POTENTIAL FOR DROUGHT TOLERANCE IN GREENGRAM (*Vigna radiata (L) wilczek*)

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DECLARATION

I hereby declare that this thesis entitled "Potential for drought tolerance in greengram (Vigna radiata (L) Wilczek)" is a bonafide record of research work done by me and that the thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Potential for drought tolerance in greengram (*Vigna radiata* (L) Wilczek)" is a record of research work done independently by Kum. ANITHA, A.R. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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INTRODUCTION

INTRODUCTION

Crop production is usually limited by insufficient water at some time or other during the growing season. Even in humid parts of the world, periods of insufficient rainfall and thus water stress commonly occur. In many dry areas of the world crop production without irrigation is very low. Water supplies that can be used for irrigation are also very limited. In future irrigation will probably face more limitations because of competing uses of water. Thus the possibility of dealing with water stress even with irrigation will become more of a reality in future. Population increase will further necessitates the cultivation of marginal lands with low water holding capacity. Thus there will undoubtedly be much more demand in future for knowledge about the influence of plant water stress on crop production.

Environmental stress problems are generally very difficult to deal with by breeding because their complex nature requires a wide array of genetic response mechanisms. The response of plants to drought is not well understood physiologically but is the net result of several systems including the leaf and root characters which can function efficiently during periods of water stress. The present study was undertaken by considering these aspects.

Greengram Vigna radiata (L) Wilczek is an important pulse crop of India cultivated in an area of 2.84 million hectares with an annual production of 1.09 million tonnes (Lal, 1987). In India where vegetarianism is the general habit of people pulses form an important source of protein in their diet. The crop is also grown as a fodder, green manure and cover crop.

At present the national average yield of greengram is as low as 384 kilogrammes per hectare. With the present trend of population growth, it is essential that immediate steps have to be taken to boost the currently stagnant pulse production in the country.

One of the major reasons for low yield is the lack of sufficient irrigation facilities. In India a major portion of the cultivated area is prone to long or short periods of drought and only very little facilities are available for irrigation. Thus a major part of the cultivated area remains under purely rainfed conditions. Apart from this the precipitation received during monsoon is only for a short period and the distribution of rainfall is often so faulty that long spells of drought occurs in the rainfed areas.

In Kerala greengram is cultivated as a rainfed crop without irrigation in the summer rice fallows after the first or second crop of paddy, as an intercrop in coconut gardens or as a mixed crop along with tapioca, banana and yams. In such a situation identification of superior greengram varieties having tolerance to drought will be a major breakthrough in increasing yield.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Moisture stress does not affect all aspects of plant growth and development equally. Some processes are highly susceptible to increasing moisture stress while others are far less affected. The final yield of the crop will be the integral result of these effects of stress on growth, respiration, photosynthesis, metabolic processes and reproduction. Only very limited works have been reported in pulses on their performance under drought conditions. Hence similar works in pulses and other crops were reviewed.

2.1. Vegetative performance

Much of the literature on crop response to drought focuses on yielding ability. However, there are several reports of specific vegetative effects associated with growth under suboptimal moisture. The general effect of drought on vegetative performance is a reduction in size of the particular plant part that is developing when the plant is subjected to stress. The major vegetative components influenced by drought stress include plant height, number of leaves per plant, leaf area index, stomatal distribution, root characters and root/shoot ratio.

2.1.1. Plant height

A considerable reduction in plant height was observed by Miler et al (1972) in *Vigna sinensis* and Kapuya (1972) in tomato under suboptimal moisture conditions.

Ali and Alam (1973) also observed a significant reduction in plant height during stress in greengram. Considerable reduction in plant height at boot stage was reported by Sandhu and Horton (1977) in oats under water stress. Momen et al (1979) reported that limited soil moisture influences field crop performance by reducing plant height in soybean.

Considerable reduction in plant height was also observed in *Vigna subterranea* under severe moisture stress. (Elia and Mwandemele, 1986).

2.1.2. Number of leaves per plant

In a study conducted by Sosbee and Wiebe (1971) in barley it was found that plants receiving adequate soil water were ahead in leaf production than the stressed plants.

Ali and Alam (1973) reported a reduction in the number of leaves per plant in greengram under conditions of water stress.

Sivakumar and Shaw (1978a) found that soybeans in irrigated plots were superior to those in non-irrigated plots in the average size and number of leaflets par plant.

Turk and Hall (1980) observed that in cowpea increasing levels of drought resulted in a reduction in the number of leaflets.

Vidal (1981) reported that drought resistant varieties of soybean tended to loose more leaves than susceptible varieties when under water stress but showed a small decrease in leaf size.

Ghuman et al (1985) reported a reduction in the number of leaves and shoot dry matter in wateryam due to early stress. Talukder (1987) also observed a reduction in number of leaves during moisture stress in wheat.

2.1.3. Leaf area

According to Kramer (1959) a small leaf area was characteristic of reduced drought injury in crop plants. Boyer (1970) reported that in corn, soybean and sunflower, leaf enlargement was considerably inhibited by low leaf water potentials. Reaction to drought by restricting leaf area development has been reported in sunflower by Eckerdt et al (1971).

A reduction in leaf area with an increase in water deficit during the vegetative and flowering to pod formation stage has been reported by Hiler et al (1972) in southern peas. Hsiao (1973) observed that sensitivity of drymatter yield to stress was greater under conditions of low leaf area index.

Ali and Alam (1973) observed significant reduction in leaf area in green gram during stress.

Leaf area adjustment has been suggested as one of the most powerful means of avoiding stress by Passioura (1976). According to Thomas et al (1976) the only visual indication of plant adaptation under moisture stress was the reduction of leaf area as compared to the control plants. Sivakumar and Shaw (1978 b) observed that rate of leaf area expansion per plant over a period of time had a close correspondence with soil water potential in soybean. Jurgens et al (1978) found that when drought was imposed in maize, leaf area began to decline. Momen et al (1979) reported that in soybean limited soil moisture influenced field crop performance by reducing the size of assimilating leaf area.

In a study on the water relations of three cowpea cultivars Babalola (1980) observed a high leaf area index under stress. Turk and Hall (1980) observed that in cowpea increasing levels of drought resulted in progressively less leaf area and average leaflet area with total leaf area having the greatest sensitivity to drought. In a study on water relations in maize and cucumber seedlings Aggarwal and Sinha (1983) observed that leaf area decreased almost linearly with increasing severity of stress. Venkataramana et al (1984) also reported similar reduction in leaf area index in field grown sugarcane under drought.

Studies conducted by Singh et al (1985) in greengram indicated a high leaf area index in varieties grown in summer as compared to Kharif.

In a study conducted by Menzel et al (1986) in passion fruit, leaf area per plant of the driest treatment was only 11.5 per cent of the regularly watered vines.

Talukder (1987) observed that in wheat moisture stress decreased the green leaf area index by reducing leaves per stem, area per leaf and by increasing the number of wilted leaves.

2.1.4. Stomatal distribution

Stomata plays an important role in deciding the plants response to water deficit. According to Kramer (1959) a reduced number of stomates per unit leaf area was an important structural characteristic that reduced drought injury in plants.

Significant differences in stomatal density, aperture and behaviour has been reported among varieties by Babalola (1980) in a study on water relations in cowpea.

Scienza and Boselli (1981) reported that stomatal frequency was lower in grapevine root stocks which were drought resistant than in those which were not.

2.1.5. Root characters

A well developed and wide spreading rootsystem is an important characteristic that reduces drought injury in plants. Kramer (1959) suggested that superior drought resistance of sorghum when compared to corn was due to its large and extensive root system. Studies conducted by Tiwari et al (1974) in wheat revealed that varieties with great number, deep vertical penetration and a more horizontal spread of seminal roots were drought escaping and high yielding. Sharma and Ghildyal (1977) reported that root length of wheat genotypes became significantly greater as the soil water tension increased. The dry weight of roots per unit root volume also increased significantly with increasing soil water tension.

Sandhu and Horton (1977) observed that oats plants growing under water stress conditions appeared to root to a greater depth than those under normal conditions. In studies conducted on the water relations of three cowpea varieties Babalola (1980) found that the variety Newera maintained a high productivity even under moisture stress conditions, because of its better root system development. Raychaudhuri and Gupta (1981) reported that a fairly deep root system was characteristic of the drought tolerant upland varieties of rice. Kavitha (1982) observed that a deep and well developed root system will help to get maximum yield under moisture stress conditions in blackgram.

In soybean, Garay and Wilhelm (1983) noticed maximum root proliferation in the deeper wetter soil layers, under midsummer drought conditions. In general roots appeared to proliferate in those soil zones with lowest soil water tension.

In a study on the drought response of grain legumes Pandey et al (1984b) observed that peanut and cowpea had greater root densities at the lower depths particularly in the driest regime which makes them more drought tolerant compared to mungbean and soybean which had a shallow root system only. Chuman et al (1985) reported that the greater drought sensitivity of water yam was due to its shallow root system. A high root weight and root length were observed by Kolotilov and Kolotilova (1985) in <u>Lathyrus sativus</u> under conditions of moisture stress. Singh and

Afria (1985) reported that high moisture stress increased root length in cotton.

A higher root density has been observed in the 20-60 cm soil layer in bean <u>Phaseolus vulgaris</u> by Guimaraes (1986).

Arjunan et al (1988) reported larger and deeper root systems in drought tolerant varieties of groundnut.

2.1.6. Root/Shoot ratio

According to Killian and Lemee (1956) a high root to shoot ratio was an effective means of adaptation of plants to drought conditions and under such conditions the growth rate of the roots considerably exceeded that of the shoots.

A high root/shoot ratio was observed in grasses by Sosbee and Wiebe (1971) and in mung bean by Ali and Alam (1973) under stress conditions.

In a study on the response of two species of rape seed to drought stress Richards and Thurling (1978a) observed that a smaller root weight relative to the above ground plant weight and a greater tap root weight relative to lateral root weight was associated with higher yield in both species.

Studies based on the effect of water stress on three cowpea varieties Babalola (1980) reported that the variety showing maximum drought tolerance had the highest root/shoot ratio as compared to the other varieties.

Aggarwal and Sinha (1983) observed that in maize and cucumber seedlings, as water potential declined roots gained weight whereas leaves lost weight resulting in a high root to shoot ratio.

Pandey et al (1984b) reported a shoot weight reduction of 78 per cent in mungbean, 52 per cent in soybean, 60 per cent in cowpea and 37 per cent in peanut under conditions of drought.

Chang and Wang (1985) observed significant differences between varieties of soybean under drought stress in root dry weight, shoot dry weight and root/shoot ratio.

Schulze (1986) also suggested that water shortage significantly affected extension growth and root/shoot ratio on a whole plant level.

In passionfruit Menzel et al (1986) reported that water stress increased the proportion of plant dry matter translocated to the roots as compared to the leaves and stems thus maintaining a high root/shoot ratio.

Arjunan et al (1988) also reported increased root/shoot ratio in groundnut grown under moisture stress conditions.

2.2. Yield performance

2.2.1. Yield and yield components

Slavik (1966) reported that drought during the period of rapid leaf development in spring wheat reduced tiller number, drought during the period of spikelet formation reduced spikelet number and drought during grain formation reduced kernel weight.

In a study on the effect of moisture stress on wheat Day and Intalap (1970) found that stress during jointing stage resulted in lower grain yield, lower grain volume and weight, fewer heads per unit area and fewer seeds per head.

Effect of soil moisture stress on the yield and quality of wheat was studied by Day and Barmore (1971) and found that moisture stress at the jointing stage decreased the flour yield but increased the flour protein.

Summerfield et al (1976) observed that in cowpea wilting during the early stages of growth reduced the yield attributes, total seed weight, seed number and fruit weight per plant. Water stress from emergence to first flower halved subsequent pod production. Wilting during the period from first flower to midpod fill however reduced the number of seeds per pod. But there was no significant effect of water stress on mean seed weight and mean pod weight.

Johnson and Moss (1976) reported that in wheat plants stress caused a 14 per cent reduction in kernel weight and a 20 per cent reduction in grainyield compared to control plants.

Sionit and Kramer (1977) reported that soybean plants stressed during flower induction and flowering, produced fewer flowers, pods and seeds than control because of a shortened flowering period and abortion of flowers. Stress during early pod formation caused greatest reduction in number of pods and seeds at harvest.

Plants stressed from anthesis to early pod formation in oats showed a significantly high floret sterility and fewer number of heads at maturity. Water stress at all stages caused a marked decline in the yield of straw, panicles, kernels and dehulled kernels (Sandhu and Horton, 1977).

Constable and Hearn (1978) found that water deficits during pod filling resulted in a cessation of pod filling thus decreasing yield in cowpea. The reduction was mainly due to the development of small seeds, few seeds per pod and few pods per plant.

Jurgens et al (1978) observed a 42 per cent reduction in the yield of maize under stress over their control plants. Grain filling was seriously affected and it was responsible for the reduction in yield.

In a study on the effect of moisture stress in Brassica napus Richards and Thurling (1978b) observed a significant reduction in the yield components - pods per plant, pods per main branch and seeds per pod.

Soybean cultivars were reported to be highly flexible with respect to yield components and moisture stress by Momem et al (1979). Moisture stress severely affected the size and number of potential storage sites for produced drymatter resulting in low yield.

Sammons et al (1980/81) reported that drought tolerant soybean cultivars were characterised by a stable grain yield even under stress. Moisture stress had a significant influence on the yield components - seeds per plant, pods per plant and seed yield. But no significant effect was observed on number of seeds per pod and hundred seed weight.

In a study with three cowpea cultivars significant reduction in yield (34-46 per cent) was observed by Babalola

(1980). Maximum yield reduction was observed when stress was imposed at flowering or podding stage.

Turk et al (1980) reported that drought imposed at the flowering and pod filling stages in cowpea cultivars substantially reduced the yield mainly through low pod density and smaller seeds.

Resistant varieties of soybean were reported to have few pods while maintaining the number of seeds per pod and thousand seed weight (Vidal, 1981).

Shouse et al (1981) concluded that in cowpea the more sensitive growth stages to drought were flowering and pod filling with yield reduction from 35 to 69 per cent depending on the timing and length of the drought treatment.

Studies conducted by Biryukov and Lyachok (1983) in wheat revealed that selection on the basis of grain number per ear rather than on thousand grain weight would be more reliable in selecting drought resistant genotypes.

Neyshabouri (1983) reported that in soybean pod drop and reduced seed weight were responsible for a reduced yield under moisture stress.

Moisture stress during the late reproductive stage resulted in significant differences in hundred seed weight, percentage of empty pods and shelling per cent in soybean (Ahmed, 1984).

Effect of moisture stress on four grain legumes studied by Pandey et al (1984a) showed a reduction in seed yield in all the four legumes. Among the yield components number of pods per m^2 was most affected by water stress in all four species, followed by number of seeds per pod while seed weight was least affected.

Wudiri and Henderson (1985) noticed in tomato a high influence of drought on major yield components such as flower initiation, number of flowers and fruits per branch and fruit set.

In a study on safflower, Hayashi and Hanada (1985) observed that the number of seeds and seed dry weight per plant were considerably decreased by soil water deficit whereas the number of florets, percentage of ripened seeds and seed dryweight per head were not affected. The decrease in seed yield was mainly due to a reduction in the number of heads per plant.

Fereres et al (1986) reported in sunflower a reduced seed yield under moisture stress. In groundnut moisture stress at flowering decreased the total number of pods per m^2 and increased the hundred kernel weight (Rao et al, 1986).

Potluri et al (1986) observed an increase in grain and haulm yield with an increase in moisture stress upto 50 per cent depletion, but with 75 per cent depletion considerable reduction in grain yield and haulm yield were observed in black gram.

A poor seed filling and a reduced seed weight were observed by Planchon et al (1986) in soybean under water stress conditions.

Sivakumar and Singh (1987) reported that in chickpea, severe water stress resulted in a reduced drymatter, seed yield and seed weight.

According to Talukder (1987) moisture stress at any stage of crop growth and development in wheat, reduced the grain and straw yields but the rate of decrease depended on the degree and duration of stress and the stage of crop growth. Reduction in grain yield under continuous drought was mainly due to a decrease in the ear per unit area and grains per ear.

2.2.2. Earliness

Varietal differences in drought resistance are mainly due to differences in the environmental conditions during different growth and development stages of varieties belonging to different flowering classes and not due to any genetic difference in their capacity to endure wilting. Often the varieties having same flowering duration do not show significant differences in response to drought.

May and Milthorpe (1962) suggested that variation in drought resistance in crop species was generally due to differences in their time of maturity in relation to the length of the growing season.

