et al. (1988) revealed that in bengalgram grain yield had positive association with plant spread, number of primary branches per plant, number of secondary branches per plant, pod bearing length, number of pods per plant, biological yield per plant and harvest index.

In cowpea Thiyagarajan and Rajasekaran (1989) reported that seed yield in cowpea exhibited significant and positive association with days to maturity, plant height, number of branches, clusters and pods per plant, pod length and seeds per pod. However, days to 50 per cent flowering and 100-grain weight exhibited negative association with yield.

B. Inter correlation among yield components

Singh and Dixit (1970) obtained phenotypic correlation of number of primary branches with the number of secondary branches and number of pods per plant in lentil. The latter was found to be associated with number of secondary branches.

Joshi (1971) reported that in field bean number of pods and seeds per plant showed very strong positive correlation among themselves.

Joshi (1973) found that in pigeonpea the number of branches and pods per plant were strongly and positively associated whereas the number of seeds per pod and the number of pods per plant were negatively correlated. The pod length and number of seeds per pod were positively correlated.

Veeraswamy et al. (1973) identified significant and positive correlation of plant height with number of days to flower, number of branches, pods per plant at both the genotypic and phenotypic levels in pigeonpea.

Correlation studies revealed that at phenotypic level pods per plant was highly and positively correlated with seeds per plant. Seeds per plant was significantly negatively associated with 100-seed weight in chickpea.

At genotypic level pods per plant was highly correlated with seeds per plant, 100-seed weight was negatively correlated with seeds per plant (Hira Chand et al., 1975).

In horsegram Aggarwal and Kang (1976) found significant positive correlation between number of branches and pods per plant, pods per plant and seed size, pod length and seeds per pod, and pod length and seed size. Days to flowering and days to maturity were negatively associated with grain size and pods per plant.

Gautam and Singh (1977) reported that in soyabean 100-seed weight was negatively correlated with all the other traits.

In pea Malik and Hafeez (1977) observed correlation of mean number of seeds per plant with mean number of pods per plant. A negative correlation was found between 1000-seed weight and most of the characters excluding mean number of seeds per pod and mean plant height. Height was not significantly correlated with any of the character studied.

In lathyrus Singh et al. (1977) observed significant genotypic and phenotypic association with number of pods per plant and 100-grain weight. A significant and positive association between number of primary branches and number of pods per plant was observed at both levels.

Rathnaswamy *et al*. (1978) observed that in greengram pods per plant was negatively correlated with pod length and 100-seed weight, but in turn the latter two characters were positively associated.

Shettar *et al*. (1978) observed that number of nodes, branches and pods per plant were correlated with each other in soyabean.

Tiwari *et al*. (1978) found that in pigeonpea number of pods was negatively correlated with number of secondary branches.

Hanchinal *et al*. (1979) reported that 100-seed weight was negatively correlated with number of pods per plant and with number of branches per plant in cowpea.

In horsegram Ganeshiah (1980) observed positive association of number of pods with seeds per pod.

Suraiya (1980) reported that in horsegram number of pods per plant had significant negative association with 100-seed weight. Number of seeds per pod had significant and positive association with pod length, plant height and number of branches. 100-seed weight showed no significant association with any of the yield components.

Boomikumaran and Rathinam (1981) found that in greengram the character 100-seed weight showed negative association with the characters except with pod length.

In chickpea Katiyar *et al*. (1981) reported that number of pods per plant was negatively correlated with number of secondary branches.

Muthiah and Sivasubramaniam (1981) reported that in blackgram pod number and cluster number not only showed high positive association among themselves but also showed positive correlation with other characters with the exception of hundred seed weight.

In soyabean Rashid and Islam (1982) found high genotypic and phenotypic correlations between seeds per pod and pods per plant, plant height and branches per plant.

Tyagi *et al*. (1982) observed positive association of pods per plant with number of primary branches and secondary branches in bengalgram.

Patil and Deshmukh (1983) recorded negative association of number of grains per pod with all characters except grain yield per plant in horsegram.

Liu *et al*. (1984) reported that in greengram 100-seed weight was negatively correlated with pod number per plant.

Ghorpade (1985) obtained positive correlation of days to 50 per cent flowering with pod number per plant and seed index in horsegram.

In soyabean Rao and Sharma (1985) observed significant positive correlation coefficient for character combinations viz. days to 50 per cent flowering vs pod yield per plant and number of seeds per plant.

Singh and Malik (1985) found a positive significant association of harvest index with pods per plant and seeds per pod while negative with branches and plant height in greengram.

Birari et al. (1987) reported that in horsegram 100-seed weight was negatively correlated with all other characters under study.

In cowpea Patil and Bhapkar (1987) found that pods per plant and seeds per pod were negatively correlated.

Prem Sagar et al. (1987) recorded that the characters number of pods, days to maturity, plant height and branches were correlated with each other in pigeonpea.

Ramana and Singh (1987) worked out the character association in greengram in the spring and rainy seasons. Days to first flower had a significant positive correlat[illegible] with plant height, seeds per pod and 100-seed weight i[illegible] the rainy season. Plant height had significant and positive correlation with pods per plant in both the seasons, positive and significant correlation with seeds per pod and 100-seed weight in the rainy season. Pods per plant and 100-seed weight exhibited significant and positive correlation with seeds per pod in the rainy season.

Govil and Kumar (1989) obtained significant and positive genotypic correlations between pods per plant and vegetative growth, and pods per secondary branches and seeds per pod in chickpea.

III. Heritability and Genetic Advance

The extent to which the variability of a quantitative character is transferable to the progeny is referred to as heritability for that particular character. Lush (1940) has defined heritability both in broad and narrow senses. According to him, heritability in the broad sense implies the percentage of total genotypic variance over phenotypic variance. In the narrow sense, heritability is the ratio of additive genetic variance to total variance and it takes into account only average effects of genes transmitted from parents to offsprings. While selecting for a character, consideration of mere phenotypic variability without estimating the heritable part of it will not be of much use. Heritability estimates along with genetic gain is usually more useful in predicting the resultant effect through selection of the best individual (Johnson _et al._, 1955).

Singh and Dixit (1970) obtained maximum heritability in plant height and number of secondary branches in lentil.

Singh *et al*. (1975) reported that in blackgram the plant height showed the highest value of heritability (97.3 per cent) while it was the lowest for cluster per plant. Genetic advance was found high for primary branches, plant height and grain yield per plant.

Singh and Singh (1975) found high heritability for test weight, seeds per pod and primary branches per plant. Primary branches and test weight showed comparatively high expected genetic advance and lowest for grain yield per plant in lentil.

In blackgram Soundrapandian *et al*. (1975) observed high heritability values for length of pod and height of plant. Number of pods per plant and plant height had high heritability combined with high genetic advance.

Aggarwal and Kang (1976) reported that seed size (100-grain weight) showed the highest heritability value (91.66 per cent) whereas heritability was lowest for number of branches (21.68 per cent) in horsegram. The value of genetic gain for yield was highest (48.21 per cent) and lowest (3.35 per cent) for seeds per pod. Genetic gain for pods per plant and seed size was also fairly high.

Malhotra and Sodhi (1977) found that in pigeonpea the high heritabilities for grain yield and the branches was accompanied by high genetic advances. The pod number had average heritability and expected genetic advance while the gain under selection was minimum for the pod length and 100-seed weight.

In horsegram Shivashankar et al. (1977) recorded that primary branches, secondary branches, days to 50 per cent flowering, number of nodes per plant and 100-seed weight were highly heritable, while height of plant, number of seeds per pod, number of pods per plant and yield showed low heritability. Genetic advance was maximum for number of secondary branches followed by number of primary branches. Lowest value was obtained for seeds per pod.

Tikka and Assawa (1977) reported that in pea heritability estimates were high for number of days to flowering, pods per plant and seed size and estimates of genetic advance were high for pods per plant, seed size and seed yield.

Tikka et al. (1977) reported that estimates of heritability and of genetic advance were high for number of pods per plant in moth bean.

Das (1978) obtained high heritability estimates combined with a high expected genetic advance for the number of branches per plant and the number of pods per plant in blackgram.

According to Ramakrishnan *et al.* (1978) in horsegram number of pods per plant, number of nodules per plant, number of branches, plant height and yield per plant showed higher genetic gain values associated with higher heritability estimates.

Singh *et al.* (1978) obtained low estimates of heritability and genetic advance for number of seeds per pod in 21 varieties of pea.

In field bean Baswana *et al.* (1980) found that yield per plant, pod weight, pod width and number of flower per inflorescence showed high heritability and genetic advance.

Ganeshiah (1980) obtained high heritability estimates for number of days to flowering and to maturity in 100 varieties of horsegram.

Godawat (1980) recorded high heritability and genetic advance for grain yield per plant and number of primary branches per plant in pigeonpea. High heritability in conjugation with low genetic advance was obtained for the 100-grain weight.

Medhi et al. (1980) reported high heritability estimates for 100-seed weight (99.43 per cent) in greengram.

Pandita et al. (1980) recorded high expected genetic gain associated with high heritability estimates for the number of flowers per cluster, pod size and yield in field bean.

Paramasivan and Rajasekharan (1980) found that in greengram pod length, 100-seed weight, cluster number and seed yield showed high genetic advance with higher heritability estimates.

Suraiya (1980) reported high heritability and genetic advance for the character days to 50 per cent flowering in horsegram.

Bainiwal et al. (1981) observed high genetic advance for seed yield, secondary branches, plant height and primary branches in pigeonpea.

In pigeonpea Yadavendra et al. (1981) reported maximum heritability for 100-seed weight (91.76 per cent) followed by number of seeds per pod (90.41 per cent). The expected genetic advance ranged from 13.86 per cent for pod length to 32.62 per cent for number of pods per plant.

Patel and Shah (1982) recorded high heritability and genetic advance for pod length and plant height in blackgram. High heritability in conjugation with low genetic advance was obtained for seeds per pod, 100-seed weight and pods per cluster.

Radhakrishnan and Jebaraj (1982) reported that number of pods recorded high genetic gain while days to maturity and plant height registered low genetic gain in cowpea.

In soyabean Rashid and Islam (1982) recorded highest heritability for days to maturity followed by 100-seed weight while it was lowest for pods per plant. High genetic advance values observed for seed yield per plant, branches per plant, plant height and pods per plant, while days to maturity, seeds per pod and 100-seed weight showed low genetic advance.

Mandal and Bahl (1983) reported that in chickpea biological yield showed highest estimated heritability and expected genetic advance, values were intermediate for economic yield and low for harvest index.

Dharmalingam and Kadambavanasundaram (1984) recorded higher heritability estimates for pod length, 100-seed weight and harvest index in cowpea.

In chickpea seeds per pod, seed yield per plant and 100-seed weight combined high heritability values with relatively high genetic advance (Dumbre et al., 1984).

In a study of nine quantitative characters in greengram, plant height had the highest heritability as reported by Liu et al. (1984).

Sarker et al. (1984) reported high heritability and genetic advance for plant height and days to maturity in blackgram.

In pigeonpea Balyan and Sudhakar (1985) obtained high estimates of heritability and expected genetic advance for primary and secondary branch number, pod number per plant, 100-seed weight and yield per plot.

Khorgade et al. (1985) recorded that in a study of 32 genotypes of chickpea, 100-seed weight, seeds per pod, days to 50 per cent flowering and branches per plant gave high estimates of genetic advance and heritability.

