POTENTIAL FOR DROUGHT TOLERANCE IN BLACKGRAM (*Vigna mungo* L. Hepper)

BY

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DECLARATION

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

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CERTIFICATE

Certified that this thesis entitled "Potential for drought tolerance in blackgram" is a record of research work done independently by Kumari SUDHA RANI, S., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

Pulses form one of the main components of the Indian diet. They are essential adjuncts to a predominantly cereal-based diet as they contain about 24-30 per cent protein which is nearly three times more than that in cereals. At the present stage of our economic development pulses hold the key to solve the protein deficiency in our diet. As regards the developed countries grain legumes are an important indirect source of protein as they are considered to be good animal feeds of biological value. Production and consumption of more pulses is now widely recognised as the cheapest and most practical way of improving nutrition of the common man. Further, their unique ability to harness the inexhaustible stock of atmospheric nitrogen in symbiosis with bacteria helps in sustaining the fertility of our soils.

Blackgram or urd (*Vigna mungo* (L) Hepper) is one of the most important and highly prized pulses, very rich in phosphoric acid. It is consumed by all sections of the society in a variety of ways. Together with rice, it is used for preparing Dosa and Idli, the popular breakfast dishes. The crop is suitable for multiple or relay cropping and also as a green manure and cover crop.

In India, blackgram is grown in about 3.07 million hectares with a total production of 1.2 million tonnes

(Lal, 1987). In Kerala it occupies an area of 3400 hectares (Anon, 1985). Kerala is producing only a small portion of its requirement of pulses and the bulk of its requirements is met by import from other states.

Pulses can be grown in Kerala in all the three major crop seasons namely kharif, rabi and summer. Over 40 per cent of the pulses in Kerala is grown in summer rice fallows following the harvest of the second crop paddy. The crop is raised utilising the residual moisture available after paddy harvest and its success depends upon obtaining one or two premonsoon showers.

At present, the summer rice fallow cultivation of pulses is confined mainly to the command areas. But majority of rice fields in the traditional areas remain fallow during the third crop season due to lack of irrigation facilities. Nearly 2.5 lakh hectares of suitable rice fallows for cultivation are now available in our state (Anon, 1984). If it is possible to develop short duration, drought tolerant varieties which can survive with the limited amount of available soil moisture, it would be possible to raise a third crop of pulse after the second crop of rice in these areas. Hence summer rice fallows offer vast scope in increasing pulse production in Kerala.

Lack of knowledge about proper pulse varieties depending upon the soil moisture availability is the major lacuna in extending the cultivation of pulses. Among the pulse crops blackgram has been reported to be more suitable for cultivation during summer especially under limited availability of irrigation water (Anon, 1977). Under this situation, evolving drought tolerant blackgram varieties will be a real boon to the farmers. In Kerala not much attention has been paid so far to assess the drought tolerance potential of this crop. Hence the present work was undertaken with the prime objective of identifying through biometrical tests the important traits that would help in the selection of superior blackgram genotypes for yield and tolerance to drought.

The major objectives of the present study were:

1) to find out the extent of variability present in the population by estimating the parameters like genotypic coefficient of variation, heritability and genetic advance.

2) to find out the association of different characters with yield and also among themselves.

3) to formulate an ideal plant type for selecting blackgram genotypes for drought prone areas and

4) to identify, based on the above studies, blackgram genotypes with tolerance to drought.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The present study was undertaken to evaluate the drought tolerance potential of different genotypes of blackgram grown under rainfed conditions during rabi season. Some of the major works conducted in India and abroad on the influence of soil moisture stress on growth and yield of pulses are reviewed hereunder. However, this review is extended to similar works done in other crops also.

I Selection criteria in screening for drought tolerance

The competitive advantage of any organism in the field, be it crop plant or pest, is dictated by its relative response to the prevailing environment. Despite the fact that water is the most abundant compound on earth, drought is the most important single factor on a world wide basis that contributes to poor crop yield.

Crop plants, however, respond to drought in a variety of ways and adapt to it or resist its adverse effects through different mechanisms. Drought resistance is therefore, a complex phenomenon conditioned by a number of internal and external factors and their interactions. Drought resistance has been defined by Turner (1979) as the ability of a crop species or variety to grow and yield satisfactorily in areas subjected to periodic water deficits. Due to the very complex nature of drought resistance and the characters associated with it, it becomes necessary to take a complex of characters into consideration for assessing the drought resistant/tolerant capacity of the plant.

1. Early maturity

In cultivated crops, the ability of a cultivar to achieve maturity before the soil dries out is the main adaptation to growth in a dry region. Fanous (1967) suggested that, in pearl millet, more progress might be made by selection for early maturity in order to avoid drought than by selection for physiological drought resistance. Ojomo (1971) suggested that earliness is a desirable character for improving the drought resistance of cowpea plants.

Saxena and Sheldrake (1977) observed that in chickpea, the drought tolerant cultivars were early in maturity but all early cultivars were not drought tolerant. Saxena *et al*. (1979) observed that in chickpea, the early cultivars escape drought and flower and pod when shoot water potentials are high because the soil and atmospheric drought at that time is not severe.

Hall and Grantz (1981) suggested that selecting plants which have mature pods early in the season can be an effective method for improving the drought resistance of cowpeas. Lawn (1982) reported that pulse crops grown in dry climates avoid moisture stress by maturing quickly. Mahalakshmi and Bindinger (1985) reported that time to panicle initiation of the main shoot and tillers was unaffected by water stress in early maturing genotypes of bajra. Singh et al. (1985) reported that early genotypes of Brassica despite their lower stomatal conductance and transpirational cooling values out yielded late genotypes under conditions of moisture stress. Ali et al. (1986) reported that in pearl millet, earliness is directly associated with productivity under drought conditions.

Sivakumar and Singh (1987) compared the response of chickpea cultivars to water stress in a semi-arid environment and observed a yield advantage of the early maturing cv. Annigeri over L 550 a cultivar with medium maturity at all irrigation levels.

In general, earliness results in an escape of the effects of drought but may restrict yield potential if rain occurs. Thus earliness may not be a true device for resistance mechanism, but it is certainly an important character for drought prone areas.

2. Leaf area and dry matter accumulation

Thangavelu *et al*. (1967) studied the drought resistance characters in sorghum and reported that less number of leaves and reduced fourth leaf area helped the plant to withstand drought by minimising the water loss by transpiration. Mehrotra *et al*. (1968) reported that larger leaf area was needed both under high and low soil moisture stress to produce the same amount of dry matter for the grains in maize.

When soybean plants were subjected to moisture stress at flowering, considerable reduction in leaf area occurred(Singh and Tripathi, 1972). From a glass house study Hiller *et al*. (1972) reported that plant height, leaf area and total dry matter were reduced due to severe water stress at all stages of growth in peas.

Ali and Alam (1973) reported a reduction in number of leaves/plant and leaf area/plant in greengram under conditions of drought. According to Hsiao (1973) sensitivity of dry matter yield to stress should be greater in a growing crop with a low LAI than in a crop with high LAI. As a rapid procedure for screening lines of dry bean for potential drought, Hildago (1977) suggested that reduction of leaf area be measured under moderate water stress.

Sivakumar and Shaw (1978) subjected soybean plants to an extended drying cycle in the field to investigate the leaf sensitivity to water deficits. They found that soybeans in irrigated plots were superior to those in non-irrigated plots in the average size and number of leaflets/plant. Dasberg _et_ _al_. (1979) reported that plant dry weight decreased by 50 per cent when cowpea was not irrigated during vegetative stage as compared to that grown under weekly irrigation.

Momem _et_ _al_. (1979) reported that limited soil moisture influences field crop performance of soybean by reducing the size of assimilating leaf area. Wein _et_ _al_. (1979) reported substantially less leaf area and number of leaves but only slightly less shoot dry matter due to moderate drought with field cowpea. Turk and Hall (1980) subjected cowpea to different intensities of drought under field condition. They found that increasing levels of drought resulted in progressively less leaf area, shoot dry matter, number of leaflets and average leaflet area.

Farah (1981) observed a reduction in leaf area, dry matter and economic yield of field beans due to water shortage. Vidal _et_ _al_. (1981) studied the effect of water stress on growth and yield of soybean and found that leaf area index was affected most rapidly by water stress.

Reduction in functional leaf area has been reported as an adaptation mechanism to drought resistance by several workers like Hernandez (1983) in sorghum, Nagarajah and Schulze (1983) in cowpea; Menzel et al. (1986) in passion fruit; Rosenthal et al. (1987) in maize and Hoogenboom et al. (1987) in soybean.

Bascur et al. (1985) reported that under drought conditions, LAI was adversely affected in sensitive varieties compared to resistant varieties of french bean. In wheat, moisture stress decreased the green leaf dry matter and green leaf area index by reducing leaves per stem, area per leaf and by increasing the number of wilted leaves (Talukder, 1987).

3. Stomata

In maize, soil moisture stress increased the number of epidermal cells and stomata but decreased their size (Ninova et al., 1979).

Ali and Naidu (1982) reported a significant negative correlation between yield and stomata number in maize.

Rojas et al. (1983) reported that in sugarcane, lower number of stomata is an indication of its likely drought resistance.

4. Filling period

The effect of moisture stress on the duration of the seed filling period in soybean was studied by Meckal et al. (1984). They observed that the duration of the seed filling period ranged from 27 days in the late stress plants to 43 days in the well watered plants. Drought after anthesis hastens maturation and leaf senescence thereby reduces the length of filling period.

The duration of seed filling is related to yield in many crops. Planchon et al. (1986) suggested that the reduction in seed weight of soybean under late stress was due to poor seed filling. Since most of the carbohydrates accumulating in the grains are synthesised during this period, its shortening will have an adverse effect on the yield (Asana et al., 1968).