Stressing wheat plants at the jointing stage resulted in fewer days from planting to flowering as reported by Day and Intalap (1970).

Blum (1979) observed that early sorghum genotypes not only escaped drought but also avoided it because of reduced transpiration demand as a result of decreased leaf area.

Similar results were also reported by Rao et al (1979) in sorghum. In the Indian peninsular, the replacement of traditional 130-180 day sorghum with early hybrids and varieties of 100-110 days duration, which matured before the rains end or before soil moisture depleted has resulted in a remarkable increase in sorghum production.

However, Sammons et al (1980/81) observed that there was no consistent relationship between maturity group and cultivar response to moisture stress in soybean.

In experiments with cowpea Turk and Hall (1980) observed that earliness determined by the dry weight of pods at the end of flowering, increased with moderate drought and decreased with more severe drought. Turk et al (1980) reported that stressed plants of cowpea matured ten days earlier than the well watered controls.

Hall and Grantz (1981) suggested that earliness was a complex phenomenon especially in indeterminate crops and hence its exploitation as a character for improving drought resistance was very limited. However early flowering has been considered as a desirable character in many breeding programmes. In cowpea they suggested that selection of plants having mature pods early in the season can be an effective method for improving drought resistance.

In a study on the response of four grain legumes to water stress, Lawn (1982) noticed that blackgram, greengram and cowpea responded to stress through faster development particularly in the flowering to maturity phase whereas soybean showed no such developmental adjustment.

Days to anthesis was found to be an important indicator of drought resistance in sorghum by O'Neill et al (1983).

Kittock et al (1983) reported speeded boll opening in cotton under conditions of stress. Bolls of stressed plants opened on an average of 17 days earlier than bolls of unstressed cotton plants.

Greenhouse and field experiments conducted by Wudiri and Henderson (1985) in tomatoes showed an earlier flowering in moderately stressed plants as compared to nonstressed plants.

According to Pinheiro et al (1985) days to flowering was an important factor deciding yield in rice under stress conditions.

Mahalakshmi and Bidinger (1985) reported that flower initiation was unaffected by water stress in early maturing genotypes of bajra, whereas in late maturing types flowering occurred only after the plants were released from stress.

Ali et al (1986) observed that earliness had a direct relationship with productivity under drought conditions in pearl millet.

Sivakumar and Singh (1987) reported that the early maturing chickpea cultivar showed an yield advantage over the cultivar with medium maturity at all irrigation levels.

Omara (1987) reported that the response of the early selections of barley to drought stressed sandy soil treatments was characterised by a ten days reduction in time to flowering. Moreover the early selections which recovered from a drought period imposed at tillering, flowering or grain filling reached maturity earlier but with significant increase in number of ears per plant and grain yield per plant over the control. Such developmental plasticity might be a reflection of the adaptation reaction of the early genotypes to dry environment.

2.2.3. Grain filling period

When drought is imposed after anthesis maturation and leaf senescence is hastened, there by reducing the length of filling period. Since most of the filling material for grain production are synthesized during this period a shortening of this period will have an adverse effect on the yield (Asana et al, 1968). Varieties which can maintain longer filling periods under drought conditions should therefore be advantageous under such stress conditions.

Meckel et al (1984) reported that in soybean the seed filling period was shortened by severe stress showing more sensitivity to moisture stress than the seed growth rate.

Relationship between high rate and short duration of grainfilling and drought tolerance was emphasized by Bruckner (1986) in wheat.

Studies conducted by Planchon et al (1986) in soybean indicated that the timing of the stress during the growing phase determined the extent and type of damage, with late stress causing poor seed filling and a reduced seed weight, but early stress reduced yield due to increased seed abortion.

Omara (1987) reported that in barley the sandy soil drought treatments were characterised by a prolongation in time from flowering to maturity as compared with the performance under the favourable clay soil conditions.

2.2.4. Proline content

Proline accumulation occurs under severe stress conditions in plants to reduce the adverse effect of drought on plant metabolism. It acts as a storage form for the otherwise injurious ammonia released during protein breakdown and increase the bound water in the cells due to the hygroscopic nature.

Palfi (1969) reported that proline content increased upto ten fold in maize and upto 100 fold in sunflower, peas and tobacco under conditions of drought.

Palfi and Juhasz (1971) observed that in plants of tobacco, sunflower and potatoes, with optimum water supplies only traces of proline were present but during water stress the levels of this aminoacid increased rapidly particularly in the drought resistant plants.

In sorghum and soybean, Waldren and Teare (1974) found that free proline did not accumulate markedly in either species until each was severely stressed, showing that it was not a sensitive indicator. Accumulation occurred at lower stress in soybean than in sorghum showing that soybean was less tolerant to drought as compared to sorghum.

In a study conducted by Mehkri et al (1977) in groundnut it was found that drought condition was associated with an increase in the free proline accumulation. The variety highly tolerant to drought showed maximum proline accumulation showing that accumulation of proline during stress was an indication of drought tolerance.

Parameswara and Krishnasastry (1980) observed that in sorghum, the magnitude of proline accumulation was high when stress was induced at initial vegetative phase and decreased at other stages.

Elmore and Mc Michael (1981) reported free proline accumulation during stress in cotton. But Garg et al (1981) suggested that changes in free proline content cannot be correlated with drought resistance as measured by yield in bajra.

Mukherjee et al (1982) studied the degree of drought resistance in cowpea, *Ipomoea aquatica* and *Trapa natans*, in relation to proline accumulation and concluded that plants having an inherent capacity to accumulate proline during moisture stress can also acquire the property of drought resistance under such conditions.

Association of free proline accumulation with drought tolerance was also reported by Singh and Singh (1986) in sugarcane and Bansal and Nagarajan (1986) in potato.

2.3. Heritability and Genetic advance

In crop improvement only the genetic component of variation is important since only this component is transmitted to the next generation. The ratio of genetic variance to the total variance is known as heritability. Lush (1940) has defined heritability both in broad and narrow senses. Estimates of heritability serve as a useful guide to the breeder. The breeder is able to appreciate the proportion of variation that is due to genotypic (broad sense heritability) or additive (narrow sense heritability) effects. The high value of heritability for quantitative characters helps the breeder to base his selection programme on the phenotypic value of a specific character for the further improvement. Heritability estimates along with genetic gain are more helpful in predicting the improvement that can be achieved through selection.

Singh and Mehndiratta (1969) recorded highest estimate of variability for hundred seed weight followed by days to flowering and days to maturity and the lowest for seed yield in cowpea. They observed high genetic advance for hundred seed weight, moderate for seed yield and lowest for days to maturity.

Empig et al (1970) observed that heritability estimates in the F2 generation of greengram had high values for number of days to flowering and maturity and low for yield.

In greengram Choudhary et al (1971) observed a high heritability and genetic gain for plant height, pod length and hundred seed weight.

Paramasivan and Rajasekharan (1980) recorded the highest estimate of heritability for hundred seed weight (100 per cent) followed by pod length, cluster number and seed yield in greengram. The genetic advance was also high for these characters.

Patel and Shah (1982), based on their studies in 20 strains of blackgram reported high heritability and genetic advance for plant height and pod length.

Studies on the genetic variability of cowpea under dry farming by Pandita et al (1982) revealed significant differences for all traits except number of pods per cluster. Wide variation was seen for yield per plant, days to flowering and plant height. They also observed a high genotypic and phenotypic coefficient of variation, heritability and genetic advance for yield per plant.

2.4. Correlation studies

Correlation studies reveal the degree of association of a character with its components and also among the components.

Mehrotra et al (1968) observed a positive correlation between yield and leaf area in hybrid maize plants during water stress.

Singh et al (1972) found that in barley cultivars accumulation of proline under severe stress has been positively correlated with drought resistance.

In sorghum Setty and Sreeramulu (1972) reported a high correlation of grain yield with plant height, number of nodes, area of fourth leaf, days to 50 per cent blooming, dry matter production, thousand grain weight, number of long roots and length of the longest roots under stress. However root/shoot ratio and root weight did not show any relationship with yield.

Doss et al (1974) observed a significant positive correlation between yield and plant height in a sample of soybean genotypes during a period of moisture stress. Similar results were observed by Ray et al (1974) in American cotton.

Saxena and Sheldrake (1977) observed that in chickpea unirrigated yield showed a significant positive correlation with drought tolerance whereas number of days to flower showed a significant negative correlation with drought tolerance.

A negative correlation between leaf area and relative growth rate was reported by Sivakumar and Shaw (1978b) in soybean.

In a study on the evaluation of drought tolerance in chickpea Saxena et al (1979) observed a negative correlation between days to 50 per cent flowering and yield under stress. Of all the components of yield, only pods per plant showed significant positive association with yield in the unirrigated treatments.

A negative correlation between seed weight and seed number was observed by Vidal and Arnoux (1981) in soybean under stress.

Sangwan and Mehrotra (1982) observed positive correlation between root length at five days and root weight at maturity and seed yield per plant in green gram.

Correlation studies conducted by Kavitha (1982) in black gram revealed a significant positive correlation between grain yield and number of fruiting branches per plant, pod length, number of seeds per pod, hundred seed weight and harvest index. Duration was found to show a negative correlation with yield and root length showed a positive correlation with yield.

Ali and Naidu (1982) reported a significant positive correlation between yield under stress and plant height, leaf area, length and size of grains and thousand seed weight in maize. Significant negative correlation was observed between yield and stomatal number.

Adaptability studies in cowpea by Ranganatha (1983) revealed that stability of pods per plant contributed significantly to stability of yield.

Mambani and Lal (1983) studied the response of upland rice varieties to stress and found that soil moisture potential was negatively correlated with root density.

In drought years yield was found to be negatively correlated with root weight in Lathyrus sativus by Kolotilov and Kolotilova (1985).

Under rainfed conditions grain yield per plant was significantly and positively correlated with spikes per plant and hundred grain weight in wheat. Path coefficient analysis revealed that spikes per plant, hundred grain weight and plant height made the most important contribution to grain yield per plant (Bhullar et al, 1985).

Ibrahim et al (1986) reported significant positive correlation of grain yield with grain number per head, grain size and number of leaves on the main stem in pearl millet.

In rice Edillo et al (1986) observed that yield was positively correlated with days to flowering suggesting a strong selection pressure for medium maturing genotypes of rice for drought prone environment.

Based on the root morphological characteristics of field grown cowpea, Kahn and Stofella (1987) proposed that seed yield was not correlated strongly with any of the root related variables.

Studies conducted by Sharma (1988) in maize indicated positive correlation of harvest index, plant height, cob placement height, leaf area per plant, cob length and grains per cob with grain yield per plant. Path analysis revealed that large direct contribution to grain yield was made by proline content, harvest index, 500 grain weight, cob length, plant height and leaf area per plant.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was undertaken in the Department of Plant Breeding, College of Agriculture, Vellayani, Kerala Agricultural University during October-December, 1988.

3.1. Materials

Twenty varieties of greengram obtained from the Regional Agricultural Research Station, Pattambi, were used for the study.

Varieties were:

1. KM - 2
2. CO-3
3. CO-4
4. Pusa Baisakhi
5. Pusa-101
6. Pusa-103
7. Pusa-119
8. Pusa-117
9. ML-131
10. Pusa-102
11. PDM-84-146
12. LGG-407
13. Pusa-116
14. Pusa-104
15. RMG-70
16. ML-322
17. PDM-84-139
18. RMG-146
19. PDM-54
20. OUM-6

3.2. Methods

A field experiment was laid out during early rabi season, 1988 adopting a Randomised Block Design with three replications. In each plot of 6 m^2 area the seeds were sown at a spacing of 25 x 15 cm. The varieties were evaluated under open conditions without any irrigation. The cultural and management practices were followed as per the package of practices recommendations of the Kerala Agricultural University (Anon., 1986).

Ten plants were selected at random from each plot for recording the following observations.

1. Plant height

Plant height was measured from the ground level to the tip of the main stem in centimetres at the time of harvest and the mean height recorded.

2. Number of leaves per plant

The number of leaves per plant were counted at 50 per cent flowering stage and the mean value recorded.

3. Number of pods per plant

Pods were harvested at maturity from each plant separately and the mean recorded.

4. Length of the pod

Ten pods were selected randomly from the observational plants and the mean length of pods recorded in centimetres.

5. Number of seeds per pod

Number of seeds in each randomly selected pod from the observational plants were counted and the average numbe of seeds recorded.

6. Hundred seed weight

A random sample of hundred well developed seeds was collected from each observational plant and the weight recorded in grams.

7. Seed size

The seeds used for taking hundred seed weight were subjected to water displacement and the mean volume recorde in cm^3.

8. Yield per plant

The total seed yield from each observational plant was recorded and the mean worked out in gram.

9. Yield per plot

The total grain yield from each plot was recorded in gram.

10. Haulm yield

The total haulm yield from each plot was recorded in gram.

11. Stomatal distribution

The right leaflet from the second well developed leaf from the top was selected to work out stomatal frequency. Thin epidermal layers were collected from different parts of the leaf and the number of stomata per microscopic field were counted from twenty different fields and the mean value recorded.

12. Leaf Area Index (LAI)

LAI was calculated using the following formula suggested by William (1946) at 50 per cent flowering stage.

$$\text{LAI} = \frac{\text{Total leaf area of the plant}}{\text{Ground area occupied (spacing).}}$$

Total leaf area was calculated using the method suggested by Sreekumar et al (1978).

Leaf	Regression equation	Coefficient of determination R^2
1. Terminal	$Y = 0.61x$	0.90
2. Side 1	$Y = 0.70x$	0.95
3. Side 2	$Y = 0.70x$	0.97

where x is the product of length and breadth

13. Root length

The plants were uprooted carefully after the last harvest and root length measured from collar to the tip of the taproot in centimetres.

14. Root spread

Root spread was studied by plotting the dried specimen on a graph paper. The spread was measured in centimetres by counting the columns at the broadest part of the root. Columns which were less than half were rejected and more than half were counted as one.

15. Root/Shoot ratio

The root and shoot portions of the observational plants were oven dried at 60°C for 24 hours and the dry weights recorded. The ratio of root dry weight to shoot dry weight was then recorded for the observational plants and the mean value worked out.

16. Days to first flowering

The number of days taken from the date of sowing to the opening of the first flower was recorded.

17. Days to maturity of first pod

The number of days taken from the date of sowing to the maturity of first pod in each plot was recorded.

18. Days to final harvest

The number of days taken from the date of sowing to the final harvest was recorded.

19. Grain filling period

The number of days taken from the opening of a flower to the maturity of the pod was recorded as the grain filling period.

20. Proline content

Fully expanded second leaf from top was collected and the proline content estimated by the method suggested by Bates et al (1973).

A quantity of 0.25 g of the dried plant sample was homogenised in 10 ml of 3 per cent aqueous sulfosalicylic acid and the homogenate filtered through a whatman number two filter paper. 2 ml of the filtrate was reacted with 2 ml acid ninhydrin (Acid nin-hydrin was prepared by warming 1.25 g ninhydrin in 30 ml glacial acetic acid and 20 ml 6M phosphoric acid with agitation until dissolved) and 2 ml of glacial acetic acid in a test tube for one hour at 100°C and the reaction terminated in an ice bath. The reaction mixture was then extracted with 4 ml toluene and mixed vigorously with a test tube stirrer for 15-20 seconds. The chromophore containing toluene was then warmed to room temperature and the absorbance read at 520 nm using toluene for a blank. The proline concentration was then determined from a standard curve and calculated on a dry weight basis as follows.

$$(\mu\text{g proline/ml} \times \text{ml toluene})\ (5/\text{g sample}) = \mu\text{g proline/g of dry weight material}$$

21. Soil moisture percentage

Soil samples were collected from each plot at weekly intervals and the moisture percentage worked out by the gravimetric method.

3.2.1. Statistical analysis

The data collected were tabulated and the mean values were subjected to statistical analysis.

3.2.1.1. Analysis of variance and covariance

The observations recorded with respect to each character were subjected to analysis of variance and covariance as given in Table 1 (Panse and Sukhatme, 1957).

Table 1. Analysis of variance/covariance

Source	Degrees of freedom	Mean sum of squares	Mean sum of products
Block	(r-1)	MSB	MSPB
Treatments	(v-1)	MSV	MSPV
Error	(v-1) (r-1)	MSE	MSPE

where r = number of replications

v = number of treatments

3.2.1.2. Variance

Components of variance for each character were worked out following the procedure of Johnson et al (1955).