Among thirty varieties of pea, grain yield, plant height, number of pods per plant and number of branches per plant had high heritability in the broad sense (Singh, 1985).

Rasaily et al. (1986) reported high heritability for height, days to flowering and days to maturity in soyabean.

Fifty genotypes of cowpea (*Vigna unguiculata*) showed high heritability for 100-seed weight, seeds per pod and days to maturity. The percentage of genetic gain was maximum for 100-seed weight, plant height, branches per plant and seeds per pod (Apte *et al*., 1987).

Studies by Birari *et al*. (1987) on 21 varieties of horsegram revealed that yield per ha, number of days to first pod maturity and 100-seed weight exhibited high heritability while number of pods per plant and number of seeds per pod showed relatively low heritability.

Maloo and Sharma (1987) obtained high genetic advance coupled with high heritabilities for grain yield, number of pods per plant and number of branches per plant in chickpea.

In cowpea Patil and Baviskar (1987) obtained highest heritability for 100-seed weight (90.94 per cent) followed by days to maturity and pod length.

Patil *et al*. (1987) found that in greengram heritability was highest for days to flowering (91.35 per cent) followed by 100-seed weight (90.78 per cent), plant height (90.11 per cent) and seeds per pod (79.24 per cent).

Rajesh Mishra *et al*. (1988) found high heritability coupled with high genetic advance for number of secondary branches per plant, number of pods per plant, seed yield per plant, biological yield per plant and harvest index in chickpea.

Covil and Kumar (1989) reported high genetic advance accompanied by high estimates of heritability in case of days to flower in the same crop.

IV. Path Analysis

The study of association of component characters with grain yield has been of immense help in selecting suitable plant types. When more number of characters are included in the correlation study, the direct association becomes more complex. In such a situation the path analysis devised by Wright (1921) provides an effective measure to find out the direct and indirect effects permitting a critical examination of the specific factors that produce a given correlation.

Path analysis done in different pulse crops by many workers and their reports are summarized below.

In pigeonpea path coefficient studies revealed that clusters per plant is the main yield component (Singh and Malhotra, 1973).

Gowda and Pandya (1975) reported that in chickpea number of pods per plant and 100-grain weight had larger effect on grain yield.

In horsegram Aggarwal and Kang (1976) reported that pods per plant and seed size were the direct components which influenced seed yield. The highest direct effect (0.75) was exhibited by pods per plant. The effect was intensified further with marginal indirect effects through seed size, number of branches, seeds per pod and days to maturity. The direct effect of 100-grain weight (0.142) was quite low in comparison to its phenotypic correlation with yield because of high indirect effect via pods per plant.

Soundrapandian et al. (1976) reported that in blackgram height of plant and cluster number had a direct effect as well as indirect effect on seed yield, while branch number, pod number, pod length and seed number per pod had either very low positive or high negative direct or indirect effects on seed yield.

In soyabean Gautam and Singh (1977) reported that number of pods, 100-seed weight and seeds per pod had a direct effect on yield and days to flowering and maturity had an indirect effect via the number of pods per plant.

In lentil path analysis revealed that pod number and plant height had highest direct effect on grain yield. Primary and secondary branch number showed negative direct effects. Singh (1977) suggested that tall varieties should be developed with good pod-bearing ability but low branch numbers.

Singh *et al.* (1977) reported that in greengram pods per cluster and pods per plant contributing directly as well as towards grain yield.

In pea Tikka and Assawa (1977) found that seed size had the greatest direct influence on yield.

Das (1978) found that number of seeds per pod and 1000-seed weight had positive direct effect and indirect effect on seed yield per plant in blackgram.

In pea Narsinghani *et al.* (1978) found maximum direct effect on yield by number of seeds per plant, followed by 100-seed weight, days to maturity, height and protein percentage. Most of the characters had an indirect effect via number of seeds per plant.

Rathnaswamy *et al.* (1978) observed that in greengram 100-seed weight, seeds per pod and pods per plant had direct positive influence on seed yield. The direct effect of 100-seed weight was however cancelled out by the indirect negative effect of number of pods per plant and seeds per pod on yield per plant.

The path coefficient study in chickpea revealed that the number of primary branches and the pod number had high and positive direct and indirect effects on seed yield whereas the secondary branches had negative direct effect (Singh *et al.*, 1978).

Dani (1979) reported that only the number of seeds per plant had a high direct effect on yield in pigeonpea.

Hanchinal et al. (1979) reported that the number of branches per plant had an important direct effect on yield and that number of seeds per pod had an important indirect effect acting through number of branches in cowpea.

Patel and Telang (1979) observed that in cowpea seed number per pod had the largest effect on seed yield followed by 100-seed weight and pod number per plant. Pod length had a marked negative effect on yield.

Baswana et al. (1980) reported that pods per plant weight of pod and height of plant had direct positive effect on yield in field bean.

In horsegram Ganeshiah (1980) found that pod weight and 100-seed weight contribute more to yield than number of seeds per pod.

Godawat (1980) found that in pigeonpea 100-grain weight had maximum direct effect on grain yield per plant.

In pea path coefficient analysis revealed that the weight of seeds had the maximum direct effect on yield followed by number of pods. Although the direct effects of length and breadth of pod and number of seeds were low, their contributions through weight of seeds were considerable (Natarajan and Arumugam, 1980).

Pandey et al. (1980) found that in field bean leaflet area, days to flowering, 100-seed weight, pod width and protein content had direct effects on yield.

Path coefficient analysis in 435 strains of greengram indicated that pods per plant, seeds per pod and 100-seed weight were important for improving grain yield (Sandhu et al., 1980).

Suraiya (1980) recorded that pod length exhibited maximum direct effect on seed yield in horsegram. The indirect effect of all the other characters through pod length was also high and positive.

Assawa et al. (1981) observed that in pigeonpea most of the traits expressed strong indirect effect on yield via secondary branches.

Boomikumaran and Rathinam (1981) reported that plant height, pods per cluster, clusters per plant were the major factors determining the grain yield in greengram.

Katiyar et al. (1981) observed that the number of days to flowering had a negative direct effect on seed yield in chickpea.

In blackgram Muthiah and Sivasubrahmaniam (1981) reported that pod length had a negative direct effect on yield.

Rani and Rao (1981) observed that in blackgram the number of pods per plant, 100-seed weight and seeds per pod had high direct effect on yield.

Tikka and Assawa (1981) reported that in cowpea height and pods per plant had a positive direct effect on yield.

Adhikari and Pandey (1982) found that days to complete flowering, pods per plant and 100-seed weight had important direct effects on yield in chickpea.

Shoran (1982) found that pods per plant had the highest direct effect on seed yield followed by 100-seed weight, seeds per pod and days to flower in pigeonpea.

Kumar and Reddy (1982) reported that pod number, plant height and number of primary branches had large positive direct effect on yield per plant in redgram.

Malik et al. (1982) observed that in greengram pods per plant and seed weight showed maximum positive direct effects on seed yield.

Patel and Shah (1982) found that clusters per plant had maximum positive direct effect on grain yield and was followed by pods per plant in blackgram.

Tyagi *et al.* (1982) reported that in chickpea primary branches per plant, seeds per pod and 100-seed weight had high positive direct effect on grain yield.

Bainiwal and Jatasra (1983) observed that in pigeon-pea plant height had the strongest direct effect on yield.

Chandel (1983) reported that in pea number of branches per plant, seeds per pod, pods per plant and 100-seed weight had strong direct effect on yield.

Huang *et al.* (1983) studied the direct and indirect effects of yield components in *Vicia faba*. Results showed that pod number per plant and 100-seed weight had the most significant direct effects on yield, while height and number of effective branches had indirect effects.

Jana *et al.* (1983) found that in cowpea pod number per plant had the highest direct effect on pod yield per plant.

In field bean Teotia *et al.* (1983) observed that number of seeds per pod, harvest index and total soluble sugars had direct effects on yield at genotypic level. Number of pods per plant had the highest indirect effect via length of internode and number of pods per axil.

Zhou (1983) found that number of internodes on the main stem, number of branches, 100-seed weight and seed number per plant had relatively major effects on yield in soyabean.

Jindal and Gupta (1984) suggested that bunches of pods per plant, seeds per pod and pod length were the major components contributing directly to seed yield in cowpea.

In greengram Thandapani and Rao (1984) found that clusters per plant had the greatest direct effect on yield while pod length and seed weight were also directly associated with yield. Number of seeds, 100-seed weight and the fertility coefficient had indirect effects on yield.

Vidhyadhar et al. (1984) reported that in greengram the number of pod clusters per plant, seeds per pod and 100-seed weight had direct effects on seed yield.

In pigeonpea path analysis indicated high direct and indirect contributions of days to maturity, pod number, seed number per pod and 100-seed weight to yield (Balyan and Sudhakar, 1985).

Dumbre et al. (1985) reported that in redgram pods per plant and 100-grain weight were the only direct components on yield.

Natarajaratinam et al. (1985) reported that in cowpea pod weight per plant was the most important component having direct effect on grain yield.

Singh *et al.* (1985) observed that in chickpea seeds per pod had the highest direct effect on yield, while most of the other characters affected yield indirectly via pods per plant.

Gupta *et al.* (1986) found that in pea direct effect of days to first flower, days to maturity, pod length, pods per plant, seeds per pod, branches per plant on seed yield per plant were positive and of high magnitude. The direct effect of days to pod development was negative towards seed yield but its indirect effect via pods per plant, pod length, pod width, 100-seed weight and pods per node was positive.

Naidu *et al.* (1986) reported that in moth bean peduncle length, seed number per pod and pod number per plant had the strongest direct influence on yield.

Rasaily *et al.* (1986) reported that number of pods per plant was the most important yield component in soyabean.

Path analysis of seven yield contributing characters and yield revealed that in chickpea pods per plant, seeds per pod and secondary branches per plant had the greatest effect on yield. Seed weight was the least important trait (Singh *et al.*, 1986).

Maloo and Sharma (1987) reported that in gram the number of pods per plant had the highest direct effect on grain yield followed by 100-grain weight and days to flower.

Prem Sagar *et al.* (1987) reported that the number of pods per plant was the most important component of yield in redgram.

MATERIALS AND METHODS

MATERIALS AND METHODS

A. Material

Forty eight varieties of horsegram (Macrotyloma uniflorum L. Verdic. Syn. Dolichos biflorus L.) exhibiting distinct diversity in characters constituted the material for the study. These varieties were obtained from the germplasm collection maintained at the Tamil Nadu Agricultural University, Coimbatore; NBPGR Regional Station, Vellanikkara and local collections from Thiruvananthapuram, Malappuram and Kozhikode districts.

Table 1 gives particulars of these varieties which were given identification number V_1 to V_{48}.

B. Methods

The experiment was conducted at the College of Agriculture, Vellayani during September-January 1989-'90.

Experimental Design and layout

The experiment consisting of forty eight treatments was laid out in a Randomised Block Design with three replications. The crop was raised adopting Package of practices recommendation (1989) of the Kerala Agricultural University.