Bruckner (1986) suggested that high rate and short duration of grain filling were associated with post anthesis drought tolerance in spring wheat.

Omara (1987) observed that the response of early selections of barley to the sandy soil drought treatments was characterised by a reduction in time to flowering and a corresponding prolongation in time from flowering to maturity.

5. Root characters

When drought sets in, the shallow layers of soil horizons are depleted of water first after which increasing proportions of water taken up by the plant come from increasing depths of soil. To make use of water at the deeper soil horizons, plants should have the ability to develop deep and well-proliferated roots.

Kramer (1959) attributed the superior drought resistance of sorghum as compared to corn, to the more extensive branching of sorghum roots, which results in more surface in contact with the soil and more rapid absorption of water.

A comparison of wheat varieties by Hurd (1974) indicated that plants with a more extensive root system could exploit a larger soil volume, thereby making more effective use of soil water and producing higher grain yields. Varietal differences in rooting depths of wheat have also been reported by Tiwari _et_ _al_. (1974). They compared sixteen wheat varieties and concluded that varieties with greater number, deep vertical penetration and a more horizontal spread of seminal roots were drought escaping.

Begg and Turner (1976) stated that the effect of water deficit on the preferential development of the root over the shoot, is an adaptive mechanism that enables the crop to explore a greater soil volume for water. Hildago (1977) compared 500 introductions of dry bean (Phaseolus vulgaris L.) for drought tolerance and found that a better developed root system than average, ie. a main central root and strong secondary roots was important for overcoming water deficit. Babalola (1980) from his studies on water relations of three cowpea cultivars suggested that deeper rooting habit is an advantage under stress conditions.

In blackgram, an increasing trend for root length under moisture stress conditions was reported by Kavitha (1982) which enabled the plants to survive better and give yields by utilizing the residual moisture from deeper layers of the soil. Garay and Wilhelm (1983) attributed the increased drought resistance of Harosoy dense pubescence isoline of soybean to its greater root density which helps to explore deeper into the soil and to extract more soil water during drought.

According to Guimaraes (1986) the drought resistance of bean (Phaseolus vulgaris L.) varieties is due to the avoidance mechanisms of deeper roots and water retention in the plant. Varietal differences in rooting pattern under moisture stress conditions has also been reported by Ekanayake et al. (1985) in rice; Sharp and Davies (1985) in maize and by Singh and Afria (1985) in cotton.

6. Root/shoot ratio

According to Begg and Turner (1976) and Levitt (1980) a high root/top ratio is an effective means of adaptation of plants to drought conditions as under such conditions the growth rate of roots considerably exceeds that of the shoots the transpiring surface. An increase in root weight may indicate a greater density of roots or a greater depth of roots, both are important morphological adaptations that enable the plants to maintain a high plant water potential under water deficit conditions.

Parao _et_ _al_. (1976) from their studies on drought resistance of rice varieties in relation to their root growth reported that sorghum and corn which are more drought resistant than rice had much higher root-shoot ratio. This seems to indicate that higher root-shoot ratio is a desirable character for increased resistance to drought. Seiler and Johnson (1984) reported an increase in root/shoot ratio (g/g) of black alder seedlings from 0.28 in the control to 0.33 in the water stressed plants.

Chang and Wang (1985) reported significant differences among soybean varieties under drought conditions in root dry weight, shoot dry weight and root/shoot ratio but none of these characteristics was significantly correlated with drought resistance. According to Schulze (1986) water shortage significantly affects extension growth and the root-shoot ratio at the whole plant level.

According to Hoogenboom et al. (1987) if a plant had developed a larger root system (higher root/shoot ratio) during early season vegetative development, it would be in an excellent strategic position for maintaining turgor during the critical seed filling stages of reproductive development. Arjunan et al. (1988) attributed the drought tolerance characters of groundnut cultivars viz. VG-77, JL-24 and Co.2 to their higher root/shoot ratios which in turn have contributed for the higher pod yields in groundnut under moisture stress conditions.

7. Proline accumulation

Accumulation of free proline in leaves has been shown to be an adaptive mechanism for tolerance to stress. Varietal differences in the accumulation of proline in leaves of drought stressed plants of Bermuda grass led Barnett and Naylor (1966) to suggest that leaf proline content was a useful measure of drought resistance. Singh et al. (1972) advocated the use of proline accumulation to measure drought resistance in barley.

The role of proline during water stress was examined by Palfi et al. (1974). According to them a species is regarded as 'proline-accumulating' if the amount of free proline in the leaves at the time of strong water deficit reached at least 1% of the dry weight. Waldren et al. (1974) studied the changes in free proline concentration in soybean plants under field conditions. They observed that accumulation of free proline was not significant until plants were suffering severe moisture stress and were wilting visibly.

Mehkri et al. (1977) observed a positive correlation between the magnitude of free proline accumulation and drought tolerance in groundnut. They also reported that for determination of proline in groundnut, the second fully expanded leaf was ideal, where the magnitude of increase in proline was high.

Stewart (1977) attributed the increased concentration of free proline in water stressed tissue to lower rates of proline oxidation under conditions of water deficit. Rao and Asokan (1978) and Singh and Singh (1986) reported a positive association between free proline accumulation and drought tolerance in sugarcane.

Studies were carried out in barley by Hanson et al. (1979) to determine if high proline accumulation was associated with susceptibility or with resistance to water stress. They observed an increase in free proline content of susceptible varieties than in resistant varieties indicating that proline accumulation had no survival value during drought. Waldren and Teare (1974) also suggested that proline accumulation could be an indicator of drought resistance or susceptibility.

Parameshwara and Sastry (1980) observed that the magnitude of proline accumulation in sorghum was high when stress was induced at initial vegetative phase and decreased when at the other stages. Fukutoku and Yamada (1981) observed that, in soybean, proline accumulated only under severe stress and attained 0.86 per cent of the dry weight. They also reported that total proline first decreased during mild to moderate stress and then increased over that of the well irrigated control plants at severe stress due to a remarkable accumulation of free proline. Pandey (1982) reported that accumulation of free proline in wheat seedlings under water stress was significantly higher in the drought resistant cultivar than in drought sensitive cultivar. From a study on proline accumulation in plants of different ecological habitates Mukherjee et al. (1982) concluded that plants having an inherent capacity to accumulate proline during moisture stress can also acquire the property of drought resistance under such conditions.

Shevyakova (1983) regarded high proline content as a character or a marker indicating that a cultivated variety is potentially resistant to drought while Bansal and Nagarajan (1986) reported a negative correlation between proline content in leaves and the relative tolerance to stress.

8. Yield and yield components

According to Keim and Kronstad (1979) an ideal cultivar must be one having both high yield under the most severe moisture stress and a strong yield response under more favourable environment. Levitt (1980), Kirkham (1981) and several others regarded yield as the ultimate criterion for measuring varietal drought resistance.

Horner and Mojtehedi (1970) observed that the yield of cowpea decreased most when moisture stress occured during flowering and early maturity. Singh and Tripathi (1972) studied the effect of withdrawal of irrigation at various growth stages of soybean like 50 per cent flowering, pod development, bean filling etc. In plants subjected to moisture stress at flowering stage, considerable reduction in number of pods was noticed.

Studies conducted by Subramanian *et al*. (1974) in groundnut revealed that moisture stress during pod formation and maturity stage will be at the expense of the pod yield. In cowpea, pod number and pod and seed weight were lowest with deficient moisture level at the podding stage (Kamara, 1976).

Summerfield et al. (1976) reported that in cowpea water stress during the first stage of growth, reduced number and weight of seeds per plant, while stress from emergence to first flower halved subsequent pod production. It was also observed that wilting during the period from first flower to mid pod fill reduced the number of seeds per pod. In general, repeated wilting prior to flowering markedly reduced seed yields compared with the unstressed control, mainly by decreasing subsequent pod formation.

Hildago (1977) reported that, in dry bean, pod set and pod filling were the yield components most reduced by water stress, while seed size was little affected. Sionit and Kramer (1977) reported that stress during early pod formation caused greatest reduction in number of pods and seeds at harvest in soybean. However, yield as measured by weight of seeds was reduced most by stress during early formation and pod filling.

Constable and Hearn (1978) reported that soil water deficits during pod filling caused early leaf death and cessation of pod filling in soybean thus decreasing yield. They also observed a reduction in number of seeds per pod and seed size of rainfed plants compared to irrigated plants. In Phaseolus vulgaris, seed yield, number of pods per plant and number of seeds per pod decreased with the application of stress (Magalhaes and Millar, 1978).

Dasberg et al. (1979) observed that cowpea plants not irrigated in the vegetative stage caused an yield reduction of 10 per cent only while drought during flowering caused an yield reduction of 40 per cent. Magalhaes et al. (1979) reported that the beginning of flowering was the most critical period for water stress in Phaseolus vulgaris, which at this stage, caused a seed yield reduction of 36.85 per cent while stress at full flowering reduced seed yield by 33.68 per cent.

Shouse (1979) reported that cowpea seed yield was adversely affected by water deficit occuring at flowering stage and pod filling stage. Yield of cowpeas was reduced by 50 per cent by water deficit during these two growth stages. Babalola (1980) observed significant difference among cowpea cultivars in both grain and dry matter yield under moisture stress conditions. Vijayakumar (1980) reported that moisture stress at both branching and flowering stages in blackgram drastically reduced the number of pods per plant as well as the 100 grain weight.

The effects of drought on Vigna unguiculata during the vegetative, flowering and pod filling stages were investigated in field trials by Labanauskas et al. (1981). They observed an yield reduction of about 67 per cent due to water stress during both flowering and pod filling stages. Shouse et al. (1981) reported that the most sensitive growth stages to drought in cowpea were flowering and pod filling with yield reduction from 35 to 69 per cent depending on the timing and length of drought.