Genotypic variance

$$V_g = \frac{MST - MSE}{r}$$

where Vg = Genotypic variance

MST = Mean sum of squares for treatment

MSE = Mean sum of squares for error

r = Number of replications

Environmental variance

$$Ve = MSE$$

where Ve = Environmental variance

MSE = Mean sum of squares for error

Phenotypic variance

$$Vp = Vg + Ve$$

where Vp = Phenotypic variance

3.2.1.3. Coefficient of variation

Both phenotypic and genotypic coefficients of variation were calculated as suggested by Burton (1952).

Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{Vp}}{mean} \times 100$$

where Vp = Phenotypic variance

Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{Vg}}{mean} \times 100$$

where Vg = Genotypic variance

3.2.1.4. Heritability and Genetic advance

Heritability in broad sense (Hanson et al, 1956)

$$H^2 = \frac{Vg}{Vp} \times 100$$

where H^2 = Heritability coefficient

Vg = Genotypic variance

Vp = Phenotypic variance

Expected Genetic Advance (GA) under selection

(Lush, 1940 and Johnson et al, 1955)

$$G.A = Kh^2 \sqrt{Vp}$$

where

$G.A$ = Genetic advance

h^2 = Heritability in the broad sense

Vp = Phenotypic variance

K = Selection differential expressed in phenotypic standard deviation

= 2.06 in the case of 5% selection in large samples (Miller et al, 1958 and Allard, 1960)

Expected Genetic gain (GG) under selection

(Johnson et al, 1955)

$$G.G = \frac{G.A}{\bar{\bar{X}}} \times 100$$

where $\bar{\bar{X}}$ = General mean

3.2.1.5. Co-variance

Genotypic covariance

$$CoVg = \frac{MSPT - MSPE}{r}$$

where $CoVg$ = Genotypic covariance

$MSPT$ = Mean sum of product for treatment

$MSPE$ = Mean sum of product for error

r = The number of replications

Environmental covariance

$CoVe = MSPE$

where

$CoVe$ = Environmental covariance

$MSPE$ = Mean sum of product for error

Phenotypic covariance

$CoVp = CoVg + CoVe$

where

$CoVp$ = Phenotypic covariance

$CoVg$ = Genotypic covariance

$CoVe$ = Error (Environmental covariance)

3.2.1.6. Correlation coefficients

Genotypic correlation coefficients (Al-jibouri et al, 1958)

$$rg = \frac{CoVg_{12}}{\sqrt{Vg_1 \times Vg_2}}$$

where Yg = Genotypic correlation coefficient

$CoVg_{12}$ = Genotypic covariance of traits 1 and 2

Vg_1 = Genotypic variance of trait 1

Vg_2 = Genotypic variance of trait 2

Environmental correlation coefficient

$$re = \frac{CoVe_{12}}{\sqrt{Ve_1 \times Ve_2}}$$

where re = Environmental correlation coefficient

$CoVe_{12}$ = Environmental covariance of traits 1 and 2

Ve_1 = Environmental variance of trait 1

Ve_2 = Environmental variance of trait 2

Phenotypic correlation coefficient

$$rp = \frac{CoVp_{12}}{\sqrt{Vp_1 \times Vp_2}}$$

where rp = Phenotypic correlation coefficient

$CoVp_{12}$ = Phenotypic covariance of trait 1 and 2

Vp_1 = Phenotypic variance of trait 1

Vp_2 = Phenotypic variance of trait 2

3.2.1.7. Path analysis

Path analysis at genotypic level was carried out using the following characters - plant height, number of leaves per plant, number of pods per plant, seed size, pod length, root/shoot ratio and days to first flowering as causes and the yield per plant as the effect.

The genotypic correlation coefficients of the above component characters with yield per plant were partitioned into direct and indirect effects as per the methodology of Dewey and Lu (1959).

The simultaneous equations which give solutions for path coefficients are

$$r_{iy} = r_{i1}\,p_{1y} + r_{i2}\,p_{2y} + \ldots\ldots\ldots + p_{iy} + \ldots\ldots\ldots + r_{ik}\,p_{ky}$$

where $i = 1, 2, 3 \ldots\ldots\ldots\ldots k$

r_{iy} is the genotypic correlation of the ith independent variable (x_i) with dependent variable (y)

p_{iy} is the direct effect of x_i on y and $r_{ik}\,p_{ky}$ is the indirect effect of x_i via x_k on y

RESULTS

RESULTS

The experimental data recorded were subjected to statistical analysis and the results presented.

4.1. Variability analysis

The mean values of ten observational plants in each plot with respect to 20 characters were subjected to analysis of variance and covariance and the ANOVA is presented in Table 2. All the varieties exhibited significant differences for characters plant height, number of leaves per plant, pod length, number of seeds per pod, hundred seed weight, seed size, yield per plot, haulm yield, stomatal distribution, leaf area index, root length, root spread, root/shoot ratio, days to first flowering, days to maturity of first pod, days to final harvest and grain filling period. Significant differences were not observed for characters, number of pods per plant, yield per plant and proline content.

The mean performance of the 20 varieties in respect of yield and other ancillary characters are furnished in Table 3.

The highest mean value for yield per plant was recorded by PBM-84-146 (4.82 g) followed by Pusa-103 (4.62 g)

Table 2. Analysis of variance for 20 characters in Green gram.

Sl. No.	Characters	Mean sum of squares			F value
		Replication df = 2	Treatments df = 19	Error df = 38	
1.	Plant height	119.04	92.54	42.38	2.10*
2.	Number of leaves per plant	2.66	7.61	2.17	3.51**
3.	Number of pods per plant	56.82	9.89	5.60	1.77
4.	Pod length	0.06	0.27	0.06	4.09**
5.	Number of seeds per pod	0.58	0.98	0.28	3.45**
6.	Hundred seed weight	0.01	0.15	0.01	12.90**
7.	Seed size	0.0001	0.06	0.003	17.07**
8.	Yield per plant	5.52	0.68	0.54	1.30
9.	Yield per plot	23238.25	14392.96	2679.14	5.37**
10.	Haulm yield	1090500.00	805602.50	266859.80	3.02**
11.	Stomatal distribution	1.93	28.89	8.92	3.24**
12.	Leaf area index	1.04	0.59	0.27	2.25*
13.	Root length	0.29	6.12	1.02	5.99**
14.	Root spread	12.75	7.63	0.74	10.32**
15.	Root/shoot ratio	0.0005	0.0007	0.0003	2.53**
16.	Days to first flowering	16.20	16.24	2.78	5.84**
17.	Days to maturity of first pod	1.05	20.84	1.82	11.44**
18.	Days to final harvest	1.27	27.98	1.02	27.41**
19.	Grain filling period	0.02	4.01	0.13	30.50**
20.	Proline content	328061.00	89095.10	49790.60	1.79

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 3. Mean values of the characters observed in twenty varieties.

Sl. No.	Varieties	Plant height (cm)	No. of leaves per plant	No. of pods per plant	Pod length (cm)	No. of seeds per pod	Hundred seed weight (g)	Seed size cm^3	Yield per plant (g)	Yield per plot (g)	Haulm yield (g)	Stomatal distribution
		1	2	3	4	5	6	7	8	9	10	11
1.	KM-2	35.53	10.87	10.60	7.27	11.47	3.33	2.80	4.03	36.00	413.03	25.75
2.	Co-3	34.76	8.97	12.10	6.92	12.70	3.21	2.72	4.08	43.00	922.71	25.25
3.	Co-4	48.43	11.59	10.43	7.70	12.27	3.38	3.01	3.55	10.83	1473.50	26.78
4.	Pusa Baisakhi	29.77	7.87	10.33	7.30	11.77	3.36	2.65	3.77	35.00	446.88	28.57
5.	Pusa-101	37.13	7.83	10.33	7.15	12.40	3.34	2.71	4.15	48.00	484.54	19.67
6.	Pusa-103	42.03	8.43	13.77	6.90	11.50	3.61	2.83	4.62	138.33	847.23	27.42
7.	Pusa-119	37.47	6.23	8.30	6.94	11.30	3.51	2.71	3.03	106.00	384.72	30.58
8.	Pusa-117	44.43	7.60	10.97	7.04	12.20	3.45	2.63	4.02	285.00	1643.65	24.60
9.	ML-131	33.53	6.43	10.50	6.86	11.40	3.33	2.83	3.57	140.33	1172.15	19.30
10.	Pusa-102	38.73	7.20	9.80	6.71	11.43	3.07	2.65	3.65	158.33	1332.56	24.33
11.	PDM-84-146	38.33	8.43	14.93	6.64	10.97	3.35	2.80	4.82	157.67	1203.15	25.13
12.	LGG-407	37.73	6.33	9.87	6.70	11.67	3.25	2.61	3.63	179.00	2400.20	22.80
13.	Pusa-118	45.03	6.07	8.80	7.14	12.47	3.10	2.28	3.10	143.67	1075.34	22.25
14.	Pusa-104	50.37	7.60	9.30	6.88	12.30	2.89	2.60	3.38	200.33	1826.37	25.23
15.	RMG-70	38.40	7.23	11.73	7.38	11.43	3.34	2.68	4.12	128.33	504.69	20.82
16.	ML-322	41.10	6.97	11.50	6.87	11.13	3.10	2.60	3.85	213.33	1443.59	22.95
17.	PDM-84-139	30.07	9.10	13.83	6.52	10.87	3.84	2.67	4.35	131.00	509.35	21.70
18.	RMG-146	32.33	5.40	9.47	6.77	10.97	3.45	2.85	3.45	99.33	599.05	19.12
19.	PDM-54	35.00	6.13	12.63	6.49	10.93	3.75	2.76	3.95	170.67	1136.94	23.52
20.	OUM-6	38.13	6.53	8.70	6.93	11.37	3.22	2.60	3.23	88.00	1430.34	21.57
	General Mean	38.41	7.64	10.90	16.96	11.63	3.35	2.70	3.82	125.61	907.90	23.87
	CD	10.76	2.43	N.S	0.39	0.88	0.18	0.10	N.S	85.59	854.20	4.94

le 3 contd.

Varieties	Leaf Area Index	Root length (cm)	Root spread (cm)	Root/ Shoot ratio	Days to first flowering	Days to maturity of first pod	Days to final harvest	Grain filling period (days)	Proline content (μg/gdw)
	12	13	14	15	16	17	18	19	20
KM-2	2.26	15.02	12.62	0.101	37.67	57.00	60.70	18.50	561.63
Co-3	1.82	14.69	12.37	0.074	37.33	55.30	60.00	17.47	750.47
Co-4	3.09	20.03	17.92	0.107	44.33	66.00	74.70	17.73	579.05
Pusa Baisakhi	1.81	13.63	11.95	0.119	37.67	57.70	60.00	17.07	438.64
Pusa-101	1.41	14.34	11.90	0.067	37.67	57.30	62.00	16.60	857.69
Pusa-103	1.72	15.53	11.05	0.094	36.33	55.00	61.00	18.00	328.16
Pusa-119	1.43	13.04	10.37	0.124	37.33	57.00	61.00	17.93	625.85
Pusa-117	1.30	14.37	11.80	0.103	36.33	56.00	60.70	18.77	439.19
ML-131	1.18	14.89	11.15	0.100	37.67	57.70	62.70	17.63	385.31
Pusa-102	1.42	14.84	10.65	0.105	37.67	56.70	62.70	17.40	717.27
PDM-84-146	1.51	14.00	11.61	0.094	36.00	55.70	61.30	19.80	1050.88
LGG-407	1.52	15.17	11.72	0.108	37.67	57.70	62.00	18.23	506.12
Pusa-118	1.37	15.18	11.59	0.106	36.67	54.00	62.70	18.10	619.32
Pusa-104	1.72	14.93	11.57	0.126	34.33	54.70	62.70	19.07	426.12
RMG-70	1.70	14.35	11.75	0.132	37.00	54.70	61.00	18.03	568.08
ML-322	1.45	13.64	11.69	0.103	35.33	55.70	62.00	19.20	434.83
PDM-84-139	1.72	13.91	10.74	0.115	34.67	58.70	61.30	21.90	610.61
RMG-146	1.09	13.57	10.11	0.097	41.67	58.70	61.70	17.33	439.19
PDM-54	1.26	13.61	10.65	0.089	34.33	53.30	62.00	18.90	551.84
OUM-6	1.22	14.46	12.14	0.089	38.33	56.30	61.70	17.80	611.15
neral Mean	1.60	14.66	11.77	0.103	37.30	56.75	62.18	18.27	575.07
CD	0.85	1.67	1.42	0.029	2.76	2.23	1.67	0.60	N.S

and the lowest mean value by Pusa-119 (3.03 g). However their difference was not statistically significant.

The mean value for plant height varied from 50.37 cm in Pusa-104 to 29.77 cm in Pusa Baisakhi. Varieties Co-4, Pusa-118, Pusa-117, Pusa-103 and ML-322 were on par with Pusa-104, the tallest.

The mean values for number of leaves per plant was the highest in Co-4 (11.59) followed by KM-2 (10.87). These two varieties were on par. The lowest mean value for this character was recorded by RMG-146 (5.40).

The highest mean value for number of pods per plant was recorded by PDM-84-146 (14.93) followed by PDM-84-139 (13.83) and Pusa-103 (13.77) and the lowest mean value by Pusa-119 (8.30) eventhough there was no significant difference among the varieties.

The variety Co-4 had the highest mean value for length of pods (7.70 cm) followed by RMG-70 (7.38 cm) and the lowest value was recorded for PDM-54 (6.49 cm) followed by PDM-84-139 (6.52 cm). RMG-70 was on par with Co-4.

The mean values for number of seeds per pod varied from 12.7 in Co-3 to 10.87 in PDM-84-139. The varieties Pusa-118, Pusa-101, Pusa-104, Co-4 and Pusa-117 were on par with Co-3.

The mean values for hundred seed weight showed a maximum of 3.84 g for the variety PDM-84-139 and a minimum of 2.89 g for the variety Pusa-104. PDM-54 (3.75 g) was on par with PDM-84-139 and Pusa-102 (3.07 g) was on par with Pusa-104.

With regard to seed size, Co-4, showed a maximum mean value of 3.01 cm^3 and Pusa-118 a minimum of 2.28 cm^3.

The mean values for haulm yield varied from 2400.20 g in LGG-407 to 384.72 g in Pusa-119. Pusa-104 (1825.37 g) and Pusa-117 (1643.65 g) were on par with LGG-407.

The maximum mean number of stomata per microscopic field was recorded for Pusa-119 (30.58) and the minimum for RMG-146 (19.12). Pusa Baisakhi (28.57), Pusa-103 (27.42), Co-4 (26.78) and KM-2 (25.73) were on par with Pusa-119.

The mean values for leaf area index at 50 per cent flowering was the highest for Co-4 (3.09) followed by KM-2 (2.26) and these two varieties were on par. The minimum value for leaf area index was recorded by RMG-146 (1.09).

The mean values for length of root varied from 20.03 cm in Co-4 to 13.04 cm in Pusa-119. Twelve varieties were found to be on par with Pusa-119, but no other variety was on par with Co-4.

The mean values for root spread was the highest for Co-4 (17.92 cm) and the lowest for RMG-146 (10.11 cm). ML-131 (11.15 cm), Pusa-103 (11.05 cm), PDM-84-139 (10.74 cm), Pusa-102 (10.65 cm), PDM-54 (10.65 cm) and Pusa-119 (10.37 cm) were on par with RMG-146 but no variety was found to be on par with Co-4.

The mean values for root/shoot ratio was maximum for RMG-70 (0.132) and minimum for Pusa-101 (0.067). RMG-70 was followed by the varieties Pusa-104 (0.126), Pusa-119 (0.124), Pusa Baisakhi (0.119) and PDM-84-139 (0.115).

The mean values for number of days to first flowering varied from 44.33 in Co-4 to 34.33 in Pusa-104 and PDM-54. RMG-146 (41.67) was on par with Co-4 the longest duration variety. Pusa-118 (36.67), Pusa-117 (36.33), Pusa-103 (36.33), PDM-84-146 (36.0), ML-322 (35.33) and PDM-84-139 (34.67) were on par with Pusa-104 and PDM-54 having the shortest duration.

Co-4 also recorded the highest mean value for number of days to pod harvest initiation (66.00) followed by PDM-84-139 (58.70) and RMG-146 (58.70). No variety was found to be on par with Co-4. PDM-54 recorded the lowest value for number of days to pod harvest initiation (53.30). Co-3 (55.30), Pusa-103 (55.00), RMG-70 (54.70), Pusa-104 (54.70) and Pusa-118 (54.00) were on par with PDM-54.

The mean number of days to final pod harvest was also the highest for Co-4 (74.70). The minimum was recorded by Pusa Baisakhi (60.00).