Table 1. Particulars of the forty eight varieties of horsegram used in the study

Variety	Source	Treatment number
Thiruvananthapuram local	Local collection from Thiruvananthapuram	V_1
Kozhikode local	Local collection from Kozhikode	V_2
Malappuram local	Local collection from Malappuram	V_3
HG-121	Tamil Nadu Agricultural University, Coimbatore	V_4
VZM-93	"	V_5
No. 476	"	V_6
No. 33	"	V_7
HG-106	"	V_8
HG-71	"	V_9
PLS-6252	"	V_{10}
POLLACHI	"	V_{11}
HG-35	"	V_{12}
PLS-6100	"	V_{13}
PLS-449	"	V_{14}
PLS-6056	"	V_{15}
CODB-1	"	V_{16}

PLS-6234	Tamil Nadu Agricultural University, Coimbatore	V_{17}
PLS-6012	"	V_{18}
PLS-6243		V_{19}
PLS-6202	"	V_{20}
IC-8619	"	V_{21}
PLS-6225	"	V_{22}
PLS-6079	"	V_{23}
PLS-6166	"	V_{24}
PLS-6046	"	V_{25}
PLS-6043	"	V_{26}
PLS-6098	"	V_{27}
PLS-6203	"	V_{28}
PLS-6227	"	V_{29}
No. 447	"	V_{30}
HG-116	"	V_{31}
PLS-6094	"	V_{32}
HG-120	"	V_{33}
PLS-6204	"	V_{34}
P. Kottai	"	V_{35}
PLS-6164	"	V_{36}

PLS-6281	Tamil Nadu Agricultural University, Coimbatore	V_{37}
HGC-103	NBPGR Regional Station, Vellanikkara	V_{38}
PLS-6058	Tamil Nadu Agricultural University, Coimbatore	V_{39}
HCC-176	NBPGR Regional Station, Vellanikkara	V_{40}
HG-76	Tamil Nadu Agricultural University, Coimbatore	V_{41}
P. Palayam	"	V_{42}
PLS-6121	"	V_{43}
PLS-6197	"	V_{44}
VZM-BUF	"	V_{45}
PLS-6028	"	V_{46}
HG-114	"	V_{47}
PLS-6169	"	V_{48}

Ten plants were selected at random from each plot and data on the following characters were recorded and the mean worked out.

1. Height of plants

The height of the plants was measured at maturity from the ground level to the tip of the plant in the field using metre scale and expressed in centimetres.

2. Number of branches

All the branches in the selected plants were counted and recorded at full maturity of the plant.

3. Number of pods per plant

The total number of pods harvested from the observational plants was recorded.

4. Number of seeds per pod

Ten pods per plant selected at random were shelled and the number of seeds per pod recorded.

5. Seed yield per plant

Yield of seed from each plant was weighed after normal drying and the weight was expressed in grams.

6. Length of pods

A random sample of 10 pods per plant was collected and the length measured in centimetres.

7. Root/shoot ratio

The observational plants were uprooted and separated into root and shoot portions. The roots were washed free of soil. Shoots and roots were dried at 60-70°C for 24 hours, cooled to room temperature and then weighed and the ratio of root/shoot worked out.

8. Harvest index

Harvest index was estimated using the formula

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

9. 100-seed weight

Hundred well dried seeds chosen at random from each treatment were weighed and expressed in grams.

10. Days to flowering

The number of days from sowing to flowering of 50 per cent plants in the plot was recorded.

11. Days to maturity

The number of days taken for maturity from the date of sowing was noted when majority of the pods become dried up (All plants constituting the sample in each plot were harvested on the same day).

12. Reaction to pests and diseases

The plots were observed for incidence of pests and diseases.

C. Statistical techniques

I. Analysis of variance and covariance

Analyses of variance and covariance were done for the following (Kempthorne, 1957).

(i) to test whether there was any significant differences between the varieties, with respect to the various traits

(ii) to estimate the variance components and

(iii) to estimate the correlation coefficients

The extent of phenotypic variation for any character is the sum of the genetic and environmental effects and can be determined by the methods given by Kempthorne (1957).

$$V(P) = V(G) + V(E) + 2\,COV\,(G, E)$$

where $V(P) = \sigma^2_{p(X)}$ = variance due to phenotype

$V(G) = \sigma^2 g(X)$ = variance due to genotype

$V(E) = \sigma^2_{e(X)}$ = variance due to environment

$COV\,(G, E)$ = covariance between genotype and environment

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If the genotype and the environment are independent COV(G, E) is equal to zero, so that V(P) = V(G) + V(E)

$$\sigma^2_{p(X)} = \sigma^2_{g(X)} + \sigma^2_{e(X)}$$

If there are observations on two characters X and Y on each individual, the extent of covariance between X and Y due to the genotype and environment can be estimated, as suggested by Kempthorne (1957), as follows:

$$COV_{P(X, Y)} = COV_{G(X, Y)} + COV_{E(X, Y)}$$

$$\text{or } \sigma_{p(X, Y)} = \sigma_{g(X, Y)} + \sigma_{e(X, Y)}$$

where $\sigma_{p(X, Y)}$ = phenotypic covariance between X and Y

$\sigma_{g(X, Y)}$ = genotypic covariance between X and Y

$\sigma_{e(X, Y)}$ = environmental covariance between X and Y

If the experiment is designed in a randomised complete block design with 'V' treatments and 'r' replications, the estimates of

$\sigma^2_{p(X)}$, $\sigma^2_{g(X)}$, $\sigma^2_{g(Y)}$, $\sigma^2_{e(X)}$, $\sigma^2_{e(Y)}$, $\sigma_{p(X, Y)}$, $\sigma_{g(X, Y)}$ and $\sigma_{e(X, Y)}$ are obtained from the variance-covariance analysis (Table 2).

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Table 2. Analysis of variance/covariance

Source	df	M.S (x,x)	Expectation of M.S(xx)	M.S.P. (x,y)	Expectation of MSP(x,y)	MS (yy)	Expectation of MS(yy)
Block	(r-1)	Bxx		Bxy		Byy	
Treatment	(v-1)	Txx	$\sigma^2_{e(x)} + r\sigma^2_{g(x)}$	Txy	$\sigma_{e(xy)} + \sigma_{g(xy)}$	Tyy	$\sigma^2_{e(y)} + r\sigma^2_{g(y)}$
Error	(r-1)(v-1)	Exx	$\sigma^2_{e(x)}$	Exy	$\sigma_{e(xy)}$	Eyy	$\sigma^2_{e(y)}$
Total	rv-1	Sxx		Sxy		Syy	

Hence we have the following estimates

$$\sigma^2_{g(x)} = \frac{1}{r}(Txx - Exx), \quad \sigma^2_{e(x)} = Exx$$

$$\sigma^2_{g(y)} = \frac{1}{r}(Tyy - Eyy), \quad \sigma^2_{e(y)} = Eyy$$

$$\sigma_{g(xy)} = \frac{1}{r}(Txy - Exy), \quad \sigma_{e(xy)} = Exy$$

II. Coefficient of variation

The coefficient of variation is a unitless measurement and is used for comparing the extent of variation between different characters measured in different scales.

Phenotypic coefficient of variation (PCV):

$$\text{PCV for character X} = \frac{\sigma p(x)}{\bar{X}} \times 100$$

Genotypic coefficient of variation (GCV):

$$\text{GCV for character X} = \frac{\sigma g(x)}{\bar{X}} \times 100$$

where $\sigma p(x)$ and $\sigma g(x)$ are the phenotypic and genotypic standard deviation respectively and $\bar{X}$ is the mean of the character X.

III. Correlations

The phenotypic correlation coefficient between X and Y was estimated as:

$$r_{p(x,y)} = \frac{\sigma p(x,y)}{\sigma p(x)\, \sigma p(y)}$$

where $\sigma p(x,y)$ is the phenotypic covariance between x and y

$\sigma p(x)$ = standard deviation of the character x

$\sigma p(y)$ = standard deviation of the character y

The genotypic correlation coefficient between x and y was estimated as:

$$r_{g(x,y)} = \frac{\sigma_{g(x,y)}}{\sigma_{g(x)}\ \sigma_{g(y)}}$$

where $\sigma_{g(x,y)}$ is the genotypic covariance between x and y

$\sigma_{g(x)}$ = standard deviation of the character x

$\sigma_{g(y)}$ = standard deviation of the character y

IV. Heritability (H^2)

Heritability in the broad sense is the fraction of the total variance which is heritable and was estimated as a percentage following Jain (1980) as:

$$H^2 = \frac{\sigma^2_g \times 100}{\sigma^2_p}$$

where H^2 = Heritability in the broad sense

Heritability provides a measure of genetic variation ie. the variance upon which all the possibilities of changing the genetic composition of the population through selection depends. Heritability per cent was categorised as suggested by Robinson *et al.* (1949) viz. low (0-30), moderate (30-60) and high (above 60).

V. Genetic advance under selection (G.A.)

Genetic advance is a measure of the change in the mean phonotypic level of the population produced by the selection and depends upon heritability of the character and selection differential. G.A. was estimated as per method suggested by Lush (1940) and Johnson *et al.* (1955).

$$G.A. = K.\ h^2 \sqrt{V_p}$$

where G.A. = Genetic advance

h^2 = Heritability in the broad sense

V_p = Phenotypic variance

K = Selection differential which is 2.06 in the case of 5 per cent selection in large samples (Miller *et al.*, 1958 and Allard, 1960)

VI. Path analysis

The path coefficients were worked out by the method suggested by Wright (1921). The simultaneous equations which gives the estimates of path coefficients are as follows:

$$\begin{Bmatrix} r_{1y} \\ \vdots \\ r_{iy} \\ \vdots \\ r_{ky} \end{Bmatrix} = \begin{Bmatrix} 1 & r_{12} & r_{13} \ldots\ldots r_{1j} \ldots\ldots r_{1k} \\ & 1 & r_{23} \ldots\ldots\ldots\ldots\ldots r_{2k} \\ & & 1 \ldots r_{ij} \ldots\ldots r_{ik} \\ & & \vdots \\ & & 1 \end{Bmatrix} \times \begin{Bmatrix} P_1 \\ P_2 \\ \vdots \\ P_i \\ \vdots \\ P_k \end{Bmatrix}$$

$$\underline{Ry} = \underset{\sim}{Rx}\ \underline{P}$$

So that $\underline{P} = \underset{\sim}{Rx}^{-1}\ \underline{Ry}$

where r_{ij} is the genotypic correlation between X_i and X_j

$i, j = 1, 2 \ldots \ldots k,$

r_{iy} is the genotypic correlation between X_i and Y and

P_i is the path coefficient of X_i

The residual factor (R) which measures the contribution of other factors not defined in the causal scheme was estimated by the formula.

$$R = \left(1 - \sum_{i=1}^{k} P_i\, r_{iy}\right)^{1/2}$$

Indirect effects of different characters on yield obtained as $P_i r_{ij}$ for the i^{th} character via j^{th} character.

RESULTS

RESULTS

The results of the experiment are presented below:

I. Variability analysis

The mean data collected on eleven characters were subjected to analysis of variance for testing the significance of the differences among varieties and the ANOVA is furnished in Table 3.

The forty eight varieties of horsegram studied, exhibited significant difference for all the characters viz. height of plant, number of branches, number of pods per plant, number of seeds per pod, seed yield per plant, length of pod, root/shoot ratio, harvest index, 100-seed weight, days to flowering and days to maturity.