Kavitha (1982) reported that in blackgram the yield components namely the number of fruiting branches per plant, number of pods per plant and 100 seed weight were adversely affected by the moisture stress condition of the soil. Biryukov and Lyashok (1983) studied the drought resistance of wheat in relation to grain number and 1000 grain weight and concluded that selection on the basis of grain number/ear would be more reliable.

Hernandez (1983) reported that in sorghum water stress during floret differentiation stage reduced grain yield and number of seeds per head. Ahmed (1984) reported significant difference in 100 seed weight due to moisture stress during late reproductive growth in soybean. Effect of moisture stress on seed yield and yield components of grain legumes was studied by Pandey et al. (1984). They reported that among the yield components, the number of pods per m^2 was most affected by water stress followed by number of seeds per pod while seed weight was least affected.

Hayashi and Hanada (1985) reported reduction in the number of seeds and seed dry weight yield per plant by soil water deficit in safflower. A reduction in seed number due to water deficits in sunflower was reported by Fereres et al. (1986).

Studies on the effects of water stress on grain yield and yield components in soybean by Planchon et al. (1986) revealed that the timing of the water stress during the growing phase determines the extent and primarily the type of damage, with late stress causing poor seed filling and a reduced seed weight but early stress reducing, yields due to increased seed abortion.

Potluri et al. (1986) studied the effect of soil moisture regimes on yield of blackgram. The yields of grain and haulm increased with increase in soil moisture stress upto 50 per cent depletion and then decreased significantly at 75 per cent.

Moisture stress at flowering decreased the total number of pods/m^2 and increased the 100 kernel weight in groundnut (Venkateswar Rao et al., 1986). From a comparison of irrigated and unirrigated treatments Sivakumar and Singh

(1987) showed that water stress resulted in reduced drymatter, seed yield and seed weight in chickpea cultivars.

II Genetic variability and correlation studies

1. Variability

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

Many workers studied the extent of variability in pulse corps by working out genotypic and phenotypic coefficient of variation. But the extent of genetic variability is more important than the total variation since greater the genetic diversity, wider would be the scope for selection. However, studies on genetic variability in pulse crops under water deficit condition is very limited.

Singh _et_ _al_. (1972) studied variability in 25 varieties of blackgram for six characters viz. seed yield, pod number per plant, number of fruiting nodes, number of primary branches, pod length and seed size. Their study revealed that seed yield and pods per plant showed high genotypic coefficients of variation.

Lal and Haque (1972) reported high phenotypic variability for days to flowering, days to maturity, number of leaves per plant, plant height and number of pods per plant in soybean. They reported that number of pods per plant, plant height, seed yield and hundred seed weight exhibited high genotypic coefficient of variation.

Veeraswamy et al. (1973) studied variability for eight characters in 25 varieties of blackgram. They found the highest value (90.73 per cent) for genotypic coefficient of variation for number of pods per plant.

Joshi and Kabaria (1973) from a diallel cross of six varieties of green gram noticed wide range of variability for yield and yield contributing characters viz. number of pods per plant, number of seeds and hundred seed weight.

Soundarapandian et al. (1975) observed high genotypic coefficient of variation for number of pods per plant and grain weight per plant in blackgram. Variability was found very low for seeds per pod.

Sagar *et al*. (1976) in their study with 27 lines of blackgram reported maximum variation for yield per plant, pods per plant and days to 50 per cent flowering.

Pillai (1980) recorded high genotypic coefficient of variation for height of the plant (31.4 per cent) followed by number of branches per plant (25.8 per cent) and the lowest value for the number of days to maturity (5.2 per cent).

Shoram (1983) worked out estimates of variability in 100 genotypes of pigeon pea and reported high GCVs for pods per plant, days to maturity and days to 50 per cent flowering.

Pandita *et al*. (1982) studied variability in 40 forms of cowpea for six traits under moisture stress condition. Their study revealed significant differences for all traits except number of pods per cluster. They reported wide variation for yield per plant, days to flowering and plant height.

2. Heritability and genetic advance

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

Singh and Mehndiratta (1969) recorded in cowpea the highest estimate of heritability for 100 seed weight (95.89 per cent) followed by days to flowering (88.79 per cent) and days to maturity (78.29 per cent) and the lowest for seed yield (35.62 per cent). They observed highest genetic advance for hundred seed weight, moderate for seed yield and lowest for days to maturity.

Empig _et al_. (1970) showed that heritability estimates in the F_2 generation of greengram had high values for number of days to flowering and maturity and low value for yield.

Goud _et al_. (1977) noticed high heritability in blackgram for pod length (96.00 per cent), plant height

(93.00 per cent), 1000 seed weight (92.50 per cent) and number of seeds per pod (91.11 per cent). Lowest heritability was observed for grain yield (52.92 per cent).

Soundarapandian et al. (1975) reported high heritability for length of pod and height of plant and medium for grain-weight, number of clusters per plant and number of pods per plant. They also observed high heritability with high genetic advance for number of pods per plant and plant height.

Sreekumar and Abraham (1979) reported high heritability with low genetic advance for height of the plant, length of pod, days to flowering, number of clusters per plant, number of pods per plant and number of seeds per pod in greengram.

Sreekumar et al. (1979) observed moderate to high heritability estimates for number of days to flowering (69.2 per cent), total duration (49.2 per cent), number of grains per pod (40.6 per cent) and grain yield per plot (43.4 per cent).

Pillai (1980) reported high estimates of heritability for days to maturity, days to flowering and hundred seed weight and low values for number of pods and seed yield per plant in blackgram.

Patel and Shah (1982) estimated various genetic parameters in twenty varieties of blackgram and observed high heritability coupled with high genetic advance for plant height and length of pod. High heritability along with low genetic advance was observed for number of seeds per pod (42.7 per cent and 6.6 per cent respectively).

Radhakrishnan and Jebaraj (1982) recorded high heritability coupled with high genetic advance for number of pods per plant and number of pod clusters per plant in cowpea, while the number of days to maturity and plant height registered high heritability and low genetic advance.

Sarkar _et al_. (1984) observed high heritability and genetic advance for plant height and days to maturity in 11 photo period insensitive pure lines of blackgram. Pods per plant and hundred seed weight showed medium heritability and genetic advance.

Khorgade _et al_. (1985) have observed high heritability for hundred seed weight, seeds per pod and time to 50 per cent flowering in chickpea.

3. Correlation studies

Information on the inter-relationship of yield with other traits is of immense help in any crop improvement programme. This will facilitate selection of suitable high yielding plants through other related characters. Correlation studies between yield and other characters under moisture stress condition is very limited.

Mehrotra et al. (1968) reported a significant positive correlation between leaf area and yield under stress in maize. Saxena and Sheldrake (1977) reported a significant positive correlation between unirrigated yield and drought tolerance of chickpea cultivars. Saxena et al. (1979) reported a negative correlation between days to 50 per cent flowering and yield under drought conditions in chickpea indicating that early maturing plants tended to do better under drought conditions.

The correlation study in blackgram by Kavitha (1982) has revealed a significant positive correlation between yield and number of pods per plant, number of seeds per pod, 100 seed weight and leaf area. Number of leaves per plant and duration were found to show a negative correlation, with yield. Root length was found to be positively correlated with yield showing that under moisture stress conditions, a deep root system enables the plant to survive better.

Sammons et al. (1980) reported a significant positive correlation between yield and yield components like pods per plant, seeds per pod and hundred seed weight in soybean.

Ibrahim et al. (1986) reported a significant correlation between yield and grain number per head, grain size and number of leaves on the main stem in pearl millet. Talukder (1987) reported a significant positive correlation between the green leaf area and dry matter in wheat.

Bidinger et al. (1987) reported a significant negative correlation between yield under stress and time to flower under control in pearl millet. They also reported a significant positive correlation between yield under stress and grains/m^2, panicles per plant and individual grain mass.

III Selection index

Success in breeding to improve the drought resistance of crop cultivars has been limited in the past by a lack of screening techniques and a lack of knowledge of what conditions drought resistance in crop plants. The importance of reliable screening techniques as an integral component of any crop improvement programme has been stressed by Levitt (1964) and Cooper (1974).

According to Johnson (1980) a good screening technique should be rapid, capable of evaluating plant performance at the critical developmental state, use

MATERIALS AND METHODS

only small samples of plant materials and also be capable of screening large populations.

Moss et al. (1974) have suggested that selection criteria for improving plant performance under drought may require a compromise between impossibly complex measurements and convenient rapid screening techniques.

Richards and Thurling (1979) suggested that joint selection for yield, as well as harvest index, hundred seed weight and seeds per pod was 20% more effective than direct selection for yield under drought.

Sharma (1979) emphasized the need for a selection criteria which are simple to measure and are of wider application. He suggested that selection based on root characters, grain filling period, earliness, yield and yield components will be effective in improving the drought resistance of plants.

MATERIALS AND METHODS

The present study was carried out at the Department of Plant Breeding, College of Agriculture, Vellayani, Trivandrum during Rabi 1988.

A. Materials

The biological materials used in this study were twenty varieties of blackgram (*Vigna mungo* (L) Hepper) maintained in the germplasm of the Department of Plant Breeding.

B. Methods

A field experiment was laid out during rabi season, 1988, adopting a randomised block design with three replications. The crop was raised adopting Package of practices recommendations (1986) of the Kerala Agricultural University.

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

1. Number of leaves per plant

The total number of compound leaves in the observational plants at maximum vegetative stage was counted and the mean number per plant was worked out.

2. Leaf area

The leaf area was computed employing the factor method for determination of leaf area in blackgram developed by Pillai *et al*. (1978). Separate K factors were employed for the estimation of the area of the terminal leaf and side leaves. The estimating equations used were as follows:

Terminal leaf Y = 0.62 x
Side leaf I (left) Y = 0.67 x
Side leaf II (right) Y = 0.68 x

where Y = area of leaf in cm^2; 0.62, 0.67 and 0.68 are the 'K' factors for the terminal leaf, side leaf I and side leaf II respectively and x = product of the maximum length (in cm) and maximum width (in cm) of the respective leaves.