The maximum mean value for duration of grain filling was shown by PDM-84-139 (21.90) and the minimum by Pusa-101 (16.60). Pusa Baisakhi (17.07) was on par with Pusa-101 having the shortest filling period, but no variety was found to be on par with PDM-84-139 having the longest filling period.

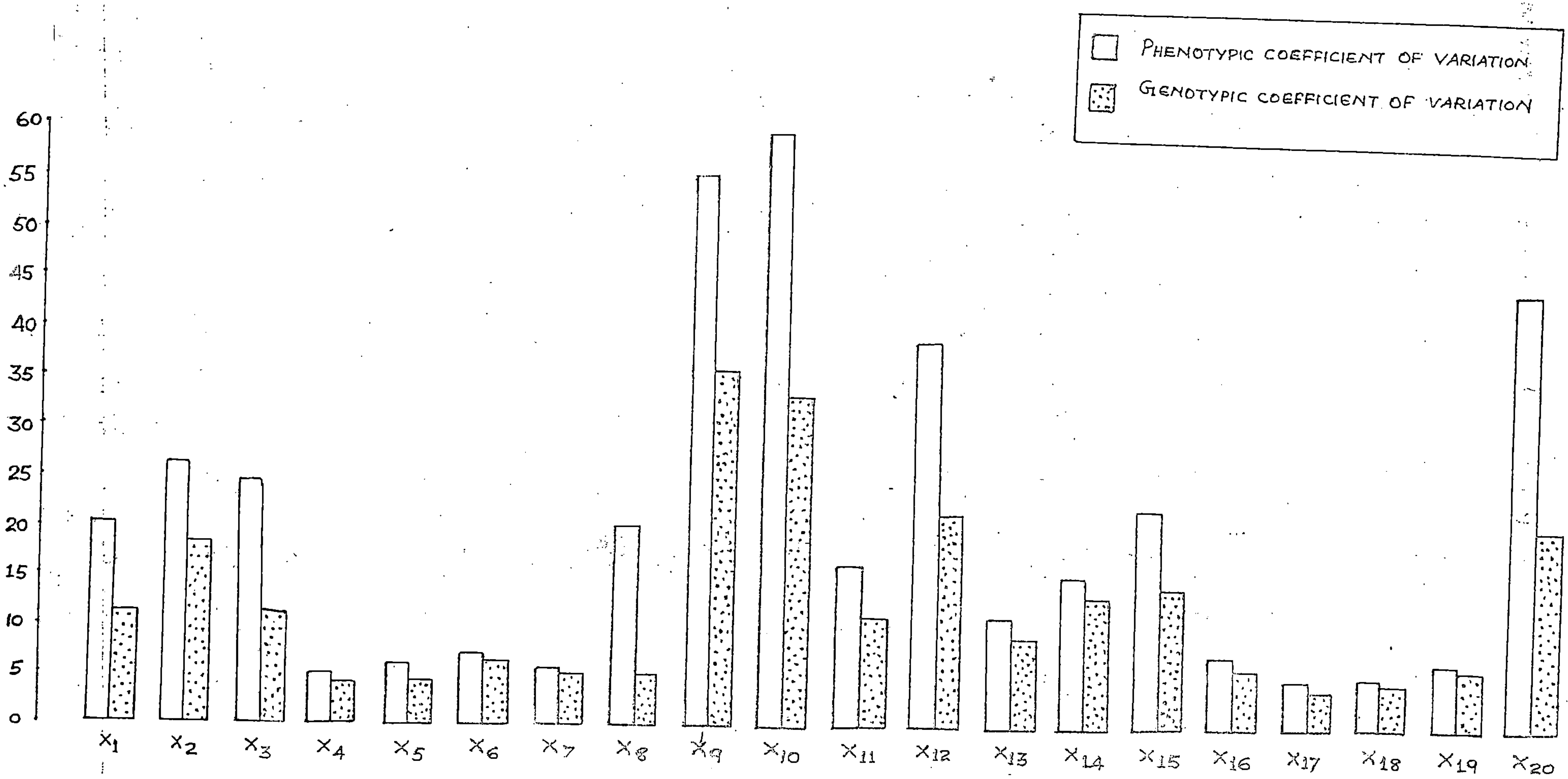
Though proline content of leaves showed no significant difference among varieties the mean value was highest for PDM-84-146 (1050.88 µg/gdw) and lowest for Pusa-103 (328.16 µg/gdw).

The phenotypic co-efficient of variation and genotypic co-efficient of variation for the 20 characters studied are given in Table 4 and presented graphically in Fig. 1. In general the phenotypic co-efficients of variation were higher than the genotypic co-efficients of variation for all the characters studied. Haulm yield showed the highest phenotypic co-efficient of variation (59.21 per cent) followed by yield per plot (54.89 per cent), proline content (43.61 per cent), leaf area index (38.32 per cent) and number of leaves per plant (26.12 per cent).

Table 4. Phenotypic Co-efficient of Variation and Genotypic Co-efficient of Variation (per cent) for 20 Characters.

Sl. No.	Characters	Phenotypic variance Vp	Genotypic variance Vg	Phenotypic coefficient of variation PCV (per cent)	Genotypic coefficient of variation GCV (per cent)
1.	Plant height	59.10	16.72	20.01	10.65
2.	No. of leaves per plant	3.98	1.82	26.12	17.64
3.	No. of pods per plant	7.03	1.43	24.32	10.97
4.	Pod length	0.13	0.07	5.14	3.86
5.	No. of seeds per pod	0.51	0.23	6.17	4.13
6.	Hundred seed weight	0.06	0.05	7.25	6.47
7.	Seed size	0.024	0.020	5.74	5.24
8.	Yield per plant	0.59	0.04	20.04	5.62
9.	Yield per plot	4752.21	2000.85	54.58	35.61
10.	Haulm yield	395767.20	123678.70	59.21	33.10
11.	Stomatal distribution	15.58	6.66	16.53	10.81
12.	Leaf area index	0.38	0.11	38.32	20.73
13.	Root length	2.72	1.70	11.25	8.89
14.	Root spread	3.04	2.30	14.81	12.89
15.	Root/shoot ratio	0.0005	0.0002	21.69	13.72
16.	Days to first flowering	7.27	4.49	7.23	5.68
17.	Days to maturity of first pod	8.16	6.34	5.03	4.44
18.	Days to final harvest	10.01	8.99	5.09	4.82
19.	Grain filling period	1.43	1.29	6.53	6.23
20.	Proline content	62892.07	13101.49	43.61	19.90

FIG.1 PHENOTYPIC AND GENOTYPIC COEFFICIENT OF VARIATION FOR TWENTY CHARACTERS IN GREENGRAM



The lowest value was recorded by days to maturity of first pod (5.03 per cent). The highest genotypic co-efficient of variation was observed for yield per plot (35.61 per cent) and the lowest for pod length (3.86 per cent).

4.2. Genetic analysis

Estimates of heritability and genetic gain are furnished in Table 5 and Fig. 2. In general the heritability values were medium to high for most of the characters. Highest heritability estimate was recorded for grain filling period (90.79 per cent) followed by days to final harvest (89.79 per cent), hundred seed weight (79.95 per cent), days to maturity of first pod (77.67 per cent) and root spread (75.65 per cent).

Low values of heritability were recorded for yield per plant (7.84 per cent), number of pods per plant (20.35 per cent), proline content (20.83 per cent) and plant height (28.29 per cent). Yield per plot recorded the maximum genetic gain (67.05 per cent) followed by haulm yield (49.06 per cent), number of leaves per plant (24.55 per cent), leaf area index (23.18 per cent) and root spread (23.07 per cent). High values of heritability coupled with high genetic gain was recorded for yield per plot and haulm yield. High heritability coupled with low genetic gain was recorded for gain filling period and days to final harvest.

Table 5. Heritability and Genetic gain for 20 characters

Sl. No.	Characters	Heritability in per cent (H^2)	Genetic gain in per cent (GG)
1.	Plant height	28.29	11.53
2.	Number of leaves per plant	45.70	24.55
3.	Number of pods per plant	20.35	10.20
4.	Pod length	56.47	5.97
5.	Number of seeds per pod	44.98	5.71
6.	Hundred seed weight	79.95	11.95
7.	Seed size	64.75	9.94
8.	Yield per plant	7.84	3.24
9.	Yield per plot	59.31	67.05
10.	Haulm yield	40.23	49.06
11.	Stomatal distribution	42.76	14.56
12.	Leaf area index	29.36	23.18
13.	Root length	62.44	14.48
14.	Root spread	75.65	23.07
15.	Root/shoot ratio	33.77	14.65
16.	Days to first flowering	61.76	9.19
17.	Days to maturity of first pod	77.67	8.05
18.	Days to final harvest	89.79	9.41
19.	Grain filling period	90.79	12.22
20.	Proline content	20.83	18.71

Fig. 2. Heritability and Genetic gain for twenty characters

X_1 - Plant height
X_2 - Number of leaves per plant
X_3 - Number of pods per plant
X_4 - Pod length
X_5 - Number of seeds per pod
X_6 - Hundred seed weight
X_7 - Seed size
X_8 - Yield per plant
X_9 - Yield per plot
X_{10} - Haulm yield
X_{11} - Stomatal distribution
X_{12} - Leaf area index
X_{13} - Root length
X_{14} - Root spread
X_{15} - Root/shoot ratio
X_{16} - Days to first flowering
X_{17} - Days to maturity of first pod
X_{18} - Days to final harvest
X_{19} - Grain filling period
X_{20} - Proline content

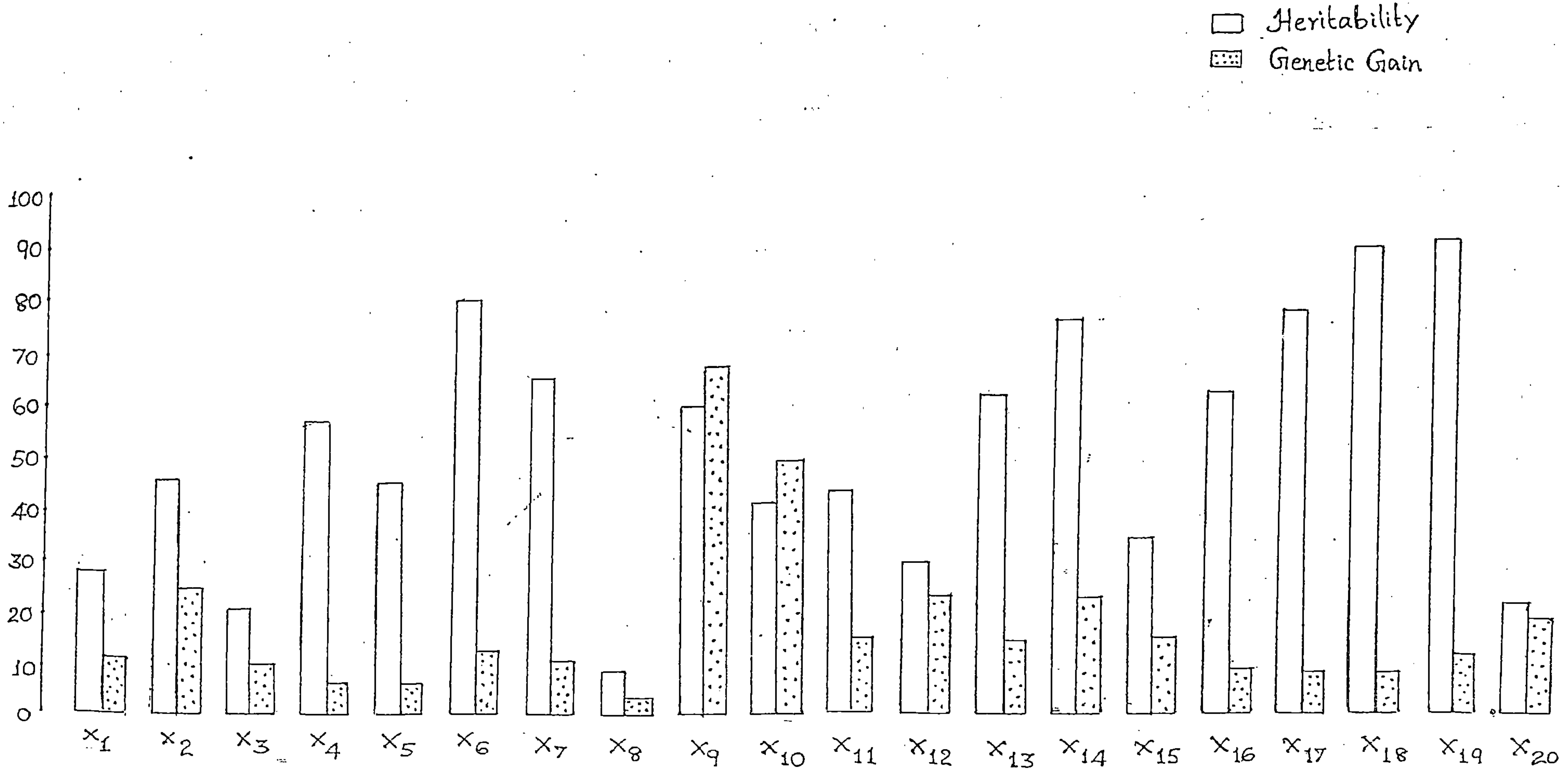


FIG. 2 HERITABILITY AND GENETIC GAIN FOR TWENTY CHARACTERS

4.3. Correlation Analysis

Genotypic and phenotypic correlation co-efficients were estimated. The data on correlation have been split up and are presented under two heads;

i) Correlation between yield and other characters.

ii) Correlation between pairs of characters other than yield.

The estimates of correlation co-efficients at the genotypic and phenotypic levels are given in Table 6.

In general the genotypic correlations were higher, in magnitude than their corresponding phenotypic correlations. Yield showed positive genotypic correlations with number of leaves per plant, number of pods per plant, hundred seed weight, seed size, grain filling period and proline content.

Proline content showed the highest positive genotypic correlation with yield per plant (1.2601) followed by hundred seed weight (1.1459), number of pods per plant (1.0544), grain filling period (0.8134), seed size (0.7508) and number of leaves per plant (0.3986).

Plant height showed a significant negative correlation of -1.4170 with yield followed by number of seeds per

Table 6. Genotypic (r_g) and Phenotypic (r_p) correlation Co-efficients between yield and other Characters.

Sl. No.	Characters	Phenotypic Correlation Coefficient (r_p)	Genotypic Correlation Coefficient (r_g)
1.	Plant height	0.1373	-1.4170
2.	No. of leaves per plant	0.4940	0.3986
3.	No. of pods per plant	0.9126	1.0544
4.	Pod length	0.0211	-0.7296
5.	No. of seeds per pod	0.0994	-1.0728
6.	Hundred seed weight	0.1367	1.1459
7.	Seed size	0.2118	0.7588
8.	Haulm yield	0.0866	-1.0097
9.	Stomatal distribution	0.1223	-0.3187
10.	Leaf area index	0.3902	-0.7081
11.	Root length	0.0793	-0.4559
12.	Root spread	0.0403	-0.2394
13.	Root/shoot ratio	-0.2952	-0.3885
14.	Days to first flowering	-0.1243	-0.8693
15.	Days to maturity of first pod	-0.1297	-0.2535
16.	Days to final harvest	-0.1039	-0.5953
17.	Grain filling period	0.2322	0.8134
18.	Proline content	0.0582	1.2601

pod (-1.0728), days to first flowering (-0.8693), length of the pod (-0.7296) and leaf area index (-0.7081).

At the phenotypic level all characters except root/shoot ratio, days to first flowering, days to maturity of first pod and days to final harvest showed positive correlations with yield. Significant positive correlations were observed for number of pods per plant (0.9126), number of leaves per plant (0.4940) and leaf area index (0.3903). Other characters showed low positive correlations only. Root/shoot ratio showed a significant negative correlation of -0.2952 with yield whereas the other negative correlations were not significant.

ii) Correlation between pairs of characters other than those with yield

Table 7 provides the data on correlation among the characters in all combinations. The genotypic correlations among yield per plant and 18 yield components are diagrammatically presented in Fig. 3.