The mean values recorded on forty eight varieties in respect of yield and other ten characters are presented in Table 4.

Table 3. Abstract of analysis of variance of eleven characters

Sl. No.	Character	Mean square			F value (Treatment)
		Replication	Treatment	Error	
1.	Height of plant	60.875	274.6835	100.7247	2.727**
2.	Number of branches	5.619	32.81	12.24	2.68**
3.	Number of pods per plant	330.52	522.65	196.77	2.66**
4.	Number of seeds per pod	0.0845	0.3172	0.1364	2.33**
5.	Seed yield per plant	9.495	16.43	7.59	2.17**
6.	Length of pods	0.2065	0.2653	0.0904	2.94**
7.	Root/shoot ratio	0.000021	0.000074	0.000029	2.46**
8.	Harvest index	0.00045	0.0032	0.00209	1.514*
9.	100-seed weight	0.1705	1.39	0.0025	552.36**
10.	Days to flowering	0.3438	461.05	9.64	47.84**
11.	Days to maturity	4.38	318.78	17.13	18.6**

* Significant at 5 per cent level ** Significant at 1 per cent level

Table 4. Mean values of eleven characters in horsegram

Sl. No.	Varieties	Height of plant (cm)	Number of branches	Number of pods per plant	Number of seeds per pod	Seed yield per plant (g)	Length of pod (cm)	Root/shoot ratio
1	2	3	4	5	6	7	8	9
1.	Thiruvananthapuram local	30.57	18.30	89.43	5.73	13.34	5.69	0.016
2.	Kozhikode local	86.13	16.20	50.60	4.99	8.82	4.85	0.022
3.	Malappuram local	84.73	10.57	34.50	4.91	4.33	5.36	0.009
4.	HG-121	85.37	18.07	51.83	4.65	6.67	4.45	0.011
5.	VZM-93	106.63	18.67	51.47	4.95	8.93	5.14	0.013
6.	No. 476	97.23	16.97	29.43	5.05	5.04	5.13	0.018
7.	No. 33	96.53	11.43	38.13	4.40	5.11	4.51	0.007
8.	HG-106	74.13	16.50	28.27	4.32	5.05	4.42	0.008
9.	HG-71	89.77	11.97	41.43	5.50	7.33	4.70	0.010
10.	PLS-6252	96.98	11.40	27.37	4.87	4.33	4.76	0.020
11.	POLLACHI	101.57	12.97	38.47	4.84	7.29	4.83	0.017
12.	HG-35	89.80	19.13	58.23	4.87	9.50	5.22	0.010
13.	PLS-6100	93.93	13.47	20.23	4.34	4.00	4.76	0.013
14.	PLS-449	97.83	12.57	26.57	4.53	5.08	4.69	0.014
15.	PLS-6056	103.93	17.20	35.20	4.44	7.54	4.97	0.016
16.	CODB-1	91.60	21.00	52.00	4.93	9.44	5.01	0.025

Table 4 (Contd.)

1	2	3	4	5	6	7	8	9
7.	PLS-6234	86.43	18.73	31.90	5.17	5.91	5.16	0.023
8.	PLS-6012	108.67	18.57	35.70	5.00	8.06	5.22	0.0152
9.	PLS-6243	102.60	16.47	28.20	4.67	6.64	4.82	0.022
20.	PLS-6202	91.80	17.03	31.87	4.82	5.53	5.13	0.011
21.	IC-8619	89.43	16.17	18.37	5.06	4.74	5.06	0.017
22.	PLS-6225	104.97	9.37	48.23	4.70	7.26	4.68	0.008
23.	PLS-6079	109.83	16.40	31.13	4.86	5.53	5.33	0.021
24.	PLS-6166	76.03	13.23	59.13	5.26	9.53	4.99	0.013
25.	PLS-6046	89.13	16.43	37.20	5.05	7.34	5.13	0.017
26.	PLS-6043	95.17	14.63	27.93	4.72	4.26	4.84	0.013
27.	PLS-6098	107.70	20.10	51.33	4.76	9.87	4.99	0.013
28.	PLS-6203	101.07	21.83	33.60	4.99	6.70	4.87	0.023
29.	PLS-6227	87.57	15.97	51.07	4.34	9.53	4.36	0.009
0.	No. 447	112.00	17.57	32.83	5.02	7.14	4.96	0.020
1.	HG-116	93.37	10.97	45.23	4.58	6.21	4.42	0.010
2.	PLS-6094	80.00	17.23	44.73	4.85	7.07	4.87	0.025

Table 4 (Contd.)

1	2	3	4	5	6	7	8	9
33.	HG-120	99.07	12.67	42.13	4.78	7.72	4.91	0.017
34.	PLS-6204	104.17	13.37	24.10	4.46	4.34	4.58	0.011
35.	P. Kottai	102.30	16.87	37.13	4.49	7.60	4.87	0.015
36.	PLS-6164	78.77	15.73	49.13	5.42	8.55	4.95	0.011
37.	PLS-6281	97.57	19.90	34.90	4.67	6.86	5.04	0.015
38.	HCC-103	92.37	10.63	50.60	4.53	6.30	4.41	0.009
39.	PLS-6058	103.07	20.30	25.27	4.59	4.00	4.16	0.016
40.	HCC-176	95.33	18.60	59.00	4.81	8.53	4.70	0.011
41.	HG-76	93.33	13.63	59.70	5.15	10.31	5.18	0.005
42.	P. Palayam	107.63	20.50	57.60	5.31	15.34	5.27	0.017
43.	PLS-6121	97.33	15.67	36.07	4.43	6.36	4.56	0.017
44.	PLS-6197	86.07	11.63	40.03	5.31	6.76	4.70	0.014
45.	VZM-BUFF	99.17	18.37	49.60	5.05	9.34	4.70	0.016
46.	PLS-6028	111.27	15.93	35.43	4.36	6.27	4.85	0.022
47.	HG-114	100.83	10.30	40.57	4.65	6.63	4.37	0.011
48.	PLS-6169	107.33	10.57	27.60	4.70	3.96	5.00	0.015
	General mean	95.59	15.66	40.63	4.83	7.12	4.87	0.015
	CD (0.05)	16.307	5.685	22.79	0.6	4.476	0.488	0.009

Table 4 (Contd.)

Sl. No.	Varieties	Harvest index	100-seed weight (g)	Days to flowering	Days to maturity
1.	Thiruvananthapuram local	0.207	2.53	41.33	97.00
2.	Kozhikode local	0.137	3.80	66.00	106.00
3.	Malappuram local	0.081	2.60	34.33	85.00
4.	HG-121	0.112	2.74	29.33	78.33
5.	VZM-93	0.161	3.52	41.33	103.00
6.	No. 476	0.114	3.33	45.33	100.00
7.	No. 33	0.103	2.90	28.33	78.33
8.	HG-106	0.098	4.09	27.33	78.33
9.	HG-71	0.124	3.42	26.33	75.00
10.	PLS-6252	0.111	3.22	40.00	97.00
11.	POLLACHI	0.141	3.71	40.33	97.00
12.	HG.35	0.170	3.59	37.33	100.00
13.	PLS-6100	0.087	4.64	56.67	106.00
14.	PLS-449	0.106	4.71	62.33	106.00
15.	PLS-6056	0.147	4.92	63.67	106.00
16.	CODB-1	0.209	3.72	67.67	106.00

Table 4 (Contd.)

Sl. No.	Varieties	Harvest index	100-seed weight (g)	Days to flowering	Days to maturity
17.	PLS-6234	0.136	3.52	65.33	106.00
18.	PLS-6012	0.157	4.55	52.33	106.00
19.	PLS-6243	0.135	4.91	62.67	106.00
20.	PLS-6202	0.133	3.40	38.00	103.00
21.	IC-8619	0.103	5.29	51.67	106.00
22.	PLS-6225	0.142	3.18	28.67	81.67
23.	PLS-6079	0.123	3.67	46.33	103.00
24.	PLS-6166	0.179	3.11	31.00	89.00
25.	PLS-6046	0.140	3.91	49.00	103.00
26.	PLS-6043	0.095	3.36	49.67	103.00
27.	PLS-6098	0.191	4.03	50.33	103.00
28.	PLS-6203	0.147	4.29	43.00	106.00
29.	PLS-6227	0.156	4.20	27.33	78.33
30.	No. 447	0.132	4.30	61.67	106.00
31.	HC-116	0.111	3.05	30.00	81.67
32.	PLS-6094	0.149	3.19	38.33	100.00

Table 4 (Contd.)

Sl. No.	Varieties	Harvest index	100-seed weight (g)	Days to flowering	Days to maturity
33.	HG-120	0.152	3.71	33.67	89.00
34.	PLS-6204	0.087	4.04	43.67	97.00
35.	P. Kottai	0.142	4.80	53.67	106.00
36.	PLS-6164	0.158	3.20	31.33	89.00
37.	PLS-6281	0.120	4.17	50.00	106.00
38.	HGC-103	0.119	2.66	32.67	81.67
39.	PLS-6058	0.086	3.44	55.00	106.00
40.	HGC-176	0.165	3.10	38.00	93.00
41.	HG-76	0.180	3.35	29.67	85.00
42.	P. Palayam	0.207	5.09	64.33	106.00
43.	PLS-6121	0.126	3.75	38.67	103.00
44.	PLS-6197	0.140	3.17	30.67	81.67
45.	VZM-BUFF	0.146	3.90	39.00	100.00
46.	PLS-6028	0.150	4.03	43.33	103.00
47.	HG-114	0.138	3.49	28.33	85.00
48.	PLS-6169	0.085	3.10	44.67	100.00
	General mean	0.136	3.72	43.53	96.50
	CD (0.05)	0.0743	0.008	5.044	6.726

1. Height of plant

The results indicated that there was significant difference among the varieties. The plant height was maximum in No. 447 (112 cm) followed by PLS-6028 (111.27 cm) and the minimum was recorded by the variety MG-106 (74.13 cm).

2. Number of branches

There was significant difference among the varieties tested for this character. The variety PLS-6203 recorded the highest mean value (21.83) followed by CODS-1 (21). The lowest value was recorded by PLS-6225 (9.37).

3. Number of pods per plant

There was significant difference among the varieties for this character (Table 3). Variety Thiruvananthapuram local had the maximum number of pods (89.43). The minimum number was found in the variety IC-8619 (18.37).

4. Number of seeds per pod

The results indicated that there was significant difference among the forty eight varieties tested. The maximum number of seeds per pod was recorded by Thiruvananthapuram local (5.73). The variety MG-106 recorded the minimum (4.32). The varieties MG-71, PLS-6164, P. Palayam, PLS-6197, PLS-6166, PLS-6234 and IC-8619 were on par with Thiruvananthapuram local.

5. Seed yield per plant

There was significant difference among the treatments. The variety P. Palayam recorded the highest yield (15.34 g) followed by Thiruvananthapuram local (13.34 g). The lowest yield was observed in PLS-6169 (3.96 g).

6. Length of pod

The length of pod showed significant difference among treatments. The Thiruvananthapuram local had the maximum pod length (5.69 cm), which was on par with Malappuram local, PLS-6079, P. Palayam, PLS-6012 and HG-35. The variety PLS-6227 recorded the minimum (4.36 cm).

7. Root/shoot ratio

There was significant difference among the treatments. The maximum root/shoot ratio was recorded by CODB-1 and PLS-6094 (0.025) and HG-76 recorded the minimum (0.005).