The length and width of all the leaves on the observational plants were recorded at the maximum vegetative growth stage and the leaf area determined.

3. Earliness (days to first flowering)

The mean value of the number of days from sowing to the appearence of the first flower, in the observational plants, in each plot was recorded.

4. Stomatal distribution

The right leaflet of the second fully expanded and mature leaf from the top was selected from one plant in each plot. Leaf impressions were taken using natural colour nail polish from three portions on the lower surface of each leaf, that is, from the tip, middle and base. The impressions were taken by giving a thin coat of nail polish on the leaf surface and peeling it off after drying. From each of these impressions, five microscopic fields were scored for number of stomata and the mean number of stomata per microscopic field was estimated for each plant.

5. Grain-filling period (flower opening to seed maturity)

Ten flowers were tagged at random in each plot on the day of their opening and the number of days from flower opening to pod maturity was recorded and the mean worked out.

6. Days to maturity

The number of days from sowing to the last harvest of the observational plants was recorded and the mean number worked out.

7. Root length

The observational plants were uprooted after soaking the soil to facilitate easy uprooting at the end of last harvest. Root length was measured in centimetres using a scale from collar to the tip of the taproot.

8. Root spread

Root spread was studied by plotting the dried root specimen of the ten observational plants on a graph paper and 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 and the spread expressed in centimetres.

9. Root/shoot ratio

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

10. Haulm yield per plot

The total bhusa yield (plant parts other than grains) at final harvest from each plot was recorded in gram.

11. Grain yield per plot

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

12. Grain yield per plant

The total grain yield from the ten observational plants in each plot was taken and their average value recorded in gram.

13. Number of pods per plant

The total number of pods harvested from the observational plants were noted and the mean worked out.

14. Number of grains per pod

From each observational plant one pod was selected at random and the number of grains counted.

15. Test weight of hundred grains

Random sample of one hundred seeds taken from each observational plant was weighed in an electronic balance and the weight recorded in gram.

16. Grain size

The volume of one hundred seeds used for finding out the test weight was determined by water displacement method using a measuring cylinder and the volume recorded in cm^3.

17. Proline content

The free proline content of leaves was determined as per the procedure suggested by Bates _et_ _al_. (1973). The second fully expanded leaf from the top was selected for the analysis. Three leaf samples collected from each plot were oven dried and well powdered. From the powdered sample 0.25 g was weighed out, homogenized in 10 ml of 3% aqueous sulfosalicylic acid and the homogenate filtered through No.2 Whatman filter paper. Two ml of the filtrate was reacted with 2 ml acid ninhydrin 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 extracted with 4 ml toluene mixed vigorously with a test tube stirrer for 15-20 seconds and the absorbance read at 520 nm using toluene for a blank. The proline concentration was determined from a standard curve and calculated on a dry weight basis as follows:

$$(\mu\text{g proline/ml} \times \text{ml toluene})\ (5/\text{g sample})$$

$$= \mu\text{g proline/g of dry weight material}$$

18. Soil moisture

Soil moisture percentage was determined at weekly intervals by gravimetric method.

C. Statistical techniques

I Analysis of variance and covariance

Analysis of variance and covariance were done as per methods suggested by Singh and Choudhary (1979) for the following:

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

(ii) to estimate the variance components and

(iii) to estimate the correlation coefficients.

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

$$V(P) = V(G) + V(E) + 2\ \mathrm{Cov}\ (G, E)$$

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

$V(G) = \sigma^2_{g(x)}$ = variance due to genotype

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

Cov (G,E) = Covariance between genotype and environment

If the genotype and the environment are independent Cov (G,E) is equal to zero, so that

Table 1. Analysis of variance/covariance

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

Hence we have the following estimates

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

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

$$\sigma g(xy) = \frac{1}{r}(Txy - Exy) \qquad \sigma e(xy) = Exy$$

$$V(P) = V(G) + V(E)$$

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

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

$$\mathrm{Cov}(x,y) = \mathrm{Cov}\,[G(x,y)] + \mathrm{Cov}\,[E(x,y)]$$

$$\text{or } \sigma_{p(x,y)} = \sigma_{g(x,y)} + \sigma_{e(x,y)}$$

where $\sigma_{p(x,y)}$ = Phenotypic covariance between x and y.

$\sigma_{g(x,y)}$ = Genotypic covariance between x and y.

$\sigma_{e(x,y)}$ = Environmental covariance between x and y

If the experiment is designed in a randomised complete block design with 'V' treatments and 'r' replications, the estimates of $\sigma^2_{p(x)}$, $\sigma^2_{g(x)}$, $\sigma^2_{g(y)}$, $\sigma^2_{e(x)}$, $\sigma^2_{e(y)}$, $\sigma_{p(x,y)}$, $\sigma_{g(x,y)}$ and $\sigma_{e(x,y)}$ are obtained from the analysis of variance-covariance (Table 1).

Variance in crop stand occured in plots due to the erratic germination resulted due to drought. Hence the population count in each plot was taken and the total yield from each plot was statistically adjusted by analysis of covariance, for eliminating the variation in plot yields due to the difference in plant population.

II Coefficient of variation

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

Phenotypic coefficient of variation (PCV):

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

Genotypic coefficient of variation (GCV):

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

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

III Heritability (H^2)

Heritability in the broad sense is the fraction of the total variance which is heritable and was estimated as a percentage following Jain (1982) as:

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

where H^2 = Heritability in the broad sense

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

Heritability provides a measure of genetic variance ie. the variance upon which all the possibilities of changing the genetic composition of the population through selection depends.

IV Genetic advance under selection (G.A)

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

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

where G.A. = Genetic advance

h^2 = Heritability in the broad sense

V_p = Phenotypic variance

K = Selection differential expressed in phenotypic standard deviation

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

V Correlations

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

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

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

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

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

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

$$r_g(x,y) = \frac{\sigma g(x,y)}{\sigma g(x) \times \sigma g(y)}$$

where $\sigma g(x,y)$ is the genotypic covariance between x and y

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

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

VI Selection Index

On the basis of characters having significant contribution to drought tolerance a selection index was formulated. A discriminant function was applied as a basis for making simultaneous selection for these characters and to discriminate the desirable genotypes from the undesirable ones on the basis of their phenotypic performance as suggested by Singh and Choudhary (1977).

The genetic worth of an individual (H) is defined as:

$$H = a_1G_1 + a_2G_2 + \ldots\ldots\ldots + a_nG_n$$

where G_1, G_2, ..., G_n are the genotypic values of individual characters and a_1, a_2, ..., a_n signify their relative economic importance. Another function (I) based on phenotypic performance of various characters was defined as:

$$I = b_1p_1 + b_2p_2 + \ldots\ldots\ldots + b_np_n$$

where b_1, b_2, ..., b_n are to be estimated such that the correlation between H and I, ie. r (H, I) become maximum. Once such a function was obtained, the discrimination of desirable genotypes from the undesirable ones would be possible on the basis of their phenotypic performance, ie. p_1, p_2, p_3, ..., p_n directly.

As the first step, the genotypic and phenotypic variances and covariances of the selected characters were written down in a matrix form. Yield and other characters used in this selection criterion were assumed to have equal importance. In this particular case, where yield and 8 characters contributing to drought tolerance were selected,

$$a_1 = a_2 = a_3 = a_4 = a_5 = a_6 = a_7 = a_8 = a_9 = 1$$

Then the simultaneous equation was written in a matrix form as follows:

$$\begin{bmatrix} p_{11} & p_{12} \cdots\cdots & p_{1k} \\ p_{21} & & \\ & & \\ p_{k1} & & \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ \\ b_k \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} \cdots\cdots & G_{1k} \\ G_{21} & & \\ & & \\ G_{k1} & & \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ \\ a_k \end{bmatrix}$$

where p_{11}, p_{12}, ... etc. are the phenotypic variance-covariance matrix and G_{11}, G_{12}, ... etc. the genotypic variance-covariance matrix.

The regression coefficient b_1 was calculated as $b_1 = p^{-1}Ga$.

The inverse of phenotypic variance matrix, p^{-1}, was prepared by the Doolittle method. This was then multiplied by the genotypic variance-covariance matrix. The resultant $p^{-1}G$ was then multiplied by a_1 vector to get b_1 values.

The mathematical description of the function (I) is known as the selection index $-I = b_1p_1 + b_2p_2 + \cdots + b_np_n$. Using this function, the selection criterion or the index value for each individual was determined and the varieties ranked accordingly.

RESULTS

RESULTS

The results of the experiment are presented below:

I Variability analysis

The mean data collected on seventeen characters were subjected to analysis of variance for testing the significance of the differences between varieties and the ANOVA is furnished in Table 2.

The twenty varieties of blackgram studied, exhibited significant difference for the characters viz. number of days to first flowering (earliness), leaf area at maximum vegetative stage, grain-filling period, days to maturity, root spread, root/shoot ratio, free proline content of leaves, number of grains per pod, hundred seed-weight and grain size (Table 2). Number of leaves per plant, root length, number of stomata per microscopic field, haulm yield per plot, grain yield per plot, grain yield per plant and number of pods per plant did not show any significant difference (Table 2).

The analysis of variance of soil moisture percentage measured from the experimental plots at weekly intervals from sowing to harvest did not show any significant difference indicating that uniform moisture conditions or stress prevailed in the experimental plots (Table 3).