At the genotypic level plant height showed a significant positive correlation with root length (0.7102), days to final harvest (0.6948), haulm yield (0.6347), number of seeds per pod (0.6342), root spread (0.5500), pod length (0.3663) and root/shoot ratio (0.3450). Significant negative

Fig. 1. Phenotypic and genotypic coefficient of variation for twenty characters

X_1 - Plant height
X_2 - Number of leaves per plant
X_3 - Number of pods per plant
X_4 - Pod length
X_5 - Number of seeds per pod
X_6 - Hundred seed weight
X_7 - Seed size
X_8 - Yield per plant
X_9 - Yield per plot
X_{10} - Haulm yield
X_{11} - Stomatal distribution
X_{12} - Leaf area index
X_{13} - Root length
X_{14} - Root spread
X_{15} - Root/shoot ratio
X_{16} - Days to first flowering
X_{17} - Days to maturity of first pod
X_{18} - Days to final harvest
X_{19} - Grain filling period
X_{20} - Proline content

Table 7. Correlation between pairs of characters other than those with yield

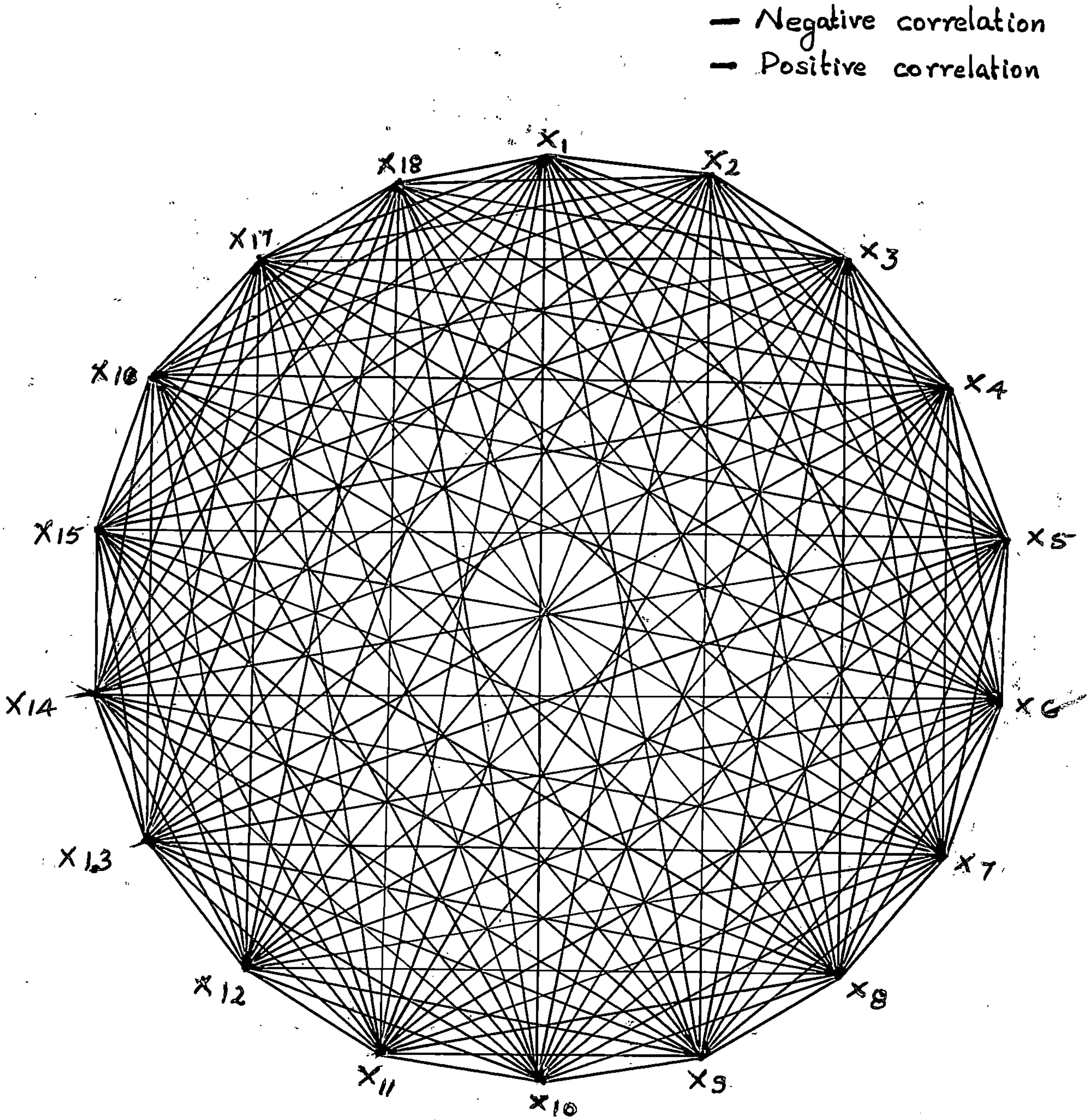
	Plant height	No. of leaves per plant	No. of pods per plant	Pod length	No. of seeds per pod	Hundred seed weight	Seed size	Haulm yield	Stomatal distribution	Leaf Area Index	Root length	Root spread	Root shoot ratio	Days to first flowering	Days to maturity of first pod	Days to final harvest	Grain filling period	Proline content
Plant height		0.0708	-0.8259	0.3383	0.8342	-0.6508	-0.2396	0.8747	0.1468	-0.0281	0.7102	0.5500	0.3450	0.2358	0.1666	0.6948	-0.0084	-0.1801
Number of leaves per plant	0.2359		0.2017	0.5289	0.2192	0.1521	0.3663	-0.3293	0.4846	0.9864	0.7276	0.7894	-0.0990	0.3383	0.6250	0.5155	0.2052	0.4108
Number of pods per plant	0.0867	0.4720		-0.6189	-0.9225	0.0103	0.5147	-0.5791	-0.1372	-0.3959	-0.2584	-0.1637	-0.1567	-0.6809	-0.1940	-0.2437	0.8357	0.8004
Pod length	0.3323	0.3734	-0.1333		0.7591	-0.2567	0.1734	-0.3802	0.2459	0.8467	0.6902	0.8391	0.3034	0.7437	0.5744	0.5315	-0.5431	-0.1013
Number of seeds per pod	0.4101	0.2978	0.0117	0.3234		-0.5723	-0.3464	0.1702	0.1033	0.2641	0.4361	0.5527	-0.3155	0.2655	0.1366	0.2992	-0.5332	0.1992
Hundred seed weight	-0.3584	0.0581	0.2321	-0.2085	-0.2849		0.4682	-0.5513	0.1024	0.0538	-0.1251	-0.1416	-0.1835	-0.0071	0.1815	-0.0715	0.3585	-0.1116
Seed size	-0.0951	0.3809	0.2241	0.0927	-0.1498	0.3429		-0.1576	0.1352	0.5668	0.4015	0.3965	-0.2916	0.6098	0.6338	0.4464	-0.1169	-0.0384
Haulm yield	0.4948	0.0855	0.1260	-0.0235	0.2211	-0.3231	-0.2001		-0.1117	-0.3391	0.3963	0.2000	0.1692	-0.0351	0.0677	0.3908	0.1344	-0.0672
Stomatal distribution	0.2950	0.2853	0.1227	0.1931	0.1836	-0.0069	0.1480	-0.0330		0.5979	0.1146	0.2320	0.5674	-0.0095	0.1591	0.1007	-0.0189	0.0347
Leaf area index	0.4964	0.8220	0.3702	0.5085	0.3616	-0.0462	0.3517	0.1766	0.3613		1.0073	1.0698	0.2664	0.7501	0.9477	[illegible]	0.0547	0.1156
Root length	0.4480	0.5045	0.0755	0.4431	0.4565	-0.1670	0.3313	0.2662	0.1615	0.6012		1.0337	0.0152	0.7537	0.7920	0.9925	-0.1917	-0.1592
Root spread	0.3789	0.6309	0.0300	0.5840	0.3531	-0.1482	0.3409	0.2356	0.2098	0.6829	0.6714		-0.0230	0.7195	0.7634	0.8875	-0.1521	0.1369
Root/shoot ratio	0.0670	-0.0517	-0.2404	0.0639	-0.1032	0.0166	-0.0883	-0.0995	0.0696	0.1053	-0.0556	-0.0620		-0.0571	0.0854	0.0829	0.3498	-0.7628
Days to first flowering	-0.0842	0.1556	-0.1715	0.3532	0.0575	-0.0922	0.3667	-0.0445	-0.0305	0.2107	0.4525	0.4925	-0.1386		0.8274	0.7368	-0.5905	0.0046
Days to maturity of first pod	-0.0799	0.3939	-0.1306	0.2857	0.0073	0.0992	0.4791	-0.0312	0.0061	0.3783	0.5115	0.6346	0.0349	0.7778		0.8185	-0.1192	-0.0427
Days to final harvest	0.3510	0.3700	-0.0712	0.4072	0.1595	-0.0428	0.3633	0.2402	0.0542	0.5042	0.7280	0.7448	0.0396	0.5548	0.7065		-0.0893	-0.0035
Grain filling period	-0.0112	0.1525	0.3773	-0.3735	-0.3236	0.0306	-0.0949	0.0683	0.0038	0.0006	-0.1449	-0.1632	-0.2380	-0.4684	-0.1023	-0.1095		0.1151
Proline content	-0.0604	0.0578	0.0090	-0.1037	-0.0298	-0.0236	0.0220	-0.2039	-0.0617	-0.0216	0.0066	0.0294	-0.1783	-0.0257	-0.0022	-0.0039	0.0188	

Upper off diagonal - Genotypic correlations   Lower off diagonal - phenotypic correlations

Fig. 3. Correlation diagram

X_1 - Plant height
X_2 - Number of leaves per plant
X_3 - Number of pods per plant
X_4 - Pod length
X_5 - Number of seeds per pod
X_6 - Hundred seed weight
X_7 - Seed size
X_8 - Haulm yield
X_9 - Stomatal distribution
X_{10} - Leaf area index
X_{11} - Root length
X_{12} - Root spread
X_{13} - Root/shoot ratio
X_{14} - Days to first flowering
X_{15} - Days to maturity of first pod
X_{16} - Days to final harvest
X_{17} - Grain filling period
X_{18} - Proline content

FIG 3 CORRELATION DIAGRAM



correlations were observed for number of pods per plant (-0.8259) and hundred seed weight (-0.6508). At the phenotypic level significant positive correlations were observed for leaf area index (0.4964), haulm yield (0.4948), root length (0.4480), number of seeds per pod (0.4101), root spread (0.3789), days to final harvest (0.3510), pod length (0.3323) and stomatal distribution (0.2950). Significant negative correlation was observed for hundred seed weight only (-0.3584).

Number of leaves per plant showed significant positive correlations with leaf area index (0.9864), root spread (0.7894), root length (0.7276), days to maturity of first pod (0.6250), pod length (0.5989), seed size (0.5663), days to final harvest (0.5155), stomatal distribution (0.4846), proline content (0.4108) and days to first flowering (0.3383) at the genotypic level. Low positive correlations were observed with number of seeds per pod, number of pods per plant and hundred seed weight. At the phenotypic level significant positive correlations were observed for all characters except hundred seed weight, haulm yield, days to first flowering, grain filling period and proline content, which showed low positive correlations and root/shoot ratio showing a low negative correlation.

Number of pods per plant was found to have significant positive genotypic correlation with hundred seed weight (0.9103), grain filling period (0.8357), proline content (0.8004) and seed size (0.5147). Significant negative correlation was observed with number of seeds per pod (-0.9225), days to first flowering (-0.6808), pod length (-0.6189), haulm yield (-0.5791), leaf area index (-0.3959) and root length (-0.2584). At the phenotypic level significant positive correlations were observed with grain filling period (0.3773) and leaf area index (0.3702) only.

Pod length was found to have significant positive genotypic correlations with leaf area index (0.8467), root spread (0.8391), number of seeds per pod (0.7591), days to first flowering (0.7437), root length (0.6902), days to maturity of first pod (0.5744), days to final harvest (0.5315) and root/shoot ratio (0.3034). Significant negative correlations were observed with grain filling period (-0.5431), haulm yield (-0.3802) and hundred seed weight (-0.2567). Phenotypic correlations of pod length with number of seeds per pod, leaf area index, root length, root spread, days to first flowering, days to maturity of first pod and days to final harvest were also positive and significant. Grain filling period showed significant negative phenotypic correlation with pod length.

Number of seeds per pod showed significant positive association with root spread (0.5527), root length (0.4361) days to final harvest (0.2992), days to first flowering (0.2655) and leaf area index (0.2641) at the genotypic level. Significant negative associations were observed with hundred seed weight (-0.5723), grain filling period (-0.5332), seed size (-0.3464) and root/shoot ratio (-0.3155). At the phenotypic level also significant positive relationships were observed with leaf area index, root length and root spread while negative association was observed with hundred seed weight.

At the genotypic level hundred seed weight showed significant positive correlation with seed size (0.4682) and grain filling period (0.3585) while significant negative correlations were observed with haulm yield (-0.5513). Leaf area index and days to maturity of first pod showed low positive genotypic correlations with hundred seed weight. At the phenotypic level also significant positive correlations were observed for seed size and grain filling period and negative correlations with haulm yield.

Seed size showed significant positive genotypic correlations with days to maturity of first pod (0.6338), days to first flowering (0.6098), leaf area index (0.5668), days to final harvest (0.4464), root length (0.4015) and root spread (0.3965). Grain filling period, root/shoot ratio and proline content showed low negative genotypic correlations with seed size. At the phenotypic level also, seed size showed significant positive associations with days to first flowering, days to maturity of first pod, days to final harvest, leaf area index, root spread and root length.

Root length (0.3963) and days to final harvest (0.3408) showed significant positive genotypic correlation with haulm yield. Root spread, root/shoot ratio, grain filling period and days to maturity of first pod showed low positive genotypic correlations, while leaf area index showed significant negative correlation with haulm yield. At the phenotypic level root length showed significant positive correlation (0.2662) with haulm yield.

Stomatal distribution showed significant positive genotypic correlations with leaf area index (0.5979) and root/shoot ratio (0.5674). Root length, root spread, days to maturity of first pod, days to final harvest and proline content showed low positive genotypic correlations. Days to first flowering and grain filling period showed very low negative correlations with stomatal distribution. At the phenotypic level leaf area index was found to have a significant positive correlation (0.3613) with stomatal distribution.

Leaf area index showed highly significant positive genotypic correlation with root spread (1.0698), root length (1.0073), days to maturity of first pod (0.9477), days to final harvest (0.8798) and days to first flowering (0.7501). Its phenotypic correlations with root length, root spread, days to maturity of first pod and days to final harvest were also positive and significant.

Root length showed a significant positive genotypic association with root spread (1.0337). Its association with days to final harvest (0.9925), days to maturity of first pod (0.7920) and days to first flowering (0.7537) were also significant and positive. However grain filling period and proline content were found to have negative genotypic associations only. At the phenotypic level also the characters root spread, days to first flowering, days to maturity of first pod and days to final harvest showed significant positive association.

Root spread was found to have significant positive correlations with days to final harvest (0.8875), days to maturity of first pod (0.7634) and days to first flowering (0.7195) at the genotypic level. Phenotypic correlations of these characters with root spread were also significant and positive. Root/shoot ratio and grain filling period showed low negative genotypic and phenotypic correlation with root spread.

Root/shoot ratio showed significant positive genotypic correlation with grain filling period (0.3498) and significant negative genotypic correlation with proline content (-0.7628). Days to first flowering showed low negative genotypic and phenotypic correlations with root/shoot ratio.

Days to first flowering was found to have a significant positive genotypic correlation with days to maturity of first pod (0.8274) and days to final harvest (0.7368) and a significant negative correlation with grain filling period (-0.5905). Similar associations were observed at the phenotypic level also.

Days to maturity of first pod showed a significant positive genotypic association of 0.8185 and phenotypic association of 0.7065 with days to final harvest. With proline content it showed a low negative genotypic and phenotypic association.

Days to final harvest showed low negative genotypic and phenotypic correlations with grain filling period and proline content.

Grain filling period was found to have a low positive genotypic and phenotypic correlations with proline content.

4.4. Path Analysis

To get a clear picture of the cause effect relationship of various component characters and yield, path coefficient analysis was undertaken. The genotypic correlations between yield and seven component characters, viz., plant height, number of leaves per plant, number of pods per plant, pod length, seed size, root/shoot ratio and days to first flowering were partitioned into their corresponding direct and indirect effects and the results obtained are presented in Table 8. The path diagram showing direct effects and the genotypic correlations are presented in Fig. 4.

Number of pods per plant showed the highest positive direct effect of 1.7462 on yield. It exerted positive indirect effect through root/shoot ratio (0.0622) and negative indirect effects through plant height, number of leaves per plant, seed size, pod length and days to first flowering.

Plant height showed the second highest positive direct effect of 0.3495 on seed yield eventhough its genotypic correlation was negative (-1.4170). It showed positive indirect effects through seed size (0.0842), pod length (0.0841) and days to first flowering (0.0647) and negative indirect effects through number of leaves per plant (-0.0035).

Table 8. Directs and indirect effects of the various characters on yield.