8. Harvest index

The treatments tested showed significant difference for this character. The variety CODB-1 recorded the maximum value (0.209) followed by Thiruvananthapuram local and P. Palayam (0.207). The lowest value obtained for Malappuram local (0.081).

9. Hundred seed weight

The results showed that there was significant difference among the forty eight varieties tested. The seed weight was maximum for the variety IC-8619 (5.29 g) followed by P. Palayam (5.09 g). Thiruvananthapuram local recorded the lowest value (2.53 g) which was on par with the Malappuram local.

10. Days to flowering

There was significant difference among the treatments. The number of days to flowering was maximum in CODB-1 (67.67 days) which was on par with Kozhikode local, PLS-6234. P. Palayam, PLS-6056 and PLS-6243. The minimum was recorded by HG-71 (26.33 days).

11. Days to maturity

There was significant difference among the varieties for this character. The number of days to maturity was maximum for the varieties Kozhikode local (106 days), PLS-6100, PLS-449, PLS-6056, CODB-1, PLS-6234, PLS-6012, PLS-6243, IC-8619, PLS-6203, No. 447, P. Kottai, PLS-6281, PLS-6058 and P. Palayam. The variety HG-71 took the least number of days (75 days) for maturity.

12. Reaction to pests and diseases

The crop was free from incidence of pests or diseases.

II. Coefficient of variation

Phenotypic variance, genotypic variance and coefficients of variation are presented in Table 5.

1. Phenotypic coefficient of variation

The seed yield per plant showed the highest value (45.59 per cent) followed by root/shoot ratio (44.72 per cent) number of pods per plant (43.01 per cent) and harvest index (32.88 per cent). The lowest value was recorded for the character length of pod (7.93 per cent).

2. Genotypic coefficient of variation

High value for genotypic coefficient of variation was recorded for days to flowering (28.18 per cent) followed by root/shoot ratio (25.82 per cent), number of pods per plant (25.65 per cent) and seed yield per plant (24.11 per cent). The minimum value was recorded by length of pod (4.95 per cent).

III. Correlation analysis

a) Correlation between seed yield and other characters

The phenotypic and genotypic correlation coefficients between seed yield and other characters are presented in Table 6.

The genotypic correlations were found to be greater than the phenotypic correlation for all the characters

Table 5. Phenotypic and genotypic variances, mean and phenotypic and genotypic coefficients of variation

Sl. No.	Characters	Phenotypic variance	Genotypic variance	Mean $\bar{x}$	Phenotypic coefficient of variation	Genotypic coefficient of variation
1.	Height of plant	158.711	57.986	95.590	13.18	7.97
2.	Number of branches	19.097	6.857	15.660	27.91	16.72
3.	Number of pods per plant	305.396	108.627	40.630	43.01	25.65
4.	Number of seeds per pod	0.197	0.060	4.830	9.10	5.07
5.	Seed yield per plant	10.537	2.948	7.120	45.59	24.11
6.	Length of pod	0.149	0.058	4.870	7.93	4.95
7.	Root/shoot ratio	0.045×10^{-2}	0.015×10^{-3}	0.015	44.72	25.82
8.	Harvest index	0.002	0.036×10^{-2}	0.136	32.38	13.95
9.	Hundred seed weight	0.464	0.462	3.720	18.31	18.27
10.	Days to flowering	160.108	150.470	43.530	29.07	28.18
11.	Days to maturity	117.683	100.548	96.500	11.24	10.39

Table 6. Genotypic (G) and Phenotypic (P) correlation coefficient between seed yield and other characters

Sl. No.	Characters	Correlation coefficients	
		G	P
1.	Height of plant	-0.0467	-0.0752
2.	Number of branches	0.4548	0.3746**
3.	Number of pods per plant	0.7801	0.8847**
4.	Number of seeds per pod	0.5999	0.4587**
5.	Length of pod	0.4209	0.3536**
6.	Root/shoot ratio	0.2780	-0.1606
7.	Harvest index	0.9342	0.9081**
8.	Hundred seed weight	0.1025	0.0510
9.	Days to flowering	0.0654	0.0335
10.	Days to maturity	-0.0249	0.0519

** Significant at 1 per cent level

except number of pods per plant and days to maturity. Seed yield per plant had positive genotypic correlation with number of branches (0.4548), number of pods per plant (0.7801), number of seeds per pod (0.5999), length of pod (0.4209) and harvest index (0.9342). Low positive genotypic correlation was observed with root/shoot ratio (0.2780), hundred seed weight (0.1025) and days to flowering (0.0654). Height of plant (-0.0467) and days to maturity (-0.0249) exhibited negative genotypic correlation with seed yield per plant and were negligible.

Significant positive phenotypic correlation was observed with number of branches, number of pods per plant, number of seeds per pod, length of pod and harvest index. The highest value was recorded by harvest index (0.9081). Seed yield per plant exhibited non-significant positive phenotypic correlation with hundred seed weight, days to flowering and days to maturity. Height of plant and root/shoot ratio showed non-significant negative phenotypic correlation with seed yield per plant.

b) Correlation between other pairs of characters

The phenotypic and genotypic correlations between characters other than yield are presented in Table 7.

Table 7. Genotypic and phenotypic correlation coefficients between pairs of characters in horsegram

Characters	Height of plant	Number of branches	Number of pods per plant	Number of seeds per pod	Seed yield per plant	Length of pod	Root/shoot ratio	Harvest index	Hundred seed weight	Days to flowering	Days to maturity
Height of plant	–	0.0421	–0.2044*	–0.1770	–0.0752	0.0678	0.0740	–0.0747	0.3013*	0.2529*	0.3116*
Number of branches	0.1553	–	0.2240*	0.1853	0.3746*	0 3126*	0 1520	0 3343*	0.2758*	0.3421*	0.4624*
Number of pods per plant	–0.4169	0.1059	–	0.3552*	0.8847*	0.2588*	–0.2494*	0.8087*	–0.3140*	–0.2125*	–0.1683
Number of seeds per pod	–0.4488	0.1581	0.6272	–	0.4587*	0.4782*	–0.0324	0.4752*	–0.1623	0.0209	0.0620
Seed yield per plant	–0.0467	0.4548	0.7801	0.5999	–	0.3536*	–0.1606	0.9081*	0.0510	0.0335	0.0519
Length of pod	–0.0074	0.4023	0.2286	0.8066	0.4209	–	0.0663	0.3754*	0.0370	0.2751*	0.3674*
Root/shoot ratio	0.4060	0.8993	–0.1362	0.4591	0.2780	0.6214	–	–0.0730	0.2401	0.4801*	0.4764*
Harvest index	0.0871	0.7283	0.7390	0.5103	0.9342	0.5460	0.7343	–	0.0336	0.0537	0.1338
Hundred seed weight	0.4953	0.4625	–0.5123	–0.2968	0.1025	0.0711	0.4179	0.1062	–	0.5988*	0.5398*
Days to flowering	0.4720	0.6472	–0.3485	–0.0166	0.0654	0.4160	0.8452	0.1379	0.6209	–	0.7922*
Days to maturity	0.5574	0.7291	–0.4128	–0.0240	–0.0249	0.5673	0.9471	0.1022	0.5873	0.8833	–

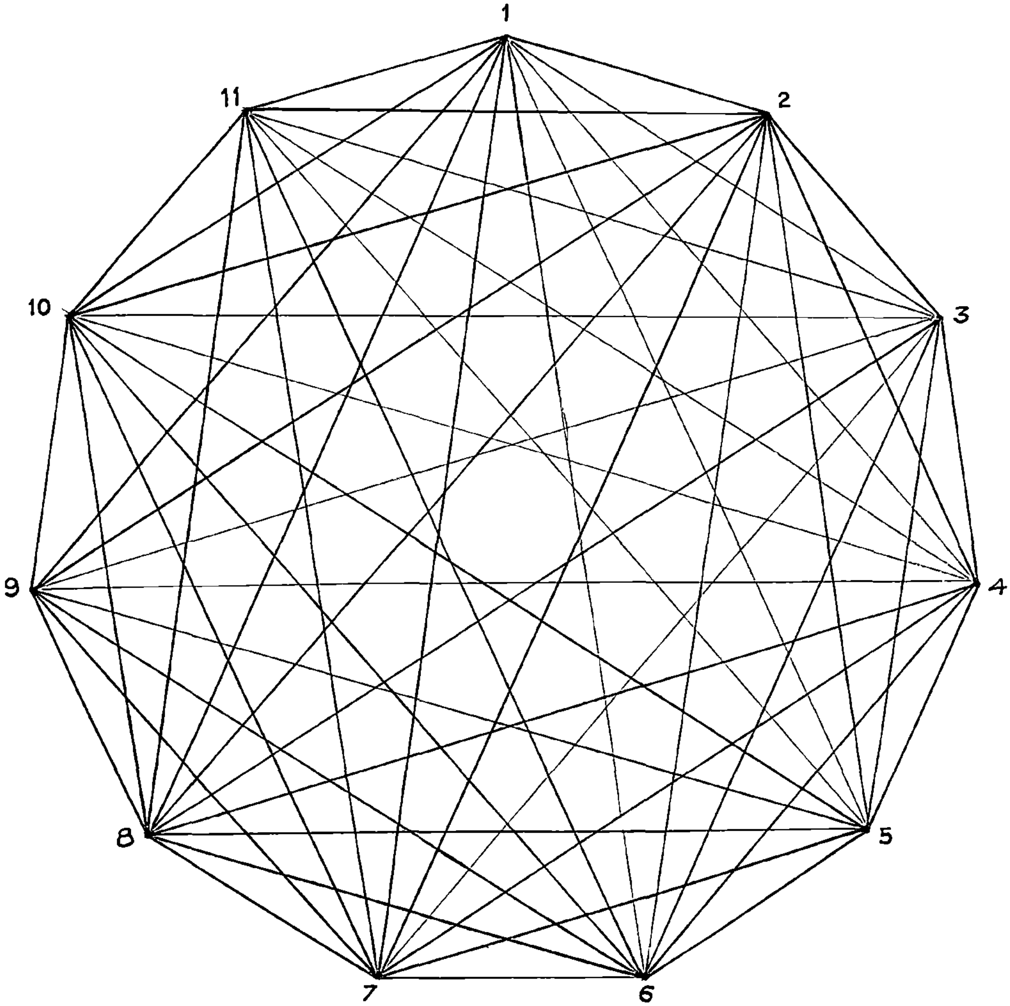
Upper off diagonal values : Phenotypic correlation coefficients * Significant at 5 per cent level

Lower off diagonal values Genotypic correlation coefficients

Figure 1. Genotypic correlation among 11 characters

1. Height of plant
2. Number of branches
3. Number of pods per plant
4. Number of seeds per pod
5. Seed yield per plant
6. Length of pod
7. Root/shoot ratio
8. Harvest index
9. Hundred seed weight
10. Days to flowering
11. Days to maturity

FIG 1 GENOTYPIC CORRELATION AMONG 11 CHARACTERS



1. Height of plant

Height of plant had positive genotypic correlation with number of branches, root/shoot ratio, harvest index, hundred seed weight, days to flowering and days to maturity. Negative genotypic correlation was observed with number of pods per plant, number of seeds per pod, and length of pod.