Table 2. Abstract of analysis of variance of seventeen characters

Sl. No.	Character	Mean square			F value
		Replication	Treatment	Error	
1	Days to first flowering	2.82	3.27	1.61	2.04*
2	Number of leaves per plant	7.31	1.86	1.22	1.52
3	Leaf area	346754.50	41595.47	15157.53	2.74*
4	Number of stomata per microscopic field	12.13	5.29	5.90	0.89
5	Grain-filling period	0.19	13.97	1.98	7.04**
6	Days to maturity	1.21	29.69	1.46	20.30**
7	Root length	3.54	0.73	1.23	0.59
8	Root spread	0.14	1.13	0.58	1.95*
9	Root/shoot ratio	0.0013	0.0049	0.0013	3.75**
10	Proline content of leaves	9980.00	174400.70	57424.16	3.03**
11	Haulm yield per plot	2425.37	83882.64	84068.68	0.997
12	Grain yield per plot	5633.73	2682.56	2447.58	1.09
13	Grain yield per plant	29.66	1.06	1.23	0.86
14	Number of pods per plant	421.65	22.46	20.97	1.07
15	Number of grains per pod	1.62	0.41	0.13	3.09**
16	Hundred seed weight	0.011	0.302	0.072	4.21**
17	Grain size	0.017	0.113	0.040	2.82**

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

Table 3. Abstract of analysis of variance for soil moisture percentage

Days after sowing	Mean square			F value
	Replication	Treatment	Error	
18 DAS	53.93	14.36	14.29	1.005
25 DAS	2.07	9.37	8.06	1.161
32 DAS	5.76	10.30	11.78	0.874
39 DAS	7.74	21.57	18.80	1.147
46 DAS	21.49	11.35	11.38	0.998
53 DAS	55.81	23.23	20.13	1.154
60 DAS	34.72	13.77	13.87	0.992

Table 4. Mean values of seventeen characters in blackgram

Sl. No.	Varieties	Days to first flowering	Number of leaves per plant	Leaf area in cm^2	Number of stomata per microscopic field	Grain-filling period	Days to maturity
1	PDU-5	36.33	8.33	443.27	22.22	23.27	68.33
2	Co-5	34.33	5.47	283.38	24.62	26.73	76.00
3	MBG-162	39.33	8.20	463.54	22.85	27.13	74.00
4	TAU-2	36.67	8.39	628.37	22.60	24.67	70.00
5	UPU-9-40-4	36.33	7.40	462.19	20.93	27.33	68.67
6	NPRB-1	34.67	7.87	425.20	20.38	20.66	67.00
7	KB-51	35.67	7.47	565.68	22.53	22.40	67.00
8	LBG-20	37.00	7.87	405.11	24.22	27.20	69.00
9	PDU-10	36.67	6.87	365.97	22.56	27.27	69.33
10	T-9	36.33	8.53	678.25	22.69	24.13	71.00
11	LBG-613	36.33	7.53	517.43	25.18	24.07	68.67
12	PDU-1	36.67	7.53	488.08	22.53	21.73	67.67
13	NPRB-3	36.33	8.00	387.62	21.35	25.80	68.00
14	PANT-U-30	37.00	8.80	452.30	23.58	28.40	69.67
15	PDU-101	36.67	9.00	499.87	24.47	25.87	65.00
16	IU-1-19	37.33	8.13	365.43	24.11	27.73	69.67
17	PDU-12	35.33	7.20	414.20	21.69	25.33	62.00
18	COBG-302	37.00	8.47	735.23	20.96	25.60	74.67
19	B-3-8-8	37.33	8.40	383.12	22.47	27.60	69.67
20	Local	36.00	7.87	651.56	21.84	25.93	69.00
	General Mean	36.47	7.87	480.89	22.69	25.44	69.22
	CD (0.05)	2.095	1.83	203.58	4.02	2.33	1.99

Table 4 (Contd....)

Sl. No.	Varieties	Root length in cm	Root spread in cm	Root/shoot ratio (g/g)	Proline content of leaves µg/g dry wt.	Haulm yield per plot(g)	Grain yield per plot(g)
1	PDU-5	12.22	9.00	0.158	940.44	606.39	184.11
2	Co-5	13.49	11.04	0.229	243.27	719.83	144.73
3	MBG-162	13.03	10.31	0.147	405.99	518.60	143.21
4	TAU-2	13.23	10.54	0.136	1075.81	472.95	169.58
5	UPU-9-40-4	12.47	10.28	0.167	685.79	524.92	162.82
6	NPRB-1	12.08	9.50	0.121	374.82	544.47	194.83
7	KB-51	12.78	10.01	0.127	500.68	633.95	211.12
8	LBG-20	12.40	9.23	0.164	549.31	555.91	141.58
9	PDU-10	12.67	9.82	0.128	714.56	529.39	143.01
10	T-9	13.32	10.65	0.152	582.31	676.76	189.86
11	LBG-613	13.06	9.35	0.101	354.29	591.35	122.99
12	PDU-1	12.79	9.78	0.198	309.76	941.69	193.29
13	NPRB-3	12.12	9.73	0.086	565.44	253.37	116.14
14	PANT-U-30	12.92	9.16	0.171	336.78	635.48	127.62
15	PDU-101	12.91	10.46	0.102	811.97	736.73	203.66
16	IU-1-19	12.55	9.82	0.144	276.02	435.37	128.58
17	PDU-12	12.69	9.46	0.136	236.45	485.48	156.95
18	COBG-302	14.05	11.22	0.156	638.37	984.97	140.23
19	B-3-8-8	13.34	9.93	0.246	427.75	555.64	124.63
20	Local	13.08	10.26	0.113	231.29	830.11	192.47
	General mean	12.86	9.98	0.151	512.17	611.67	159.57
	CD (0.05)	1.84	1.26	0.060	396.25	492.42	84.02

Table 4 (Contd.....)

Sl. No.	Varieties	Grain yield per plant (g)	Number of pods per plant	Number of grains per pod	Hundred seed weight (g)	Grain size (cm^3)
1	PDU-5	4.30	22.67	6.23	4.21	3.68
2	Co-5	2.65	14.30	6.80	4.48	3.85
3	MBG-162	2.97	17.17	6.10	3.57	3.20
4	TAU-2	4.77	20.57	6.66	4.63	3.95
5	UPU-9-40-4	5.12	26.27	6.47	4.10	3.75
6	NPRB-1	4.50	19.53	6.90	4.75	3.92
7	KB-51	4.18	19.60	7.03	4.33	3.89
8	LBG-20	3.88	19.16	5.93	4.53	3.92
9	PDU-10	3.75	17.13	6.10	4.67	3.67
10	T-9	4.22	21.73	6.60	4.64	3.83
11	LBG-613	3.65	18.67	6.53	4.67	3.89
12	PDU-1	4.15	16.93	6.93	4.86	3.95
13	NPRB-3	3.35	18.37	6.50	4.20	3.73
14	PANT-U-30	3.83	22.43	6.17	4.13	3.77
15	PDU-101	3.90	20.53	6.27	4.54	3.91
16	IU-1-19	3.53	16.53	6.00	4.38	3.81
17	PDU-12	3.28	17.00	6.20	4.10	3.59
18	COBG-302	4.12	16.47	6.80	4.70	4.05
19	B-3-8-8	3.45	18.53	6.07	4.13	3.57
20	Local	4.28	20.27	7.10	4.73	4.03
	General Mean	3.89	19.19	6.47	4.42	3.79
	CD (0.05)	1.84	7.57	0.60	0.44	0.33

The mean values recorded on twenty varieties in respect of yield and other sixteen characters are presented in Table 4.

1. Days to first flowering

The results presented in Tables 2 and 4 indicate that there was significant difference among the treatments. The number of days to first flowering was maximum in MBG-162 (39.33 days) and the minimum was recorded by the variety Co-5 (34.33 days). The varieties T-9, NPRB-3, UPU-9-40-4, PDU-5, LBG-613, Local, KB-51, PDU-12 and NPRB-1 were on par with Co-5.

2. Number of leaves per plant

The results are presented in Tables 2 and 4. There was no significant difference among the varieties tested for this character. However, variety PDU-101 records the highest mean value (9.00) followed by PANT-U-30 (8.80), T-9 (8.53), TAU-2 (8.39). The lowest value was recorded by Co-5 (5.47).

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3. Leaf area

Leaf area at maximum vegetative stage showed significant differences among the varieties (Table 2). The mean value for this character was maximum for COBG-302 (735.23 cm^2) and minimum for Co-5 (283.38 cm^2). The varieties T-9, Local, TAU-2 and KB-51 were on par with COBG-302 (Table 4).

4. Stomatal distribution

The result indicated that there was no significant difference among the varieties tested for this character (Tables 2 and 4). The maximum number of stomata per microscopic field (25.18) was recorded by the variety LBG-613 and the minimum was recorded by the variety NPRB-1 (20.38). All the varieties except LBG-613, PDU-101 and Co-5 were on par.

5. Grain-filling period

The result presented in Tables 2 and 4 indicated that there was significant difference in grain-filling period. The duration of grain-filling ranged from 20.66 days in NPRB-1 to 28.40 days in PANT-U-30. The varieties Local, PDU-12, T-9 and KB-51 recorded 25.93, 25.33, 24.13 and 22.40 days respectively as grain-filling period.

6. Days to maturity

There was significant difference among the varieties for this character (Table 2). The number of days to maturity was maximum for the variety Co-5 (76.00 days) and the variety COBG-302 was found to be on par with Co-5. The variety PDU-12 took the least number of days (62.00) for maturity (Table 4).

7. Root length

The varieties did not show any significant difference with regard to root length (Tables 2 and 4). However, COBG-302 had the maximum root length (14.05 cm) followed by Co-5 (13.49 cm), B-3-8-8 (13.34 cm), T-9 (13.32 cm) and TAU-2 (13.23 cm). The minimum length was observed in the variety NPRB-1 (12.08 cm).