Characters	Plant height	No. of leaves per plant	No. of pods per plant	Seed size	Pod length	Root/ shoot ratio	Days to first flowering	Genotyp Correlation
Plant height	0.3495	-0.0035	-1.4422	0.0842	0.0841	-0.1369	0.0647	-1.41
No. of leaves per plant	0.0248	-0.0491	0.3522	-0.1969	0.1376	0.0393	0.0928	0.39
No. of pods per plant	-0.2887	-0.0099	1.7462	-0.1803	-0.1421	0.0622	-0.1868	1.054
Seed size	-0.0837	-0.0278	0.8989	-0.3513	0.0398	0.1157	0.1673	0.75
Pod length	0.1280	-0.0294	-1.0807	-0.0609	0.2297	-0.1204	0.2041	-0.72
Root/shoot ratio	0.1206	0.0049	-0.2736	0.1024	0.0697	-0.3968	-0.0157	-0.38
Days to first flowering	0.0824	-0.0166	-1.1888	-0.2142	0.1708	0.0227	0.2744	-0.86

Residue = 0.3761

(Underlined figures represent direct effects)

Fig. 4. Path diagram showing direct effects and genotypic correlations in greengram

Y - Grain yield per plant

X_1 - Plant height

X_2 - Number of leaves per plant

X_3 - Number of pods per plant

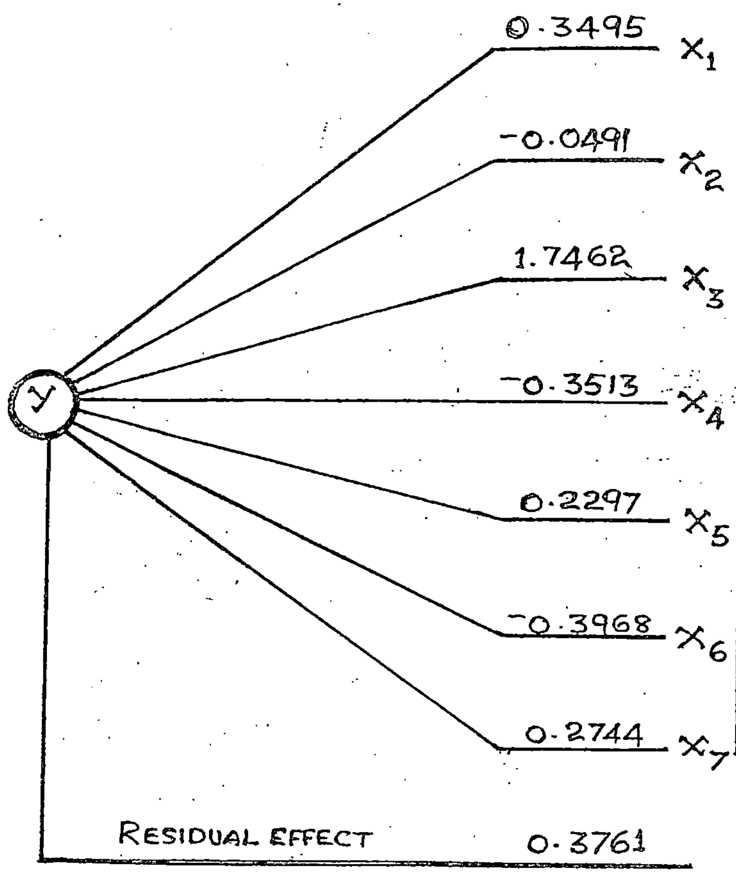
X_4 - Seed size

X_5 - Pod length

X_6 - Root/shoot ratio

X_7 - Days to first flowering

FIG-4 PATH DIAGRAM SHOWING DIRECT EFFECTS AND GENOTYPIC CORRELATIONS IN GREENGRAM



0.0708					
-0.8259	0.2017				
-0.2396	0.5663	0.5147			
0.3663	0.5989	-0.6189	0.1734		
0.3450	-0.0990	-0.1567	-0.2916	0.3034	
0.2358	0.3383	-0.6808	0.6098	0.7437	-0.0571

number of pods per plant (-1.4422) and root/shoot ratio (-0.1369) leading to a negative correlation.

Days to first flowering exerted positive direct effect on yield (0.2744) and positive indirect effects through plant height (0.0824), pod length (0.1708) and root/shoot ratio (0.0227). A high negative indirect effect was observed through number of pods per plant (-1.1880).

Pod length showed a positive direct effect of 0.2297 on yield with positive indirect effects through plant height (0.1280) and days to first flowering (0.2041) and a high negative indirect effect through number of pods per plant (-1.0807).

Root shoot ratio recorded negative direct effect (-0.3968) on yield. But this character exerted positive indirect effects through plant height (0.1206), number of leaves per plant (0.0049), seed size (0.1024) and pod length (0.0697). Negative indirect effects were shown through number of pods per plant (-0.2736) and days to first flowering (-0.0157).

Seed size showed a negative direct effect of -0.3513 on yield but its indirect effect through number of pods per plant was high and positive (0.8988). Pod length (0.0398), root shoot ratio (0.1157) and days to first flowering

(0.1673) also showed positive indirect effects, while plant height (-0.0837) and number of leaves per plant (-0.0278) showed negative indirect effects.

Number of leaves per plant showed a very low negative direct effect of -0.0491 but its indirect effect through number of pods per plant was positive (0.3522). Indirect effect through other characters except seed size were also found to be positive.

In this study the residual effect was worked out to be 0.3761. About 62 per cent of the variation in yield was explained through the direct influence of these characters. Number of pods per plant was found to be the major factor among these characters which had maximum influence on the yield directly.

4.5. Soil Moisture Analysis

The data collected on soil moisture at weekly intervals were subjected to analysis of variance and the results presented in Table 9.

Results indicated that the varieties were subjected to uniform stress conditions for almost the entire growth period except at 53 days after sowing, where significant difference at one per cent level was observed.

Table 9. Analysis of variance for soil moisture.

Sl. No.	Days after sowing	Mean sum of Squares			'F' Value
		Replication df=2	Treatments df=19	Error df=38	
1.	18	0.74	3.16	6.48	0.49
2.	25	8.92	8.19	8.24	0.99
3.	32	114.63	9.33	12.67	0.74
4.	39	130.86	6.51	5.44	1.20
5.	46	87.37	8.25	5.13	1.61
6.	53	53.99	5.90	3.16	1.87*
7.	60	28.22	2.22	1.90	1.17

* Significant at 5 per cent level

Mean values of soil moisture recorded in different plots at different stages of growth are presented in Table 10 and graphically presented in Figures 5 to 8. The results revealed that a comparatively high soil moisture was prevalent during the initial stages of crop growth that is upto 31 days after sowing. This period corresponds to the vegetative growth phase of the crop. From 32 days to 45 days after sowing the soil moisture level was very low. This period happens to be the flowering stage. Thus the plants were subjected to a fairly high waterstress during the critical period of flowering. During the later stages of crop growth also low soil moisture levels were recorded. But the mean values of soil moisture from 46 days to 59 days of crop growth was slightly higher than those during the flowering period. Minimum moisture levels were recorded at the time of harvest after 60 days of crop growth.

Table 10. Mean values of soil moisture (per cent) at weekly intervals.

Sl. No.	Varieties	18 days after sowing	25 days after sowing	32 days after sowing	39 days after sowing	46 days after sowing	53 days after sowing	60 days after sowing
1.	KM-2	11.17	6.41	4.26	4.19	5.67	4.91	3.81
2.	Co-3	8.32	11.46	5.85	4.97	7.99	6.44	4.56
3.	Co-4	9.10	7.53	6.51	2.39	4.61	5.67	4.54
4.	Pusa Baisakhi	9.49	7.53	8.05	6.49	8.44	7.22	5.32
5.	Pusa-101	8.70	7.56	8.59	6.12	8.09	7.62	5.67
6.	Pusa-103	7.16	9.11	4.72	5.02	7.22	6.44	5.28
7.	Pusa-119	8.83	7.53	5.02	6.54	7.60	6.81	5.29
8.	Pusa-117	10.71	8.34	4.62	6.97	7.22	6.44	4.93
9.	ML-131	9.09	7.15	5.07	6.62	7.28	6.49	4.61
10.	Pusa-102	7.58	9.51	5.43	5.72	7.20	6.04	4.57
11.	PDM-84-146	8.72	7.53	5.41	5.72	4.61	6.44	4.91
12.	LGG-407	9.90	8.30	2.74	4.96	6.05	5.28	4.54
13.	Pusa-118	10.90	10.90	1.70	6.49	4.91	4.17	3.81
14.	Pusa-104	8.32	7.53	2.43	2.77	4.19	3.81	3.09
15.	RMG-70	8.72	6.80	5.32	3.81	5.65	4.53	4.55
16.	ML-322	9.85	8.32	3.88	3.82	4.20	3.81	3.45
17.	PDM-84-139	9.14	9.50	5.73	5.27	6.03	4.55	3.45
18.	RMG-146	9.50	7.92	4.66	3.81	3.45	3.45	3.09
19.	PDM-54	9.90	8.70	3.48	3.45	3.45	3.45	3.45
20.	OUM-6	9.10	12.95	2.41	2.39	3.81	3.09	2.74
	Mean	9.22	8.53	4.79	4.98	5.88	5.33	4.28
	CD	4.21	4.75	5.38	3.88	3.75	2.94	2.28