Significant positive phenotypic correlation was recorded with hundred seed weight, days to flowering and days to maturity while number of pods per plant showed significant negative phenotypic correlation. It had non-significant positive correlation with number of branches, length of pod and root/shoot ratio and non-significant negative phenotypic correlation with number of seeds per pod and harvest index.

2. Number of branches

High positive genotypic correlation was observed with root/shoot ratio (0.8993) followed by days to maturity, harvest index, days to flowering, hundred seed weight and length of pod. Number of seeds per pod and number of pods per plant showed low positive genotypic correlation.

Significant positive phenotypic correlation was recorded with number of pods per plant, length of pod, harvest index, hundred seed weight, days to flowering and days to maturity. It showed non-significant positive correlation with number of seeds per pod and root/shoot ratio.

3. Number of pods per plant

Number of seeds per pod, length of pod and harvest index had positive genotypic correlation with number of pods per plant where harvest index recorded the highest value (0.7390). Root/shoot ratio, hundred seed weight, days to flowering and days to maturity exhibited negative genotypic correlation.

Number of pods per plant exhibited significant positive phenotypic correlation with number of seeds per pod, length of pod and harvest index. This character showed significant negative phenotypic correlation with root/shoot ratio, hundred seed weight and days to flowering. Non-significant negative phenotypic correlation was observed with days to maturity.

4. Number of seeds per pod

Positive genotypic correlation with length of pod, root/shoot ratio and harvest index was observed where length of pod showed the highest value (0.8066). Hundred seed weight, days to flowering and days to maturity recorded negative genotypic correlation with number of seeds per pod.

Significant positive phenotypic correlation was observed with length of pod and harvest index. Non-significant positive phenotypic correlation was exhibited with days to flowering and days to maturity. Root/shoot ratio and hundred seed weight showed non-significant negative correlation with number of seeds per pod.

5. Length pod

Positive genotypic correlation was observed with root/shoot ratio, harvest index, hundred seed weight, days to flowering and days to maturity.

Harvest index, days to flowering and days to maturity exhibited significant positive phenotypic correlation with length of pod. Non-significant positive phenotypic correlation was observed with root/shoot ratio and hundred seed weight.

6. Root/shoot ratio

Harvest index, hundred seed weight, days to flowering and days to maturity recorded positive genotypic correlation with root/shoot ratio.

Significant positive phenotypic correlation was observed with days to flowering and days to maturity. There was non-significant negative phenotypic correlation between harvest index and root/shoot ratio and non-significant positive correlation of root/shoot ratio with hundred seed weight.

7. Harvest index

Hundred seed weight, days to flowering and days to maturity recorded positive genotypic and phenotypic correlation with harvest index.

8. Hundred seed weight

Positive genotypic correlation was recorded with days to flowering and days to maturity. Significant positive phenotypic correlation was observed with days to flowering and days to maturity.

9. Days to flowering

There was positive genotypic and significant positive phenotypic correlation between days to flowering and days to maturity.

IV. Heritability in the broad sense

Estimates of heritability in broad sense are presented in Table 8.

High values of heritability were recorded for the characters viz. hundred seed weight (99.46 per cent), days to flowering (93.98 per cent) and days to maturity (85.44 per cent). Moderate heritability values were observed for length of pod (39.25 per cent), height of plant (36.54 per cent), number of branches (35.91 per cent), number of pods per plant (35.57 per cent), root/shoot ratio (32.79 per cent) and number of seeds per pod (30.65 per cent). Seed yield per plant (27.97 per cent) and harvest index (14.63 per cent) showed low heritability.

V. Expected genetic advance

Results are presented in Table 8.

Days to flowering (56.28 per cent) recorded the maximum genetic advance followed by hundred seed weight (37.63 per cent), number of pods per plant (31.50 per cent), root/shoot ratio (30.00 per cent), seed yield per plant (26.26 per cent), number of branches (20.63 per cent) and days to maturity (19.78 per cent). Very low values were observed for harvest index (11.03 per cent), height of plant (9.92 per cent) and length of pod (6.37 per cent).

Figure 2. Genetic parameters

X_1 - Height of plant

X_2 - Number of branches

X_3 - Number of pods per plant

X_4 - Number of seeds per pod

X_5 - Seed yield per plant

X_6 - Length of pod

X_7 - Root/shoot ratio

X_8 - Harvest index

X_9 - Hundred seed weight

X_{10} - Days to flowering

X_{11} - Days to maturity

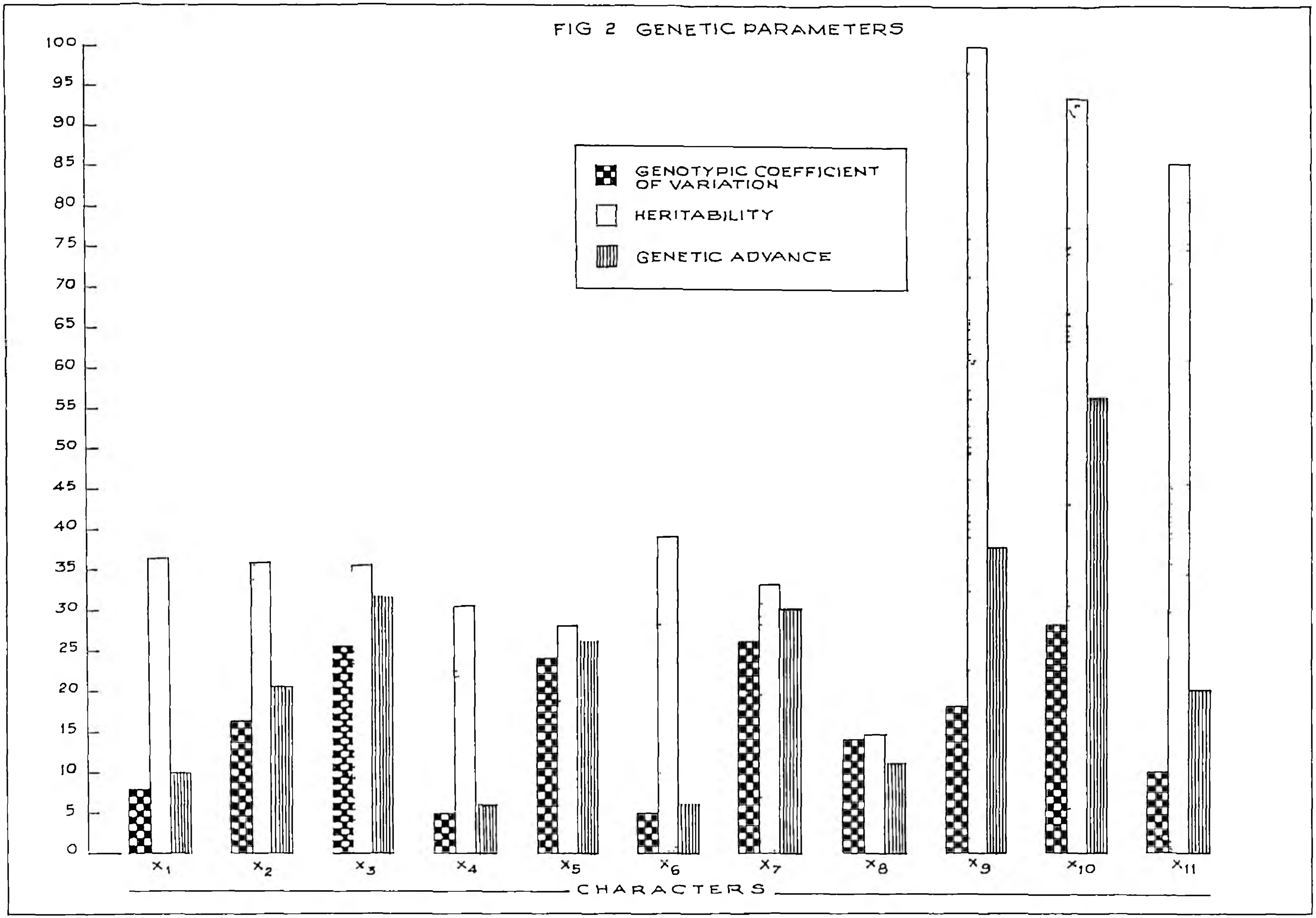


FIG 2 GENETIC PARAMETERS
GENOTYPIC COEFFICIENT OF VARIATION
HERITABILITY
GENETIC ADVANCE
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
X1
X2
X3
X4
X5
X6
X7
X8
X9
X10
X11
CHARACTERS

Table 8. Heritability and expected genetic advance

Sl. No.	Characters	Heritability percentage (H^2)	Expected genetic advance as percentage of mean
1.	Height of plant	36.54	9.92
2.	Number of branches	35.91	20.63
3.	Number of pods per plant	35.57	31.50
4.	Number of seeds per pod	30.65	5.80
5.	Seed yield per plant	27.97	26.26
6.	Length of pod	39.25	6.37
7.	Root/shoot ratio	32.79	30.00
8.	Harvest index	14.63	11.03
9.	Hundred seed weight	99.46	37.63
10.	Days to flowering	93.98	56.28
11.	Days to maturity	85.44	19.78

VI. Path Analysis

Path analysis was done using those characters which showed positive correlation with seed yield. This technique is effective in partitioning the observed genotypic correlation into direct and indirect effects. The results obtained by path analysis are presented in Table 9 and Figure 3.

From the results it is seen that the maximum direct effect on yield was contributed by number of pods per plant (1.6597) while its genotypic correlation with seed yield was 0.7801. The positive indirect effects via number of branches (0.0669) and length of pod (0.2182) and negative indirect effect via number of seeds per pod (-0.5606) and harvest index (-0.6042) along with its direct effect contributed resulted in this genetic correlation.

Length of pod had the second highest positive direct effect on seed yield (0.9547), but the value of genotypic correlation was low (0.4209) compared to the direct effect. It had positive indirect effect via number of branches (0.2541) and number of pods per plant (0.3794) and negative indirect effect via number of seeds per pod (-0.7209) and harvest index (-0.4464). The negative indirect effects were larger than the positive direct effects and this led to a reduction in the magnitude of correlation.