8. Root spread

The result presented in Tables 2 and 4 indicated that there was significant difference in root spread. Maximum root spread was recorded by the variety COBG-302 (11.22 cm) which is on par with Co-5, T-9, TAU-2, PDU-101, MBG-162, UPU-9-40-4, Local and KB-51. The minimum root spread (9.00 cm) was recorded by the variety PDU-5.

9. Root/shoot ratio

The results are presented in Tables 2 and 4. There was significant difference among the treatments. The variety B-3-8-8 recorded the highest root/shoot ratio (0.246) followed by Co-5 (0.229) and PDU-1 (0.198). The lowest root/shoot ratio was observed for the variety NPRB-3 (0.086).

10. Proline content

The result showed that there was significant difference in proline content of the various varieties tested (Tables 2 and 4). Maximum proline content was recorded by the variety TAU-2 (1075.81 µg/g) and the varieties PDU-5, PDU-101, PDU-10 and UPU-9-40-4 were on par with the above variety. The lowest value was recorded by the local variety (231.29 µg/g).

11. Haulm yield per plot

The haulm yield per plot did not show any significant difference among treatments (Tables 2 and 4). Maximum haulm yield was recorded by the variety COBG-302 (984.97 g) followed by PDU-1 (941.69 g) and the local (830.11 g). The minimum value was recorded by the variety NPRB-3 (253.37 g).

12. Grain yield per plot

The results presented in Tables 2 and 4 did not show any significant difference among the varieties tested for this character. Maximum grain yield was recorded by the variety KB-51 (211.11 g) followed by the varieties PDU-101 (203.66 g) and NPRB-1 (194.83 g). The varieties PDU-101, NPRB-1, PDU-1, Local, T-9 and PDU-5 were on par with KB-51. The lowest grain yield was observed in the variety NPRB-3 (116.14 g).

13. Grain yield per plant

The result showed that there was no significant difference among the varieties tested for this character.

UPU-9-40-4 recorded the maximum grain yield per plant (5.12 g) followed by the varieties TAU-2 (4.77 g) and NPRB-1 (4.5 g) and the minimum yield per plant was recorded by the variety Co-5 (2.65 g). All the varieties except MBG-162 and Co-5 were on par with UPU-9-40-4.

14. Number of pods per plant

There was no significant difference among the varieties tested for this character (Tables 2 and 4). UPU-9-40-4 had the maximum number of pods (26.27) followed by PDU-5 (22.67) and PANT-U-30 (22.43) and the minimum number was found in the variety Co-5 (14.30).

15. Number of grains per pod

The results presented in Tables 2 and 4 indicated that there was significant difference between the twenty varieties tested. The local variety had the maximum number of grains per pod (7.10) followed by KB-51 (7.03), PDU-1 (6.93) and NPRB-1 (6.90). The lowest number was recorded by LBG-20 (5.93).

16. Hundred seed weight

There was significant difference among the treatments for this character (Table 2). The seed weight was maximum for the variety PDU-1 (4.86 g) followed by NPRB-1 (4.75 g), Local (4.73 g) and COBG-302 (4.7 g). The minimum weight was recorded by the variety MBG-162 (3.57 g).

17. Grain size

The treatments tested showed significant difference for this character (Tables 2 and 4). The variety COBG-302 recorded the maximum grain size ($4.05 cm^3$) followed by Local ($4.03 cm^3$), TAU-2 ($3.95 cm^3$) and PDU-1 ($3.95 cm^3$). The minimum grain size was observed in the variety MBG-162 ($3.2 cm^3$).

II Genetic parameters

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

1. Phenotypic coefficient of variation

The free proline content of leaves showed the highest value (60.63 per cent) followed by haulm yield per plot (48.92 per cent) grain yield per plot (38.16 per cent) root/shoot ratio (36.76 per cent) and leaf area (32.2 per cent). The lowest value was recorded for the character days to first flowering (4.03 per cent).

2. Genotypic coefficient of variation

High value for genotypic coefficient of variation was recorded for free proline content of leaves (38.55 per cent) followed by root/shoot ratio (21.22 per cent) and leaf area (19.53 per cent). The minimum value was recorded by days to first flowering (2.05 per cent).

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

Sl. No.	Characters	Phenotypic variance	Genotypic variance	Mean $\bar{x}$	Phenotypic coefficient of variation	Genotypic coefficient of variation
1	Days to first flowering	2.163	0.560	36.47	4.03	2.05
2	Number of leaves per plant	1.434	0.211	7.87	15.22	5.84
3	Leaf area	23970.180	8812.650	480.79	32.20	19.53
4	Grain-filling period	5.982	3.997	25.44	9.61	7.86
5	Days to maturity	10.873	9.411	69.22	4.76	4.43
6	Root spread	0.765	0.184	9.98	8.76	4.30
7	Root/shoot ratio	0.003	0.001	0.149	36.76	21.22
8	Proline content of leaves	96416.340	38992.190	512.17	60.63	38.55
9	Haulm yield per plot	89521.940	6076.480	611.67	48.92	12.74
10	Grain yield per plot	3708.009	355.193	159.57	38.16	11.81
11	Number of pods per plant	21.470	0.498	19.19	24.15	3.68
12	Number of grains per pod	0.225	0.093	6.47	7.33	4.71
13	Hundred seed weight	0.149	0.077	4.42	8.73	6.28
14	Grain size	0.064	0.024	3.79	6.67	4.09

Table 6. Heritability and expected genetic advance

Sl. No.	Characters	Heritability percentage (H^2)	Expected genetic advance as percentage of mean
1	Days to first flowering	25.75	2.14
2	Number of leaves per plant	14.71	4.61
3	Leaf area	36.77	24.39
4	Grain filling period	66.82	13.23
5	Days to maturity	86.55	8.49
6	Root spread	24.05	4.34
7	Root/shoot ratio	33.33	25.24
8	Proline content of leaves	40.44	50.51
9	Haulm yield/plot	6.78	6.83
10	Grain yield/plot	5.26	3.41
11	Number of pods per plant	2.32	1.15
12	Number of grains per pod	41.33	6.24
13	Hundred seed weight	51.68	9.30
14	Grain size	37.50	5.16

3. Heritability in the broad sense

Estimates of broad sense heritability are presented in Table 6.

High values of heritability were recorded for the characters viz. days to maturity (86.55 per cent) grain-filling period (66.82 per cent) and hundred seed weight (51.68 per cent). Moderate heritability values were observed for number of grains per pod (41.33 per cent), free proline content of leaves (40.44 per cent), grain size (37.50 per cent), leaf area(36.77 per cent) and root/shoot ratio (33.33 per cent). Days to first flowering (25.75 per cent), root spread (24.05 per cent) number of leaves per plant (14.71 per cent), haulm yield per plot (6.78 per cent) grain yield per plot (5.26 per cent) and number of pods per plant (2.32 per cent), showed low heritability.

4. Expected genetic advance

Results are presented in Table 6.

The free proline content of leaves (50.51 per cent) recorded the maximum genetic advance followed by root/shoot ratio (25.24 per cent) and leaf area (24.39 per cent). Low values were observed for grain-filling period (13.23 per cent), hundred seed weight (9.30 per cent), days to maturity (8.49 per cent), number of grains per pod

(6.24 per cent), grain size (5.16 per cent), number of leaves per plant (4.61 per cent) root spread (4.34 per cent), grain yield per plot (3.41 per cent), days to first flowering (2.14 per cent) and number of pods per plant (1.15 per cent).

III Correlation analysis

a) Correlation between grain yield and other characters

The phenotypic and genotypic correlation coefficients between grain yield and other characters are presented in Table 7.

The genotypic correlation were found to be greater than the phenotypic correlation except for the characters number of pods per plant, number of leaves per plant, leaf area and root spread. Grain yield per plot had high positive genotypic correlation with leaf area (0.3287), free proline content of leaves (0.9981), number of grains per pod (1.5218), hundred seed weight (0.5467) and grain size (0.8057). Low positive genotypic correlation was observed with root spread (0.1026) and number of pods per plant (0.2644). Days to first flowering (¯1.4254), number of leaves per plant (¯0.1020), grain-filling period (¯1.7331), days to maturity (¯0.9209) and root/shoot ratio (¯0.6621) exhibited negative genotypic correlation with grain yield per plot.

Table 7. Genotypic (G) and phenotypic (P) correlation coefficients between grain yield and other characters

Sl. No.	Characters	Correlation coefficients	
		G	P
1	Days to first flowering	-1.4254	-0.1170
2	Number of leaves per plant	-0.1020	0.1235
3	Leaf area	0.3287	0.4775*
4	Grain filling period	-1.7331	-0.4158*
5	Days to maturity	-0.9209	-0.2130
6	Root spread	0.1026	0.1578
7	Root/shoot ratio	-0.6621	-0.0472
8	Proline content of leaves	0.9981	0.0117
9	Number of pods per plant	0.2644	0.3257*
10	Number of grains per pod	1.5218	0.3340*
11	Hundred seed weight	0.5467	0.3389*
12	Grain size	0.8057	0.2439

*Significant at 5 per cent level

Significant positive phenotypic correlation was observed with leaf area, number of pods per plant, number of grains per pod and hundred seed weight. Leaf area recorded the highest value of 0.4775. Grain yield per plot exhibited significant negative phenotypic correlation with grain-filling period. Number of leaves per plant, root spread, free proline content of leaves and grain size exhibited non-significant positive phenotypic correlation while days to first flowering, days to maturity and root/shoot ratio showed non-significant negative phenotypic correlation with grain yield per plot.

b) Correlation between other pairs of characters

The phenotypic and genotypic correlation between characters other than yield are presented in Table 8.

1. Days to first flowering

Days to first flowering had positive genotypic correlation with number of leaves per plant, leaf area, grain-filling period, days to maturity, root spread, root/shoot ratio, free proline content of leaves and number of pods per plant. Negative genotypic correlation was observed with number of grains per pod, hundred seed weight and grain size.