FIG.5 _ SOIL MOISTURE PER CENT AT WEEKLY INTERVALS

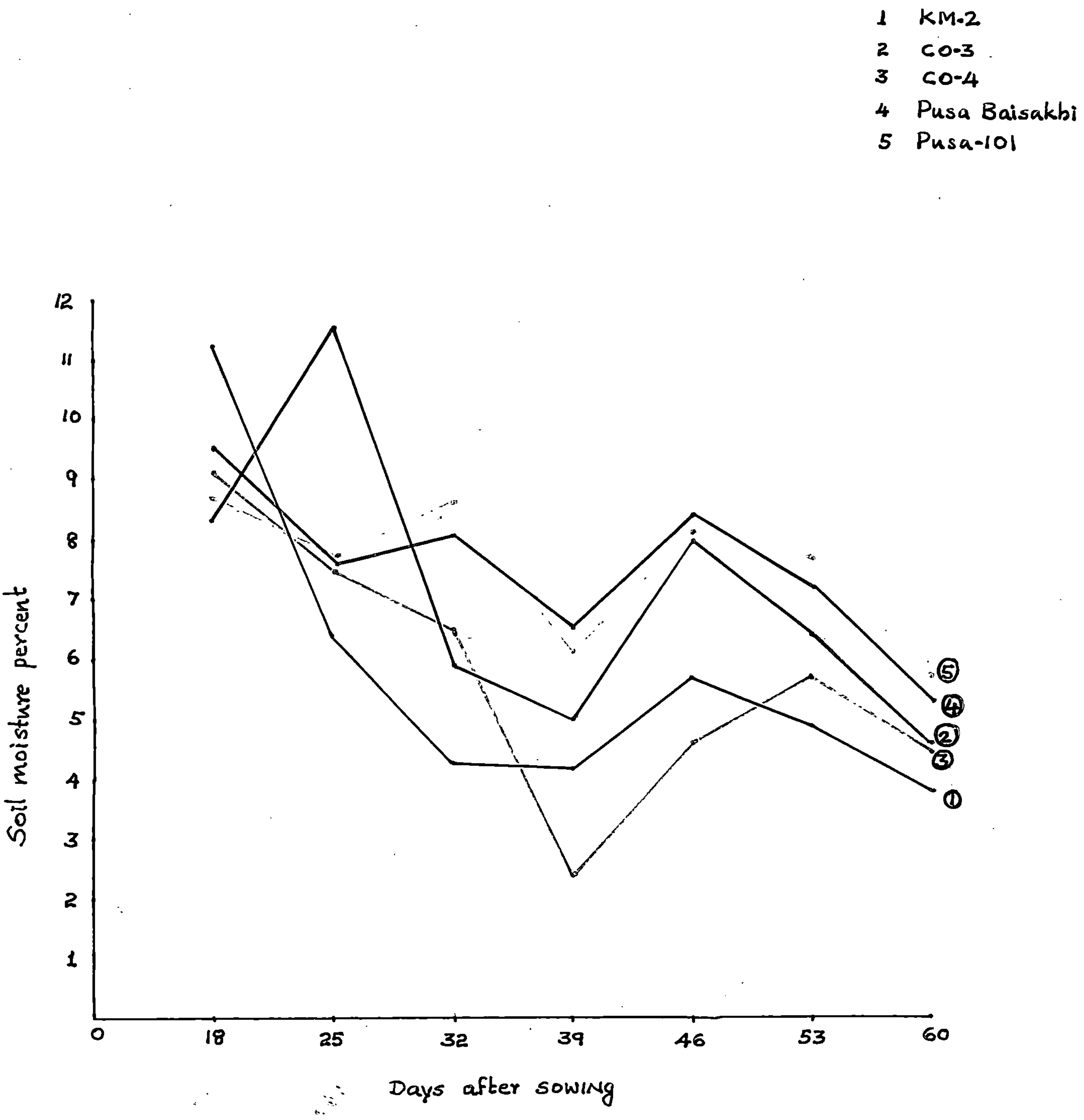


FIG. 6 SOIL MOISTURE PER CENT AT WEEKLY INTERVALS

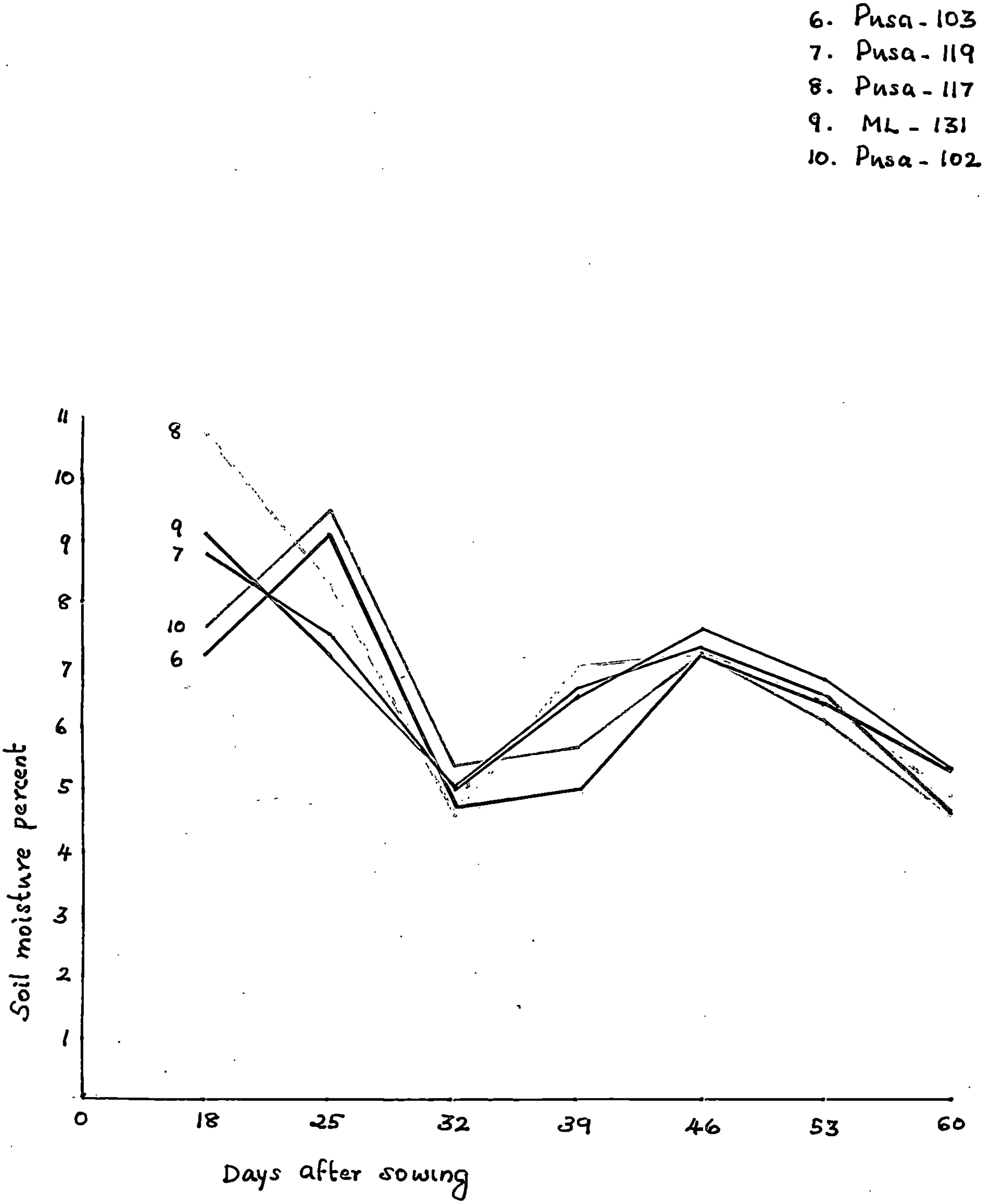


FIG. 7 SOIL MOISTURE PER CENT AT WEEKLY INTERVALS

11. PDM-84-146
12. LGG-407
13. Pusa-118
14. Pusa-104
15. RMG-70

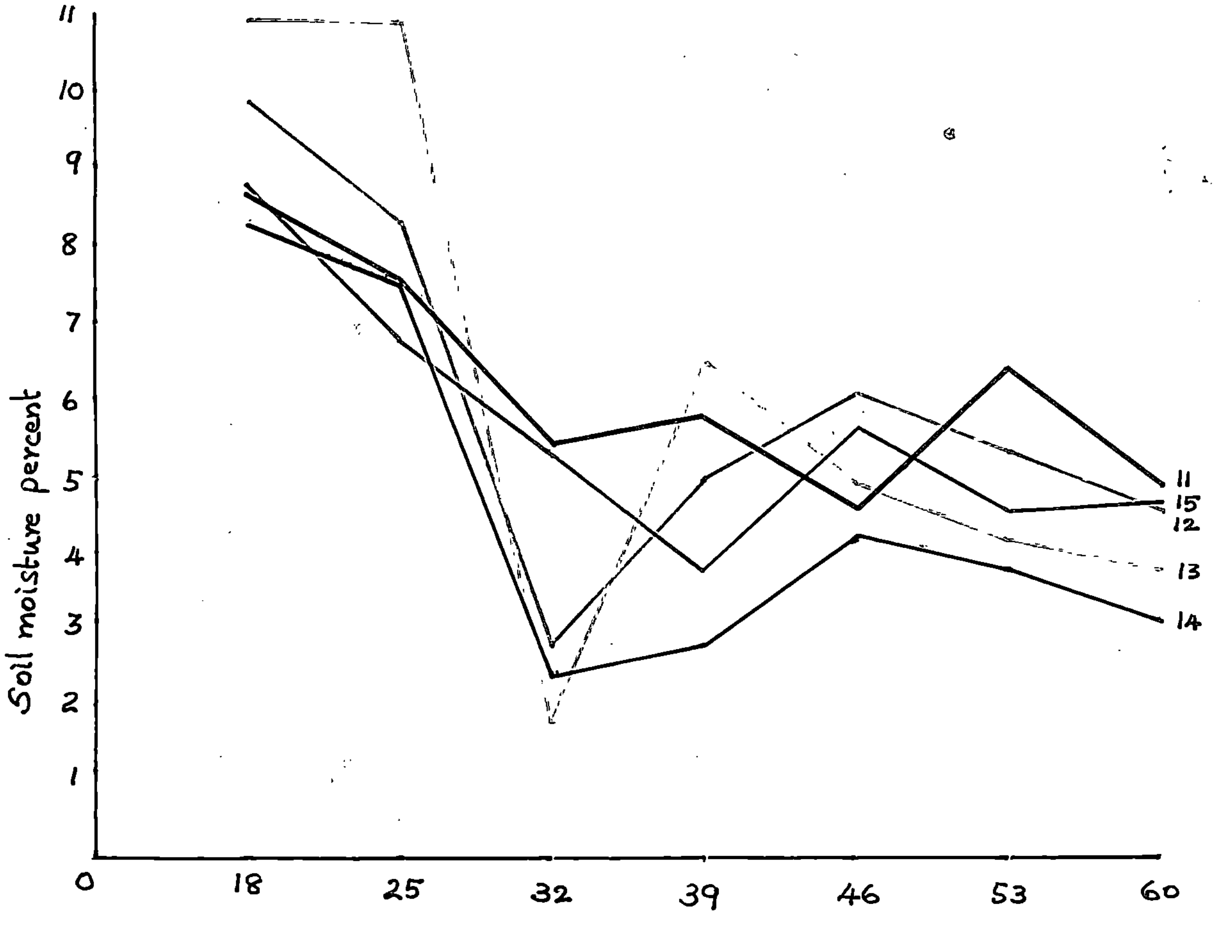
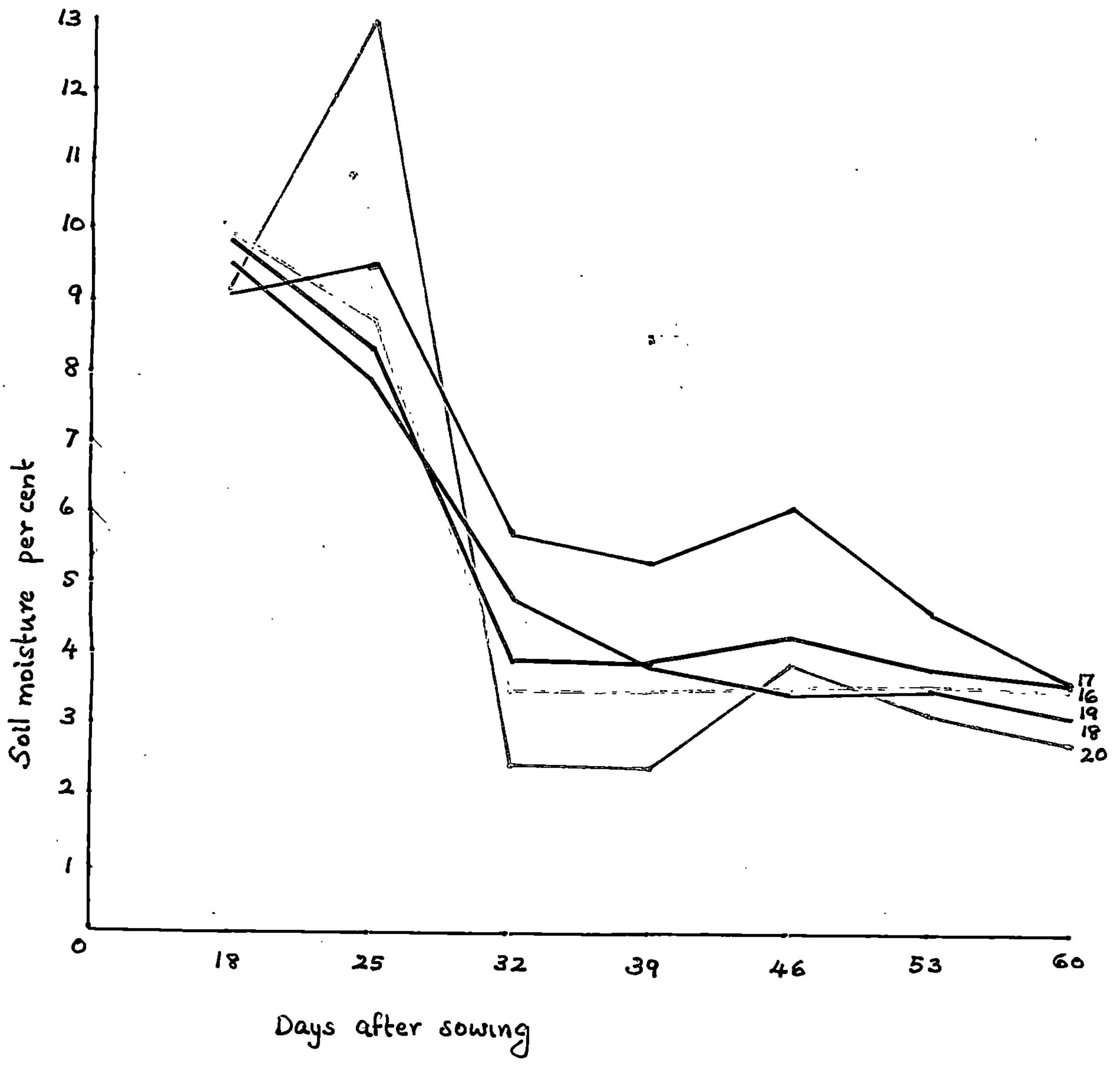


FIG-8 SOIL MOISTURE PERCENT AT WEEKLY INTERVALS

16. ML-322
17. PDM-84-139
18. RMG-146
19. PDM-54
20. OUM-6



DISCUSSION

DISCUSSION

Drought resistance is a complex phenomenon conditioned by a number of internal and external factors and their interaction. Plants respond to drought in a variety of ways thereby adapting to it or resisting its adverse effect. These interactions always lead to a change in the vegetative as well as reproductive performance of the crop. In the present study twenty varieties of greengram were evaluated for their potential to tolerate moisture stress and the results obtained are discussed below.

5.1.1. Plant height

Plant height is an important vegetative component influenced adversely by moisture stress. Considerable reduction in plant height was observed in all the varieties evaluated which was in accordance with the reports of Ali and Alam (1973) in greengram and Momen et al. (1979) in soybean. Medium height was found to be advantageous under stress conditions as evidenced from the high yield recorded by moderately taller plants. An increase in the height may increase the transpirational loss of water as well as water requirement of the plant due to an increased vegetative growth there by hindering the reproductive growth and ultimately reducing the yield.

5.1.2. Number of leaves per plant

The reduced number of leaves per plant observed in the present study is in accordance with the reports of Ali and Alam (1973) in greengram and Turk and Hall (1980) in cowpea. Waterloss through transpiration is greatly reduced by a reduction in the number of leaves so that the available moisture can be effectively utilized for the reproductive growth thereby enhancing the yield.

5.1.3. Leaf area index

Reduction in leaf area is an important mechanism for transpiration control under drought stress during the entire reproductive and grain filling period. A reduced leaf area observed in this study is in consonance with the reports of Ali and Alam (1973) in greengram, Momen et al. (1979) in soybean and Turk and Hall (1980) in cowpea. A reduced leaf area decreases the transpirational loss of water as well as avoid mutual shading and thereby enhances the photosynthetic activity of the plant.

5.1.4. Stomatal distribution

Stomata plays an important role in deciding the plants response to water deficit. An increase in the number of stomates will increase the transpirational loss of water. Hence a reduced number of stomates per unit area is recorded the lowest yield per plant and most of the high yielding varieties recorded a moderate number of stomates per unit area confirming the reports of Kramer (1959) that a reduced number of stomates per unit area decreases drought injury in plants.

5.1.5. Root length and spread

Root length and spread influence grain yield under stress conditions by influencing the water uptake of plant. A well developed and wide spreading root system is characteristic of reduced drought injury and increased yield in crop plants as reported by Babalola (1980) in cowpea, Kavitha (1982) in blackgram and Arjunan et al. (1988) in groundnut. In contrast to this in the present study the varieties with high root length and spread were found to be low yielding and it may be due to the increased vegetative growth at the expense of reproductive growth. These varieties were found to have an increased shoot growth which was evident from their high leaf area index. A moderate root length and spread were recorded by most of the high yielding varieties under stress.

5.1.6. Root/shoot ratio

Water stress increases the proportion of plant dry matter translocated to the roots compared to the leaves and stems thus increasing the root/shoot ratio, eventhough the absolute amount of root growth was reduced. In the present study varieties maintained a moderate root/shoot ratio and a massive increase in the root/shoot ratio was not observed. Increased root/shoot ratios during stress were reported by Ali and Alam (1973) in greengram, Babalola (1980) in cowpea and Arjunan et al. (1988) in groundnut.

5.1.7. Earliness

Earliness may not be a true device for resistance mechanism, but it is certainly an important character for drought prone areas. Earliness results in an escape of the effect of drought because the plants are able to complete their growth before the advent of drought. In the present study the varieties identified as high yielding were found to require only short periods for first flowering, maturity of first pod and final harvest. These results are in accordance with the reports of Turk et al. (1980), Hall and Grantz (1981) in cowpea and Sivakumar and Singh (1987) in chickpea. However, Sammons et al. (1980/81) reported no consistent relationship between maturity group and response to drought stress in soybean.

5.1.8. Grain filling period

Filling period influences yield by influencing the size and weight of seeds produced. A reduction in the filling period reduces the time available for the filling of seeds, resulting in a poor seed filling, because most of the dry matter for filling the seeds are synthesized during this period. Hence varieties which can maintain longer filling periods are advantageous under stress conditions. In the present investigation the varieties identified as high yielding recorded longer filling periods which were in consonance with the reports of Omara (1987) in barley.

5.1.9. Proline content

Accumulation of proline during stress is considered to be an adaptive mechanism for drought tolerance. Proline increases considerably the amount of strongly bound water in the leaves there by enhancing the leaf water potential. Thus the varieties showing accumulation of proline during stress will be drought tolerant and high yielding. In the present study maximum proline accumulation was observed in the variety having the highest yield per plant which is in conformity with the results of Mehkri et al. (1977) in groundnut, Elmore and Michael (1981) in cotton and Mukherjee et al. (1982) in cowpea.

5.1.10. Yield and yield components

The ability of a crop species to yield when subjected to suboptimal moisture is of fundamental importance in the measurement of tolerance to moisture stress. In general yield is greatly reduced under moisture stress because of a generalised reduction in all yield components, some being more affected than others. Considerable reduction in yield was observed in all the 20 varieties in the present study. This is in confirmity with the findings of Sionit and Kramer (1977) and Sammons et al. (1980/81) in soybean, Summerfield et al. (1973), Dabalola (1980) and Turk et al. (1980) in cowpea, Potluri et al. (1986) in blackgram and Sivakumar and Singh (1987) in chickpea.

Water stress influences seed yield by reducing the number of pods per plant. In the present study a reduction in number of pods was observed which was in conformity with the reports of Sionit and Kramer (1977) and Sammons et al. (1980/81) in soybean, Constable and Hearn (1978) in cowpea and Rao et al. (1986) in groundnut. However in the present study number of pods per plant contributed significantly to high grain yield and this is evident from the fact that the varieties showing higher grain yield also had more number of pods per plant.

Pod length and seeds per pod were found to be influenced significantly in the present study indicating that varieties with longer pods and more number of seeds per pod are less suitable for stress conditions. This is further proved by the fact that the high yielding varieties identified had a comparatively reduced pod length and seeds per pod. Reduction in pod length and seeds per pod was in agreement with the reports of Summerfield et al. (1976) and Constable and Hearn (1978) in cowpea.

The two other yield components hundred seed weight and seed size were not much affected by stress. They contributed significantly to seed yield along with the number of pods per plant. Similar results for hundred seed weight was reported by Summerfield et al. (1976) in cowpea, Semmons et al. (1980/81) in soybean and Rao et al. (1986) in groundnut. Significant reduction in seedsize was not observed in this study eventhough the reports of Constable and Hearn (1978) and Turk et al. (1980) in cowpea are against this result.

From these it is clear that the reduction in yield observed as the general response of greengram cultivars under stress can be attributed to a reduction in the various yield components, pods per plant, pod length, seeds per pod, hundred seed weight and seed size with a relatively high influence on pod length and seeds per pod. Pods per plant, hundred seed weight and grain size were less affected and they contributed significantly to yield under stress.

Maintenance of a high seed weight and seed size may be due to a longer grain filling period which provide sufficient time for the plants to fill the seeds. In general drought reduces plant yield by influencing the various yield components to different dimensions.

Considering yield and the various parameters that contribute to drought tolerance, the varieties PDM-84-139, PDM-84-146 and Pusa-103 were found to be performing favourably under stress conditions. These varieties showed high seed yield owing to more number of pods and an increased seed size and weight. These varieties were early in flowering and had a longer grain filling period which contributed to an increased seed size and weight.

5.2. Variability

Greengram is a highly self pollinated species and hence only very limited variability is available among the varieties. Moreover the continuous selection practiced in the past years to develop varieties suited to local conditions and demands, has further narrowed down the variability in the population.

Variance and coefficient of variation are the measures of variability in a population. Genetic variance as modified by the environment is measured as phenotypic variance.

Phenotypic variability cannot be used for varietal improvement. Hence the total variability available in a population could be partitioned into heritable and non-heritable components with the aid of genetic parameters.

In the present study estimates of variance components indicated only little differences between phenotypic and genotypic variances for the characters viz. pod length, number of seeds per pod, hundred seed weight, seed size, leaf area index, root spread, root/shoot ratio and grain filling period. This indicated that variations observed in these characters are mainly due to genetic causes and that environment had only negligible influence over them. But the characters, plant height, number of leaves per plant, number of pods per plant, yield per plot, haulm yield, stomatal distribution, days to first flowering, and proline content showed wide variation with regard to genotypic and phenotypic variances indicating a greater environmental influence over these characters.