Table 9. Direct and indirect effects of the various characters on yield in horsegram

Characters	Number of branches	Number of pods per plant	Number of seeds per pod	Length of pod	Harvest index	Total correlation
Number of branches	0.6317	0.1758	-0.1413	0.3841	-0.5954	0.4548
Number of pods per plant	0.0669	1.6597	-0.5606	0.2182	-0.6042	0.7801
Number of seeds per pod	0.0999	1.0410	-0.8938	0.7700	-0.4172	0.5999
Length of pod	0.2541	0.3794	-0.7209	0.9547	-0.4464	0.4209
Harvest index	0.4601	1.2265	-0.4561	0.5213	-0.8176	0.9342

Residual effect - 0.5622

Diagonal elements - Direct effects

Off-diagonal elements - Indirect effects

Figure 3. Path diagram

Sy - Seed yield

X_1 - Number of branches

X_2 - Number of pods per plant

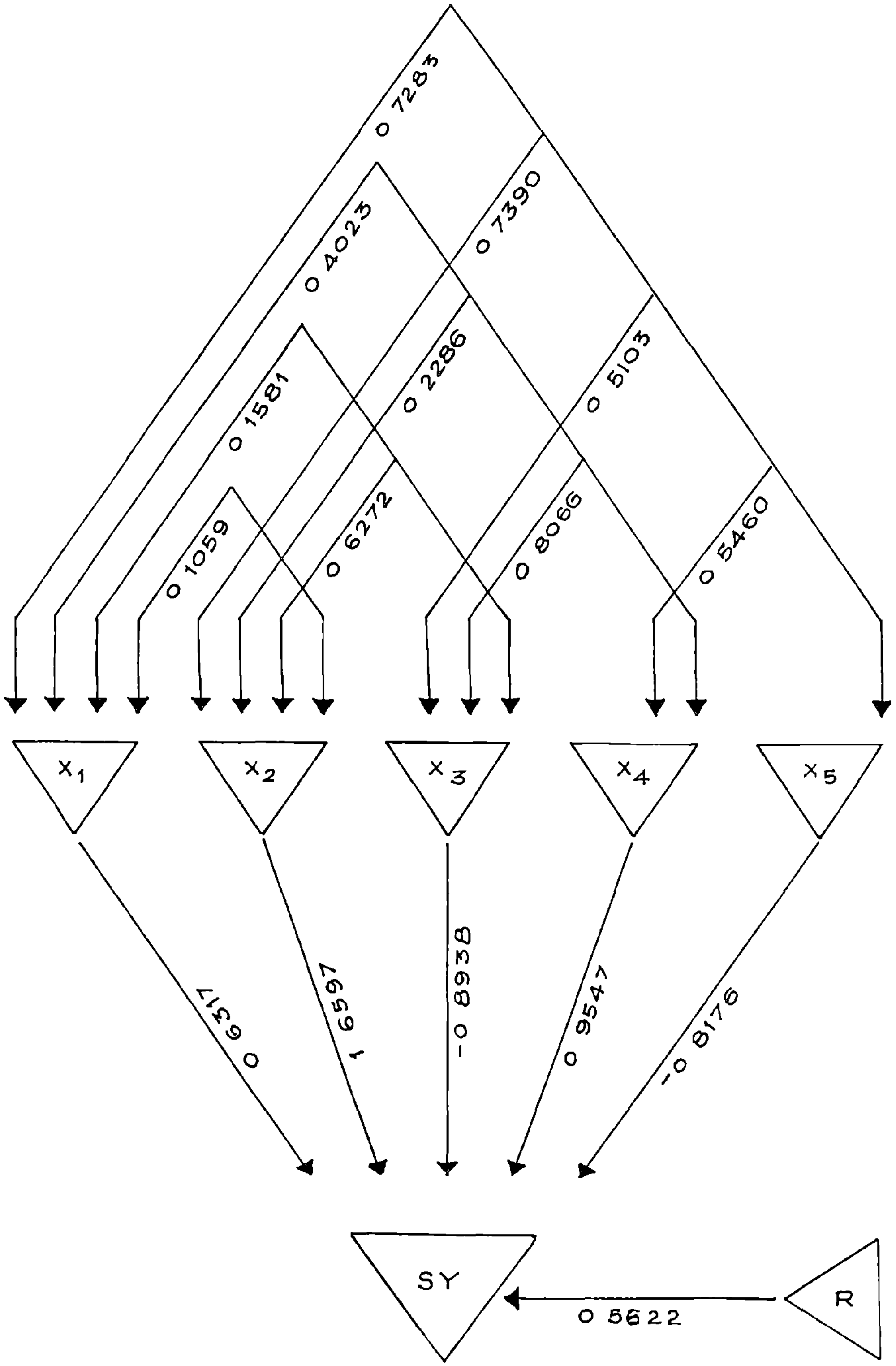
X_3 - Number of seeds per pod

X_4 - Length of pod

X_5 - Harvest index

R - Residue

FIG 3 PATH DIAGRAM



Number of branches had a positive direct effect on yield (0.6317). The positive indirect effects via number of pods per plant and length of pod and negative indirect effects via number of seeds per pod and harvest index resulted in a reduction of direct effect leading to a genotypic correlation of 0.4548.

The correlation between number of seeds per pod and yield was positive (0.5999) while its direct effect was negative. Its high positive indirect effect via number of pods per plant (1.0410) and length of pod (0.7700) resulted in a positive correlation. The indirect effect of it in harvest index was negative (-0.4172).

The correlation between harvest index and yield was positive and high (0.9342) while the direct effect of harvest index on yield was negative (-0.8176). The positive indirect effects via number of branches (0.4601), number of pods per plant (1.2265) and length of pod (0.5213) are responsible for this positive correlation. The indirect effect of number of seeds per pod was negative (-0.4561).

All the above characters explained the variation in yield by about 44 per cent as evidenced from the residue value of 0.5622.

DISCUSSION

DISCUSSION

In the present study forty eight genotypes of horsegram were evaluated for yield and yield components. The results are discussed here under.

Variability

The naturally occurring variation in population of self pollinated species is the primary basis for improvement of these species (Allard, 1960). Horsegram, being a self pollinated crop, the natural variability for yield and its components is very limited. However, a knowledge of the extent of the genetic variation available for yield and its components is always helpful to the breeder.

Variance and coefficient of variation help to measure the variability in a population. It is necessary to partition the overall variability into heritable and non-heritable components.

The differences between the genotypes were highly significant for all the eleven characters studied. The estimates of variance components indicated only little difference between phenotypic and genotypic variances for the characters viz. number of seeds per pod, length of pod, root/shoot ratio, harvest index and hundred seed weight (Table 5). This indicates that variations observed in these characters were mainly due to genetic causes and that environment had only negligible influence over them and there is better scope of improvement of these characters through selection.

On the other hand, the characters viz. height of plant, number of branches, number of pods per plant, seed yield per plant, days to flowering and days to maturity showed wide difference between phenotypic and genotypic variance denoting the greater influence of environment on them.

Coefficient of variation

High genotypic coefficient of variation observed for number of branches, number of pods per plant, seed yield per plant, root/shoot ratio, hundred seed weight and days to flowering indicates the presence of high degree of genetic variability and better scope for the improvement of these characters through selection.

The characters viz. height of plant, number of seeds per pod, length of pod, harvest index and days to maturity showed low genotypic coefficient of variation indicating the low amount of variability in these characters and thereby limiting the scope for their improvement through selection. Hence it is suggested to create variability for these traits through either biparental crosses or mutation.

The low genotypic coefficient of variation observed for height of plant in this study agrees with the findings of Shivashankar et al. (1977) in horsegram and Kumar et al. (1981) in chickpea.

Number of branches showed a high genotypic coefficient of variation in the present investigation which is in agreement with the findings of Rashid and Islam (1982) in soyabean and Gupta et al. (1986) in pea.

The high genotypic coefficient of variation obtained for number of pods per plant agrees with the results of Srivastava and Sachan (1974) and Gupta et al. (1986) in pea; Arunachala (1979) in field bean; Radhakrishnan and Jebaraj (1982) and Patil and Baviskar (1987) in cowpea; Rashid and Islam (1982) in soyabean; Shoran (1983) in redgram and Liu et al. (1984) in greengram. In horsegram, Ganeshaiah et al. (1982) reported low genotypic coefficient of variation for this character.

Number of seeds per pod exhibited a low genotypic coefficient of variation in this study. Hirachand et al. (1975) and Kumar et al. (1981) in chickpea, Shivashankar et al. (1977) and Ganeshaiah et al. (1982) in horsegram and Kumar and Reddy (1982) in redgram obtained the same result, but in horsegram Birari et al. (1987) reported high gcv.

High genotypic coefficient of variation was obtained for seed yield per plant which agrees with the findings of Aggarwal and Kang (1976) in horsegram, Arunachala (1979) and Pandita et al. (1980) in field bean, Rashid and Islam (1982) in soyabean, Gupta et al. (1986) in pea, Maloo and Sharma (1987) in gram and Patil and Baviskar (1987) in cowpea.

Length of pod showed low genotypic coefficient of variation in this investigation. In horsegram Ramakrishnan et al. (1978) and in chickpea Kumar et al. (1981) obtained the same result while Patel and Shah (1982) reported high gcv in blackgram.

Root/shoot ratio exhibited high genotypic coefficient of variation which is in agreement with the finding of Sudha Rani (1989) in blackgram.

In this investigation harvest index showed low genotypic coefficient of variation as against observation by Ram et al. (1976) in pigeonpea. Mandal and Bahl (1983) obtained low value of gcv for this character in chickpea.

Hundred seed weight showed high genotypic coefficient of variation which agrees with the findings of Singh and Singh (1975) in lentil, Balyan and Sudhakar (1985) in pigeonpea, Gupta et al. (1986) in pea and Patil and Baviskar

(1987) in cowpea. In horsegram Suraiya (1980) and Ganeshaiah et al. (1982) reported low values of gcv.

High genotypic coefficient of variation obtained for days to flowering is in agreement with the finding of Suraiya (1980) in horsegram. However Ganeshaiah et al. (1982) reported low values of gcv for this character in horsegram.

Low genotypic coefficient of variation was obtained for days to maturity in this study. Aggarwal and Kang (1976), Ganeshaiah et al. (1982) and Birari et al. (1987) obtained the same result in this crop.

Correlation studies

Yield, an extremely complex character is the result of many growth functions of the plant. Therefore, an estimation of inter-relationship of yield with other traits is of immense help in any crop improvement programme. This would facilitate effective selection for simultaneous improvement of one or many yield contributing components.

In the present study, number of branches, number of pods per plant, number of seeds per pod, length of pod, root/shoot ratio, harvest index, hundred seed weight and days to flowering exhibited positive genotypic correlation with seed yield. The positive genotypic correlation observed for seed yield with number of pods per plant and hundred seed weight agrees with the findings of Aggarwal and Kang (1976) and Patil and Deshmukh (1983) in horsegram and Maloo and Sharma (1987) in chickpea. Singh (1977) in lentil, Singh (1978) in chickpea and Thiyagarajan and Rajasekaran (1989) in cowpea reported negative correlation between seed yield and hundred seed weight.

The positive genotypic correlation obtained between seed yield and number of branches is in agreement with the finding of Aggarwal and Kang (1976) in horsegram.

Srivastava *et al.* (1976) in soyabean, Shivashankar *et al.* (1977) and Birari *et al.* (1987) in horsegram reported positive correlation between seed yield and seeds per pod as observed in the present study.

The positive correlation of seed yield with length of pod agrees with the findings of Aggarwal and Kang (1976) and Suraiya (1980) in horsegram.

The positive genotypic correlation between seed yield and harvest index is in agreement with the findings of Ram *et al.* (1976) in pigeonpea, Singh (1977) in lentil, Singh and Malik (1985) in greengram and Rajesh Mishra *et al.* (1988) in bengalgram.

Height of plant and days to maturity showed negative genotypic correlation with seed yield which is contradictory to the findings of Gautam and Singh (1977) in soyabean and Thiyagarajan and Rajasekaran in cowpea (1989). Tong (1986) reported negative genotypic correlation between seed yield and plant height in soyabean. Days to maturity was negatively correlated to seed yield in horsegram as reported by Aggarwal and Kang (1976).

Heritability

Burton (1952) suggested that genotypic coefficient of variation along with heritability would provide a better picture of the amount of advance to be expected by phenotypic selection.