Grain-filling period exhibited significant positive phenotypic correlation while number of grains per pod,

Table 8. Genotypic and phenotypic correlation coefficients between pairs of characters in blackgram

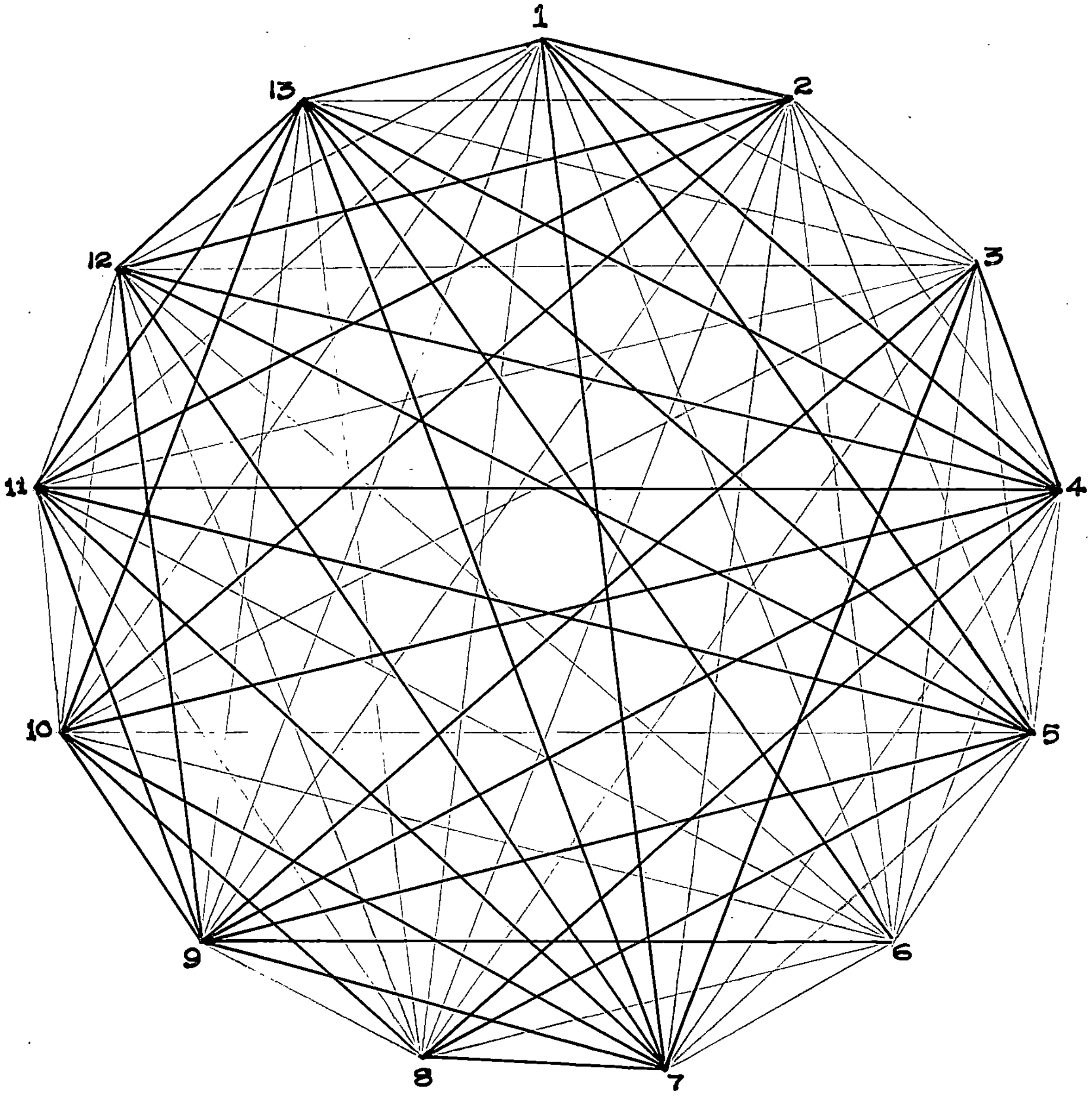
ters	Days to first flowering	Number of leaves per plant	Leaf area	Grain filling period	Days to maturity	Root spread	Root/shoot ratio	Proline content of leaves	Grain yield per plot	Number of pods per plant	Number of grains per pod	Hundred seed weight	Grain size
o first ing	1.0000	0.1462	-0.0782	0.2882*	0.2056	-0.1068	-0.1092	0.0882	-0.1170	-0.0315	-0.3021*	-0.4354*	-0.3644*
of leaves ant	1.6215	1.0000	0.5793*	0.1259	-0.1040	0.0377	-0.0954	0.1742	0.1235	0.4527*	0.0056	0.0775	0.1811
rea	0.4602	0.2792	1.0000	-0.1702	0.0645	0.3407*	-0.1361	0.1671	0.4775*	0.4026*	0.4834*	0.4109*	0.4592*
filling	0.6774	-0.1505	-0.4494	1.0000	0.2742*	0.1014	0.1320	-0.0369	-0.4158*	-0.0028	-0.4879*	-0.3108*	-0.2140
o maturity	0.3446	-0.2940	0.1486	0.3487	1.0000	0.4027*	0.3579*	0.0032	-0.2130	-0.2380	0.0372	-0.0316	-0.0388
pread	0.1845	-0.5377	0.5816	0.1574	0.8275	1.0000	0.1385	0.0464	0.1578	-0.1530	0.1687	0.0971	0.0819
hoot ratio	0.2486	-0.5641	-0.4748	0.3353	0.4840	0.1997	1.0000	-0.0591	-0.0472	-0.0723	-0.0876	-0.0809	-0.1548
e content	0.2819	0.8033	0.4212	-0.1149	-0.0427	0.2610	-0.3596	1.0000	0.0117	0.0731	-0.0656	0.0332	0.1089
yield/plot	-1.4254	-0.1020	0.3287	-1.7331	-0.9209	0.1026	-0.6621	0.9981	1.0000	0.3257*	0.3340*	0.3389*	0.2439
of pods lant	0.3803	0.4698	-0.1790	-0.1680	-0.8479	-0.7992	-0.6944	2.8591	0.2644	1.0000	0.1703	-0.0030	0.1524
of grains od	-0.9216	-0.7665	0.5465	-0.7977	0.1452	0.7971	-0.1635	-0.2049	1.5218	-1.0319	1.0000	0.4071*	0.4813*
ed seed t	-0.4908	-0.4577	0.2879	-0.5828	-0.0518	0.2655	-0.2123	0.0937	0.5467	-0.9216	0.6636	1.0000	0.7459*
size	-0.7163	-0.3659	0.4141	-0.5050	-0.0666	0.3775	-0.1634	0.0272	0.8057	-0.3507	0.7473	0.9770	1.0000

Upper off diagonal elements : Phenotypic correlation coefficients
Lower off diagonal elements : Genotypic correlation coefficients

*Significant at 5 per cent level

Figure 1. Genotypic correlations among 13 characters

1. Grain yield/plot
2. Days to first flowering
3. Leaf area
4. Grain-filling period
5. Days to maturity
6. Root spread
7. Root/shoot ratio
8. Proline content
9. Number of pods per plant
10. Number of grains per pod
11. Hundred seed weight
12. Grain-size
13. Number of leaves per plant



Positive correlation

Negative correlation

FIGURE 1

hundred seed weight and grain size showed significant negative phenotypic correlation. It had non-significant positive phenotypic correlation with number of leaves per plant, days to maturity and free proline content of leaves and non-significant negative phenotypic correlation with leaf area, root spread, root/shoot ratio and number of pods per plant.

2. Number of leaves per plant

High positive genotypic correlation was observed with free proline content of leaves (0.8033) followed by number of pods per plant. Leaf area recorded the least positive genotypic correlation (0.2792). The genotypic correlation of this character with grain-filling period, days to maturity, root spread, root/shoot ratio number of grains per pod, hundred seed weight and grain size were found to be negative.

Significant positive phenotypic correlation was recorded with leaf area and number of pods per plant. It showed non-significant positive phenotypic correlation with grain-filling period, root spread, free proline content of leaves, number of grains per pod and hundred seed weight. Days to maturity and root/shoot ratio exhibited non-significant negative phenotypic correlation with number of leaves per plant.

3. Leaf area

Root spread, days to maturity, free proline content of leaves, number of grains per pod, hundred seed weight and grain size had positive genotypic correlation with leaf area where root spread recorded the highest value. Grain-filling period, root/shoot ratio and number of pods per plant exhibited negative genotypic correlation.

Leaf area exhibited significant positive phenotypic correlation with the root spread, number of pods per plant, number of grains per pod, hundred seed weight and grain size. This character showed non-significant positive phenotypic correlation with days to maturity and free proline content of leaves and non-significant negative phenotypic correlation with grain-filling period and root/shoot ratio.

4. Grain-filling period

Positive genotypic correlation with days to maturity, root spread and root/shoot ratio was observed where days to maturity showed the highest value. Free proline content of leaves, number of pods per plant, number of grains per pod, hundred seed weight and grain size recorded negative genotypic correlation with grain-filling period. Number of grains per pod had the highest negative genotypic correlation with grain-filling period.

There was significant positive phenotypic correlation between grain-filling period and days to maturity. The phenotypic correlation of this character with number of grains per pod and hundred seed weight were found to be negative and significant. Positive non-significant phenotypic correlation was exhibited by root spread and root/shoot ratio whereas free proline content of leaves, number of pods per plant and grain size exhibited non-significant negative correlation with grain-filling period.

5. Days to maturity

Root spread, root/shoot ratio and number of grains per pod recorded positive genotypic correlation with days to maturity. Root spread recorded the highest positive genotypic correlation (0.8275). Free proline content of leaves, number of pods per plant, hundred seed weight and grain size were negatively correlated with days to maturity, number of pods per plant recording the highest negative genotypic correlation.