Coefficient of variation is another reliable measure of variability, in a population. The phenotypic coefficient of variation measures the total variability whereas the genotypic coefficient of variation measures the genetic diversity for quantitative characters. In the present study comparatively high values of phenotypic and genotypic coefficients of variation were recorded for number of leaves per plant, yield per plot, haulm yield, leaf area index, root/shoot ratio and proline content indicating high amount of variability for these characters. This suggests that there is no scope for the improvement of these characters through selection. Comparatively high values of phenotypic coefficient of variation with correspondingly low values of genotypic coefficient of variation were recorded for the characters plant height, number of pods per plant, yield per plant, and stomatal distribution indicating a high influence of the environment in the expression of these characters. Similar trends were reported for plant height by Khorgade et al. (1985) in bengalgram.

All the other characters viz. pod length, number of seeds per pod, hundred seed weight, seed size, root length, root spread, days to first flowering, days to maturity of first pod, days to final harvest and grain filling period exhibited low phenotypic and genotypic coefficients of variation indicating a low variability for these characters. This suggests that there is not much scope for the improvement of these characters. Similar results were obtained in blackgram for pod length by Soundarapandian et al. (1975) and Goud et al. (1977).

5.3. Heritability and Genetic gain

The estimates of heritable portion of variation are given by such genetic parameters as heritability. Johnson et al. (1955) have suggested that heritability estimates along with genetic gain is more useful than heritability alone in predicting the resultant effect and selecting the best individuals.

In the present study grain filling period showed maximum heritability (90.79 per cent) and yield per plant the minimum (7.84 per cent). High heritability values were also shown by days to final harvest, hundred seed weight, days to maturity of first pod, root spread, seed size, root length, days to first flowering, yield per plot and pod length. High values of heritability indicate minimum influence of environment on these characters.

The high heritability observed for days to final harvest was in consonance with the reports of Singh and Malhotra (1970) and Veeraswamy et al. (1973) in greengram. High heritability observed for hundred seed weight is confirmed by the reports of Chowdhury et al. (1971) and Paramasivan and Rajasekharan (1980) in greengram and Singh and Mehndiratta (1969) in cowpea. The high heritability observed in respect of days to maturity of first pod is in agreement with the reports of Empig et al. (1970) in greengram. The comparatively high heritability for days to flowering in this study is in conformity with the results of Sreekumar and Abraham (1979) in greengram. Pod length also showed a comparatively high heritability confirming the reports of Gupta and Singh (1969) in greengram and Goud et al. (1977) in blackgram.

Moderate heritability estimates were observed for plant height, number of leaves per plant, number of seeds per pod, haulm yield, stomatal distribution, leaf area index and root/shoot ratio. Moderate heritability observed for seeds per pod is in consonance with the reports of Goud et al. (1977) in blackgram.

The other characters, number of pods per plant, yield per plant and proline content exhibited very low heritability values. However, Soundarapandian et al. (1975) in blackgram reported medium heritability for number of pods per plant. Low heritability values in respect of seed yield obtained by Goud et al. (1977) in blackgram and Lakshmi and Goud (1977) in cowpea are in agreement with the present results.

A high value of heritability alone does not provide the necessary information about the genetic progress that could be achieved by practicing selection. Hence genetic advance and genetic gain should also be considered along with the heritability values (Johnson et al., 1955).

Genetic gain was found to be maximum for yield per plot followed by haulm yield and minimum for yield per plant.

Among other characters studied medium genetic gains were exhibited for number of leaves per plant, leaf area index, root spread and proline content. The other characters viz. plant height, number of pods per plant, pod length, number of seeds per pod, hundred seed weight, seed size, yield per plant, stomatal distribution, root length, root/shoot ratio, days to first flowering, days to maturity of first pod, days to final harvest and grain filling period exhibited low genetic gain.

The low genetic gain expressed by yield per plant is in agreement with the findings of Singh and Mehndiratta (1969) in cowpea. Low genetic gains observed for pod length and number of seeds per pod are in conformity with the reports of Lakshmi and Goud (1977) in greengram.

The high heritability coupled with high genetic gain expressed by plot yield indicates additive gene action for this character which envisages greater scope for selection (Panse and Sukhatme, 1957).

Grain filling period, days to final harvest, days to maturity of first pod, hundred seed weight, seed size, root length, days to first flowering and pod length had high heritability coupled with low genetic gain. This indicates non additive gene action which greatly limits the scope for improvement of these characters through selection (Panse and Sukhatme, 1957).

Leaf area index and number of leaves per plant showed moderate heritability in association with moderate genetic gain. Proline content showed low heritability coupled with moderate genetic gain.

Pods per plant and yield per plant had low heritability and low genetic gain suggesting poor response to selection under normal situations.

5.4. Correlation

The correlation studies conducted revealed that genotypic correlations are higher in magnitude than phenotypic correlations. Seed yield is an important character that combines the expression of many other associated characters. An estimate of the interrelationship between yield and yield contributing characters thus facilitates effective selection for simultaneous improvement of one or more characters.

The extent of association between characters are measured by genotypic and phenotypic correlation coefficients (Mode and Robinson, 1959). Phenotypic correlations will help in designing effective breeding programmes. Genotypic correlations provide a reliable measure of genetic association between characters and help to differentiate the vital associations useful in breeding from the non vital ones (Falconer, 1981). A knowledge of genotypic correlation between characters is also of theoretical interest, because it may arise from genetic linkage, pleiotropy or from developmentally induced relationships between components that are indirect consequences of gene action (Stebbins, 1950). In the present study seed yield was found to have significant positive genotypic correlations with number of pods per plant, hundred seed weight, seed size, grain filling period, number of leaves per plant and proline content. Negative correlations were observed for all other characters viz. pod length, number of seeds per pod, plant height, root length, root spread, root/shoot ratio, leaf area index, stomatal distribution, haulm yield, days to first flowering, days to maturity of first pod and days to final harvest.

Number of pods per plant showed high positive correlation with seed yield showing that production of more number of pods under stress conditions contributed significantly to yield. This result is confirmed by the studies of

Saxena et al. (1979) in chickpea, Ranganatha (1983) in cowpea and Bhullar et al. (1985) in wheat.

Hundred seed weight had high positive association with seed yield. Similar significant associations were reported by Setty and Sreeramulu (1972) in sorghum, Kavitha (1982) in blackgram, Ali and Naidu (1982) in maize and Bhuller et al. (1985) in wheat.

Seed size also showed high positive association with yield which is in confirmity with the reports of Ali and Naidu (1982) in maize and Ibrahim et al. (1986) in pearl millet.

Number of leaves per plant showed positive correlation with yield and similar results were reported by Ibrahim et al. (1986) in pearl millet.

Grain filling period had significant positive association with yield which shows that longer filling periods are favourable for getting high seed yield under moisture stress conditions. This result is confirmed by the reports of Asana et al. (1968).

High positive association was also reported between proline content and seed yield. Similar results were reported in barley by Singh et al. (1972).

Number of seeds per pod had a high negative association with seed yield which may be due to the adverse effect of drought on seed filling. An increase in the number of seeds decrease the efficiency of seed filling thereby reducing the seed size and weight and ultimately the yield.

Pod length also showed high negative association with yield. Reports contradicting this results were presented by Kavitha (1982) in blackgram and Sharma (1988) in maize.

Negative association was found between plant height and yield mainly because of the low general vigour of the plant due to stress. However contradicting reports were presented by Doss et al. (1974) in soybean and Ali and Naidu (1982) in maize.

Root length and spread had negative associations with yield. This association may also be due to the low general vigour of the plants due to stress. Kahn and Stofella (1987) did not find any correlation between root character and grain yield. Contrary to this, significant positive association for root length and spread was reported by Sangwan and Mehrotra (1982) in greengram and Kavitha (1982) in blackgram.

Negative correlation was observed between root/shoot ratio and yield. Negative correlation between root weight and yield was reported by Kolotilov and Kolotilova (1985) in Lathyrus sativus. Opposing results were reported by Setty and Sreeramulu (1972) in sorghum and Sangwan and Mehrotra (1982) in greengram.

Seed yield showed a significant negative association with leaf area index eventhough its association with number of leaves per plant was significant and positive. This suggests that an increased number of leaves coupled with a reduced individual leaf area is advantageous under moisture stress conditions. Sivakumar and Shaw (1978b) reported negative association between leaf area and relative growth rate. Contrary to this significant positive association was observed by Mehrotra et al. (1968) and Sharma (1988) in maize and Setty and Sreeramulu (1972) in sorghum.

Stomatal distribution had negative association with yield confirming the reports by Ali and Naidu (1982) in maize.

Days to flowering showed significant negative association with yield. Similar reports were given by Saxena and Sheldrake (1977) and Saxena et al. (1979) in chickpea.

Days to maturity had a negative association with yield. Confirmatory results were reported by Kavitha (1982) in blackgram.

5.5. Path analysis

Path analysis helps to split up the direct and indirect effects of various characters on seed yield. Among the characters studied number of pods per plant was found to have the highest positive direct effect on yield followed by plant height, days to first flowering and pod length. All the other characters studied showed a negative direct effect on yield.

Number of pods per plant showed the highest positive direct effect on yield. This is in agreement with the findings of Muthiah (1976) in blackgram, Singh et al. (1977) and Prosannakumari and George (1986) in greengram. The direct effect of this character on seed yield was found to be more than its correlation coefficient. The correlation value was reduced probably due to its high negative indirect effect via plant height, seed size and days to first flowering.

Plant height also showed positive direct effect on yield. However its correlation with seed yield was negative. It was mainly due to the high negative indirect effect via number of pods per plant. The positive direct effect observed for plant height is in conformity with the findings of Giriraj and Vijayakumar (1974) and Soomikumaran and Rathinam (1981) in greengram and Soundarapandian et al. (1976) in blackgram.

The negative association between days to first flowering and yield inspite of a very high positive direct effect was mainly due to the negative indirect effect of number of pods per plant. It exerts a substantial indirect effect through pod length. Positive direct effect of days to flowering on yield was reported by Giriraj and Vijayakumar (1974) in greengram.

Pod length also showed positive direct effect inspite of its high negative association with seed yield. Pod length exerts positive indirect effect via plant height and days to first flowering, and negative indirect effect via number of pods per plant. The high negative association with yield may be due to the negative indirect effect through pods per plant.

Positive direct effect of pod length on yield was reported by Thandapani and Rao (1984) in greengram. However Muthiah (1976) in blackgram reported a negative indirect effect.

Seed size and number of leaves per plant which had a strong positive correlation with yield had negative direct effect on yield. These negative direct effects were counterbalanced by the high positive indirect effects via number of pods per plant and days to first flowering in the case of seed size and via number of pods per plant in the case of number of leaves per plant.

Root/shoot ratio showed negative direct effect on yield. Its association with yield was also negative and the value was almost equal to the value of direct effect indicating that the negative direct effect was entirely due to the negative association between the characters.

SUMMARY

SUMMARY

The present investigation was undertaken at the Department of Plant Breeding, College of Agriculture, Vellayani during October to December, 1988. Twenty different varieties of greengram were evaluated for their potential to tolerate moisture stress. Observations were made on plant height, number of leaves per plant, number of pods per plant, pod length, number of seeds per pod, hundred seed weight, seed size, yield per plot of grains and haulm, yield per plant, stomatal distribution, leaf area index, root length, root spread, root/shoot ratio, days to first flowering, days to maturity of first pod, days to final harvest, grain filling period, and proline content from each of the twenty varieties under study. Variability, correlation and path analysis were studied.

The varieties evaluated exhibited significant differences for all the characters studied except for number of pods per plant, yield per plant and proline content which indicated that considerable amount of variability existed among them.

Considerable variability both at the phenotypic and genotypic levels was observed for number of leaves per plant, grain yield per plot, haulm yield, leaf area index,

root/shoot ratio and proline content indicating that these characters are potentially variable. A high environmental influence was observed on characters, plant height, number of pods per plant, yield per plant and stomatal distribution as evidenced from their high phenotypic coefficient of variation and low genotypic coefficient of variation. All the other characters recorded very low variability only.

Heritability estimates were medium to high for most of the characters in general. Very high heritability value was recorded for grain filling period followed by days to final harvest and hundred seed weight. The yield components - seed size and pod length showed high heritability where as number of seeds per pod showed moderate heritability. Yield per plant was found to have the minimum heritability in the present study which showed that this character is highly influenced by environment.

Heritability in conjunction with genetic advance is more effective and reliable in predicting the resultant effect of selection than heritability alone. The high heritability coupled with high genetic gain recorded by yield per plot indicated additive gene action for this character which envisages greater scope for selection. Grain filling period, days to final harvest, days to maturity of first pod, hundred seed weight, seed size, root length, days to first flowering and pod length showed high heritability coupled with low genetic gain indicating non-additive gene action. Leaf area index and number of leaves per plant showed moderate heritability in association with moderate genetic gain while pods per plant and yield per plant showed low heritability and genetic gain suggesting poor response to selection under normal situations.

A knowledge of interrelationship between yield and yield contributing characters is vital because this would facilitate effective selection for simultaneous improvement of one or more of the yield components. The intensity and direction of association were measured by genotypic and phenotypic correlation coefficients.

The genotypic correlation coefficients were higher than the phenotypic correlation coefficients indicating the masking effect of the environment in the total expression of the genotypes. Seed yield was found to have significant positive correlations with number of pods per plant, hundred seed weight, seed size, grain filling period, number of leaves per plant and proline content. Negative correlations were observed for pod length, number of seeds per pod, plant height, leaf area index, root/shoot ratio and days to first flowering. The yield components also exhibited varying degrees of association among themselves.

In path analysis number of pods per plant was found to have the highest positive direct effect on yield. Plant height, days to first flowering and pod length also exhibited positive direct effect on grain yield. Seed size and number of leaves per plant showed negative direct effect on yield and positive indirect effects via number of pods per plant. Root/shoot ratio also exhibited negative indirect effect on grain yield.

A considerable reduction in vegetative as well as reproductive performance was observed, some being influenced more than the others. Among the yield components pod length and seeds per pod were greatly affected where as number of pods per plant, hundred seed weight and seed size were not much affected and they contributed significantly to grain yield under stress conditions.

The varieties PDM-84-139, PDM-84-146 and Pusa-103 showed high grain yield as well as high mean values for almost all the yield contributing characters indicating their potential to tolerate moisture stress and suitability for cultivation in drought prone areas.

The study thus reveals that drought tolerant varieties of greengram should have early maturity, longer grain filling period, medium height and leaf area index, more number of pods per plant and a moderately high seed weight and size.

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* Originals not seen

POTENTIAL FOR DROUGHT TOLERANCE IN GREENGRAM (*Vigna radiata (L) wilczek*)

By

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ABSTRACT OF A THESIS
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ABSTRACT

A research programme was carried out at the Department of Plant Breeding, College of Agriculture, Vellayani, during October to December, 1988 with an objective of evaluating the potential for drought tolerance in greengram through estimation of genetic variability, correlation of yield with component characters and the direct and indirect effects of different components on yield. Twenty varieties of greengram were evaluated under open conditions without any irrigation adopting a randomised block design replicated thrice. Data on twenty characters were recorded and subjected to analysis of variance and covariance. The genotypic and phenotypic coefficient of variation, heritability in the broad sense, genetic advance and genotypic and phenotypic correlations were estimated. Path analysis was conducted with yield per plant as the effect and seven component characters as the cause.

Analysis of variance revealed significant differences among the varieties for plant height, number of leaves per plant, pod length, number of seeds per pod, hundred seed weight, seed size, yield per plot, haulm yield, stomatal distribution, leaf area index, root length, root spread, root/shoot ratio, days to first flowering, days to maturity of first pod, days to final harvest and grain filling period.

Analysis of variance for number of pods per plant, yield per plant and proline content revealed no significant difference among varieties. Maximum heritability was recorded for grain filling period. The yield components, pod length, number of seeds per pod, hundred seed weight and seed size recorded moderate to high heritability and genetic gain. Grain yield per plant recorded significant positive genotypic correlations with number of pods per plant, hundred seed weight, grain filling period and proline content. Significant negative genotypic correlations were recorded with plant height, pod length, number of seeds per pod, leaf area index and days to first flowering.

Path analysis revealed that number of pods per plant had the maximum direct contribution for grain yield followed by plant height, days to first flowering and pod length. Root/shoot ratio and seed size exhibited negative indirect effect on yield. Seed size exerted positive indirect effect through number of pods per plant.

The study thus reveals that in greengram early varieties of medium height and leaf area index having longer grain filling period, more number of pods and a moderately high seed size and weight are suitable for cultivation under moisture stress conditions.