In the present study, hundred seed weight, days to flowering and days to maturity recorded high heritability values indicating that they are less influenced by environment. Aggarwal and Kang (1976) and Ramakrishnan et al. (1978) obtained the same result in horsegram. High heritability recorded for hundred seed weight is in agreement with the findings of Singh and Singh (1975) in lentil, Shivashankar et al. (1977) and Birari et al. (1987) in horsegram, Godawat (1980) and Yadavendra et al. (1981) in pigeonpea, Medhi et al. (1980) and Patil et al. (1987) in greengram. Regarding days to flowering high heritability estimates were observed by Tikka and Assawa (1977) and Rasaily et al. (1986) in pea, Ganeshaiah (1980) in horsegram and Patil et al. (1987) in greengram.

Rashid and Islam (1982) in soyabean, Rasaily et al. (1986) in pea, Birari et al. (1987) in horsegram and Patil and Baviskar (1987) in cowpea reported high heritability values for days to maturity.

Moderate values of heritability were recorded for height of plant, number of branches, number of pods per plant, number of seeds per pod, length of pod and root/shoot ratio. Moderate heritability recorded for height of plant is in agreement with the findings of Aggarwal and Kang (1976) in horsegram. However, high heritability values for plant height was recorded by Singh and Dixit (1970) in lentil, Singh et al. (1975) and Soundrapandian et al. (1975) in blackgram, Ramakrishnan et al. (1978) in horsegram, Singh (1985) in pea and Patil et al. (1987) in greengram. However, Shivashankar et al. (1977) reported low heritability for this character in horsegram.

Moderate heritability value for number of branches agrees with the findings of Aggarwal and Kang (1976) in horsegram. Malhotra and Sodhi (1977) in pigeonpea and Das (1978) in blackgram.

Number of pods per plant showed moderate heritability value in this study which is in agreement with the findings of Aggarwal and Kang (1976) in horsegram, Malhotra and Sodhi (1977) in pigeonpea and Pandita et al. (1980) in Indian bean. High heritability values for this character was obtained by Tikka and Assawa (1977) and Singh (1985) in pea, Tikka et al. (1977) in moth bean, Das (1978) in blackgram, Ramakrishnan et al. (1978) in horsegram and Maloo and Sharma (1987) and Rajesh Mishra et al. (1988) in chickpea. However, Shivashankar et al. (1977) and Birari et al. (1987) reported low heritability values for number of pods per plant in horsegram.

Number of seeds per pod showed moderate heritability estimate which is in agreement with the findings of Aggarwal and Kang (1976), Shivashankar et al. (1977) in horsegram and Baswana et al. (1980) in Indian bean, but Yadavendra et al. (1981) and Patil et al. (1987) in greengram obtained high values. Ramakrishnan et al. (1978) and Birari et al. (1987) recorded low values of heritability for this character in horsegram.

Moderate heritability estimate for length of pod obtained in this study agrees with the findings of Aggarwal and Kang (1976) and Ramakrishnan et al. (1978) in horsegram.

Moderate heritability value for root/shoot ratio recorded is in agreement with the findings of Sudha (1989) in blackgram.

Low heritability values observed for seed yield per plant and harvest index agrees with the findings of Shivashankar *et al.* (1975) in horsegram.

Genetic advance

Heritability values alone may not provide a clear predictability of the breeding value. Heritability along with genetic advance is more effective and reliable in predicting the resultant effect of selection than heritability alone (Johnson *et al.*, 1955). High heritability along with high genetic advance was recorded by days to flowering and hundred seed weight. Moderately high heritability and appreciable genetic advance were recorded by number of branches, number of pods per plant and root/shoot ratio. High heritability along with high genetic advance indicate the role of additive gene action for the character concerned as suggested by Panse (1957).

High heritability and low genetic advance were recorded for days to maturity, while moderately high heritability and low genetic advance were observed for height of plant, number of seeds per pod and length of pod. High heritability coupled with low genetic gain indicates non-additive gene action which greatly limit the scope for improvement of these characters through selection. Non-additive gene action can be capitalised through biparental mating followed by development of purelines through pedigree method.

Hundred seed weight showed high estimates of heritability and genetic advance which agrees with the findings of Singh and Singh (1975) in lentil, Shivashankar et al. (1977) in horsegram, Balyan and Sudhakar (1985) in pigeonpea and Khorgade et al. (1985) in chickpea. High heritability and genetic advance for days to flowering is in agreement with the findings of Govil and Kumar (1989) in chickpea.

High heritability and low genetic advance were obtained for days to maturity as reported by Aggarwal and Kang (1976). Ganeshaiah et al. (1982) in horsegram and Radhakrishnan and Jebaraj (1982) in cowpea.

Moderate heritability and genetic advance were recorded for pods per plant and root/shoot ratio. Aggarwal and Kang (1976) in horsegram and Malhotra and Sodhi (1977) in pigeonpea reported moderate estimates of heritability and genetic advance for pods per plant. Sudha (1989) obtained moderate values of heritability and genetic advance in blackgram for root/shoot ratio.

Moderate heritability in conjuction with low genetic advance obtained for length of pod i in agreement with the findings of Aggarwal and Kang (1976) Ramakrishnan et al. (1978) in horsegram and Malhotra an Sodhi (1977) in pigeonpea. Number of seeds per po also recorded moderate heritability and low genetic advance which agrees with the findings of Shivashankar et al. (1977) in horsegram. Radhakrishnan and Jebaraj (1982) reported moderate heritability and low genetic advance for plant height which supports the result obtained in the present study.

Low heritability and low genetic advance were observed for seed yield per plant and harvest index. The present finding regarding seed yield per plant is in agreement with Singh and Singh (1975) in lentil and Shivashankar et al. (1977) in horsegram. Mandal and Bahl (1983) in chickpea reported low heritability and genetic advance for harvest index.

Path analysis

The path analysis revealed that number of pods per plant had the highest positive direct effect on seed yield followed by length of pod and number of branches. Number of seeds per pod and harvest index showed a negative direct effect on seed yield.

The high positive direct effect of number of pods per plant found in this study is in agreement with the findings of Gowda and Pandya (1975), Maloo and Sharma (1987) in chickpea, Aggarwal and Kang (1976) in horsegram, Singh (1977) in lentil, Jindal and Gupta (1984) in cowpea, Rasaily (1986) in soyabean and Prem Sagar et al. (1987) in redgram. It was interesting to note that the direct effect of this character on seed yield was even more than its correlation coefficient. The correlation value of this character with yield was reduced probably due to its high negative indirect effect via number of seeds per pod and harvest index.

Length of pod also showed positive direct effect on yield. This result is in agreement with the findings of Suraiya (1980) in horsegram and Jindal and Gupta (1984) in cowpea. This shows that selection of varieties with longer pod would be effective in improving yield in this crop.

Number of branches showed positive direct effects on yield. However, total correlation is lower than the direct effect due to its negative indirect effect via number of seeds per pod and harvest index. Veeraswamy et al. (1975) in pigeonpea, Hanchinal et al. (1979) in cowpea and Geetha Philip (1987) in blackgram reported that number of branches per plant produced a positive direct effect on seed yield.

It was interesting to note that number of seeds per pod and harvest index which had a strong positive correlation with seed yield had negative direct effect on seed yield. These negative direct effects were counter-balanced by high positive indirect effects via number of pods per plant and length of pod.

The direct negative effect of number of seeds per pod on yield was in conformity with the findings of Soundrapandian et al. (1976) and Geetha Philip (1987) in blackgram. However, Narasinghani et al. (1978) in pea, Sandhu et al. (1980) in greengram, Pani and Rao (1980) in blackgram, Tyagi et al. (1982) in chickpea and Jindal and Gupta (1984) reported that number of seeds per pod had the greatest direct effect on seed yield.

Harvest index had a negative direct effect on yield but the total correlation was positive. Here the indirect effects seem to be the cause of correlation and the indirect causal factors such as number of pods per plant, length of pod and number of branches are to be considered simultaneously during selection programme (Singh and Choudhary, 1979). However, in field bean, Teotia et al. (1983) obtained positive direct effect of harvest index on yield.

The charactors studied in this model explained the variation in yield by about 44 per cent as indicated by the residue value of 0.5622.

Therefore, it is recommended on the basis of the present investigation carried out in horsegram, that for selection of a high yielding and adaptable variety, the model for selection should be based on number of pods per plant, length of pod and number of branches per plant.

The varieties P. Palayam, CODB-1, Calicut local, PLS-6056 and No. 447 were found to fit in this model.

SUMMARY

SUMMARY

The present study was conducted at the Department of Plant Breeding, College of Agriculture, Vellayani during Rabi 1989. Forty eight varieties of horsegram belonging to different agro-climatic regions were grown in a Randomised Block Design with three replications. Data were collected on seed yield per plant and ten other characters viz. height of plant, number of branches, number of pods per plant, number of seeds per pod, length of pod, root/shoot ratio, harvest index, hundred seed weight, days to flowering and days to maturity.

The following are the important results obtained in this investigation:

1. Analysis of variance revealed significant differences among the varieties in respect of all characters studied.
2. Of the eleven characters studied genotypic coefficient of variation was maximum for days to flowering. For characters like hundred seed weight, days to flowering and days to maturity there was only little difference in phenotypic coefficient of variation and genotypic coefficient of variation. For all other characters there was wide difference between phenotypic coefficient of variation and genotypic coefficient of variation indicating higher environmental influence.

3. At genotypic level, seed yield per plant showed positive correlation with all characters except height of plant and days to maturity. Harvest index and number of pods per plant showed high positive correlation with seed yield per plant.

4. Heritability was maximum for hundred seed weight and minimum for harvest index. Characters like days to flowering and days to maturity also had high heritability estimates indicating lesser influence of environment.

5. Genetic advance as percentage of mean showed that days to flowering had maximum genetic gain followed by hundred seed weight. High heritability coupled with high genetic gain was recorded for days to flowering and hundred seed weight indicating the presence of additive gene action.

6. Path coefficient analysis at the genotypic level revealed that number of pods per plant, length of pod and number of branches exerted high direct influence on yield.

The above results thus, shows that a model based on number of branches, number of pods per plant and length of pod should be given due weightage by pulse breeders in making selection for high yielding and adaptable strains in horsegram.

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* Original not seen

GENETIC ANALYSIS OF PRODUCTIVITY PARAMETERS IN HORSEGRAM

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ABSTRACT OF A THESIS

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ABSTRACT

A study on the parameters of variability, correlation and path coefficient were undertaken in forty eight horsegram varieties. The study was conducted at the Department of Plant Breeding, College of Agriculture, Vellayani during Rabi 1989.

The varieties showed significant differences in all the characters studied. Genotypic coefficient of variation was maximum for days to flowering and minimum for length of pod. High heritability estimates were observed for hundred seed weight and days to flowering. Genetic gain was maximum for days to flowering. Hundred seed weight and days to flowering recorded high heritability and high genetic gain indicating the presence of additive gene action. At the genotypic level seed yield showed high positive correlation with harvest index and number of pods per plant. Path coefficient analysis projected number of pods per plant, length of pod and number of branches as the traits exerting high positive direct effect on seed yield.

The study indicated that the model for plant selection in horsegram should be one with more number of branches, long pods and more number of pods per plant.

The varieties P. Palayam, CODB-1, Calicut local, PLS-6056 and No. 447 were found to fit in this model.