Root spread and root/shoot ratio showed significant positive phenotypic correlation with days to maturity. Free proline content of leaves and number of grains per pod had non-significant positive phenotypic correlation. Non-significant negative phenotypic correlation was observed with number of pods per plant, hundred seed weight and grain size.

6. Root spread

Root spread exhibited a high positive genotypic correlation with number of grains per pod and a high negative genotypic correlation with number of pods per plant. It had positive genotypic correlation with root/shoot ratio, free proline content of leaves, hundred seed weight and grain size.

Root/shoot ratio, free proline content of leaves, number of grains per pod, hundred seed weight and grain size showed non-significant positive phenotypic correlation whereas number of pods per plant showed non-significant negative phenotypic correlation.

7. Root/shoot ratio

Free proline content of leaves, number of pods per plant, number of grains per pod, hundred seed weight and grain size recorded a negative genotypic and phenotypic correlation with root/shoot ratio.

8. Proline content

Number of pods per plant, hundred seed weight and grain size recorded positive genotypic correlation where as number of grains per pod recorded negative genotypic correlation with free proline content of leaves.

Non-significant positive phenotypic correlation was recorded with number of pods per plant, hundred seed weight and grain size. Number of grains per pod was negatively correlated with free proline content of leaves and the correlation was non-significant.

9. Number of pods per plant

Number of pods per plant exhibited a high negative genotypic correlation with number of grains per pod followed by hundred seed weight and grain size.

Number of grains per pod and grain size recorded non-significant positive phenotypic correlation while hundred seed weight had non-significant negative phenotypic association.

10. Number of grains per pod

This character showed high positive genotypic and phenotypic correlation with hundred seed weight and grain size.

11. Hundred seed weight

High positive genotypic and phenotypic correlation existed between grain size and hundred seed weight.

IV Selection index

Leaf area, grain-filling period, days to maturity, root/shoot ratio, number of pods per plant, number of grains per pod, hundred seed weight, grain size and grain yield which are the most important and easy to measure drought tolerant parameters were selected for the formulation of selection index. The selection index prepared by exercising five per cent selection are presented in Table 9.

The b_i-values calculated for the characters were as follows:

Leaf area = b_1 = 0.420036
Grain-filling period = b_2 = 20.45543
Days to maturity = b_3 = $^{-}$1594.632
Root/shoot ratio = b_4 = $^{-}$40.01948
Number of pods per plant = b_5 = 15.81376
Number of grains per pod = b_6 = $^{-}$155.5194
Hundred seed weight = b_7 = 10.08454
Grain size = b_8 = 0.4167175
Grain yield per plot = b_9 = $^{-}$0.1896809

Using the function $I = b_1p_1 + b_2p_2 + \ldots\ldots + b_np_n$ the index value for each variety was determined and the varieties were ranked accordingly. The highest index was recorded by variety TAU-2 (243.04) followed by PDU-5 (189.39), T-9 (99.70), COBG-302 (52.55), PDU-101 (37.37)

Figure 2. Graphical representation of Soil Moisture percentage

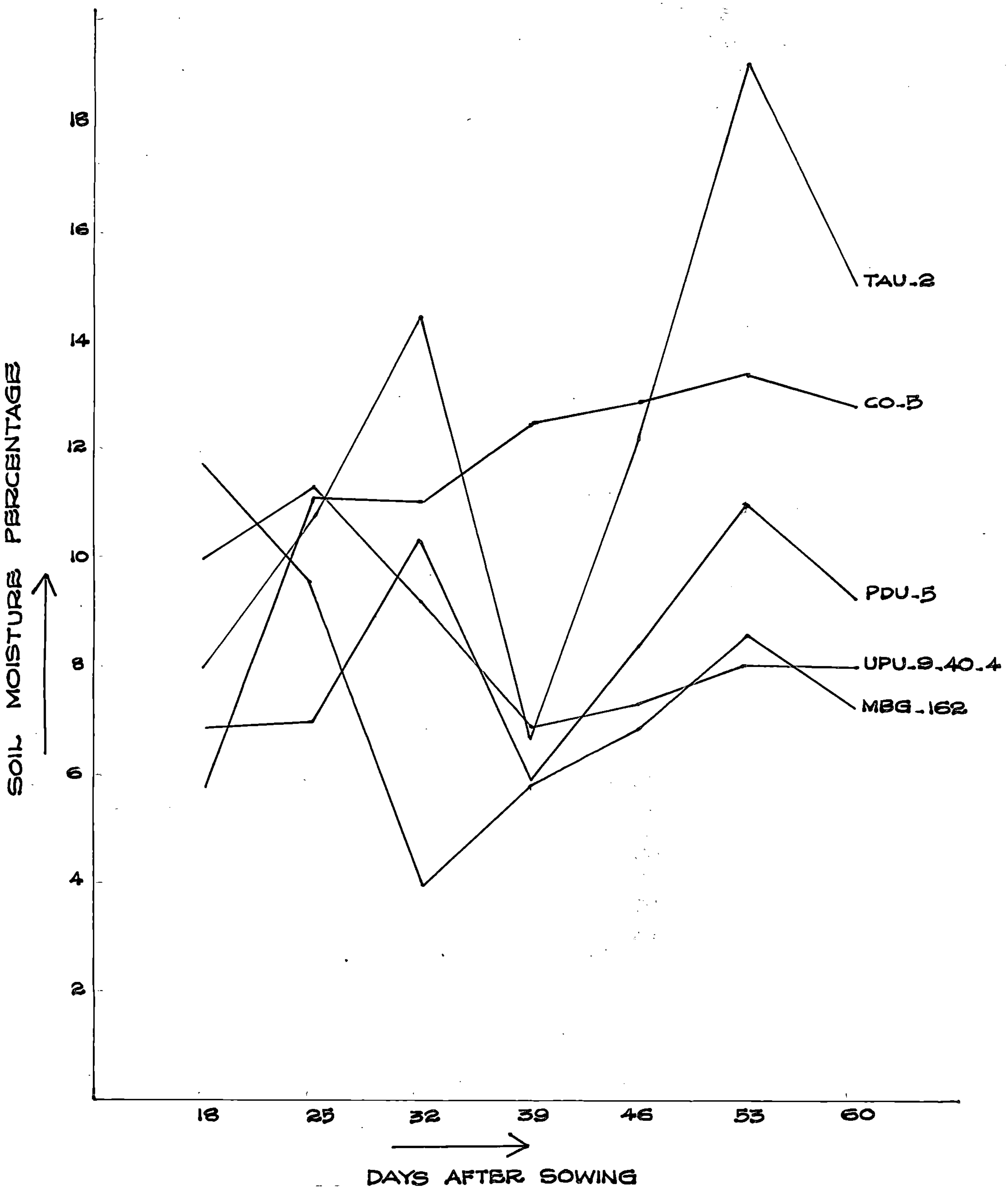


Table 9. Selection Index (Score) for twenty different varieties

Sl. No.	Varieties	Selection index
1	TAU-2	243.04
2	PDU-5	189.39
3	T-9	99.70
4	COBG-302	52.55
5	PDU-101	37.37
6	LBG-613	-51.23
7	UPU-9-40-4	-54.98
8	KB-51	-62.51
9	NPRB-1	-67.99
10	NPRB-3	-80.36
11	PDU-10	-83.88
12	MBG-162	-110.99
13	LBG-20	-140.42
14	Local	-208.52
15	PANT-U-30	-241.69
16	PDU-1	-265.94
17	IU-1-19	-297.28
18	B-3-8-8	-365.02
19	PDU-12	-374.31
20	Co-5	-473.68

Table 10. Mean values of soil moisture percentage

Sl. No.	Varieties	18 DAS	25 DAS	32 DAS	39 DAS	46 DAS	53 DAS	60 DAS
1	PDU-5	6.79	6.86	10.29	5.76	8.37	10.85	9.19
2	Co-5	5.73	11.99	11.99	12.39	12.80	13.30	12.83
3	MBG-162	11.55	9.51	3.89	5.68	6.76	8.45	7.18
4	TAU-2	7.92	10.70	14.37	6.58	12.06	19.09	15.03
5	UPU-9-40-4	9.89	11.17	9.10	6.84	7.15	8.02	7.95
6	NPRB-1	8.32	8.73	9.10	5.41	9.13	14.59	11.15
7	KB-51	12.97	9.92	9.89	3.45	7.15	11.55	9.11
8	LBG-20	8.70	11.96	10.74	4.31	9.19	15.48	12.06
9	PDU-10	9.10	8.70	11.12	13.02	13.25	14.98	14.08
10	T-9	11.12	10.39	8.72	3.46	8.32	13.84	10.76
11	LBG-613	7.60	10.45	10.29	5.33	10.45	16.70	13.02
12	PDU-1	11.19	11.55	11.53	9.14	11.94	16.01	13.70
13	NPRB-3	9.95	7.16	10.76	6.55	8.32	11.53	9.89
14	PANT-U-30	9.51	8.32	10.33	6.86	10.44	14.67	12.08
15	PDU-101	15.33	8.30	14.42	8.09	9.99	12.09	10.81
16	IU-1-19	9.09	9.51	9.09	4.61	8.37	12.84	9.95
17	PDU-12	8.73	8.30	10.70	11.14	12.39	15.03	13.70
18	COBG-302	9.42	8.34	9.14	6.44	10.33	14.98	12.39
19	B-3-8-8	7.58	9.49	9.09	6.48	10.40	15.07	12.06
20	Local	10.29	13.84	14.84	5.99	10.61	17.06	13.53
	General Mean	9.54	9.76	10.77	6.88	9.87	13.80	11.52
	CD (0.05)	6.25	4.69	5.67	7.17	5.57	7.41	6.16

Figure 2. Graphical representation of Soil Moisture percentage

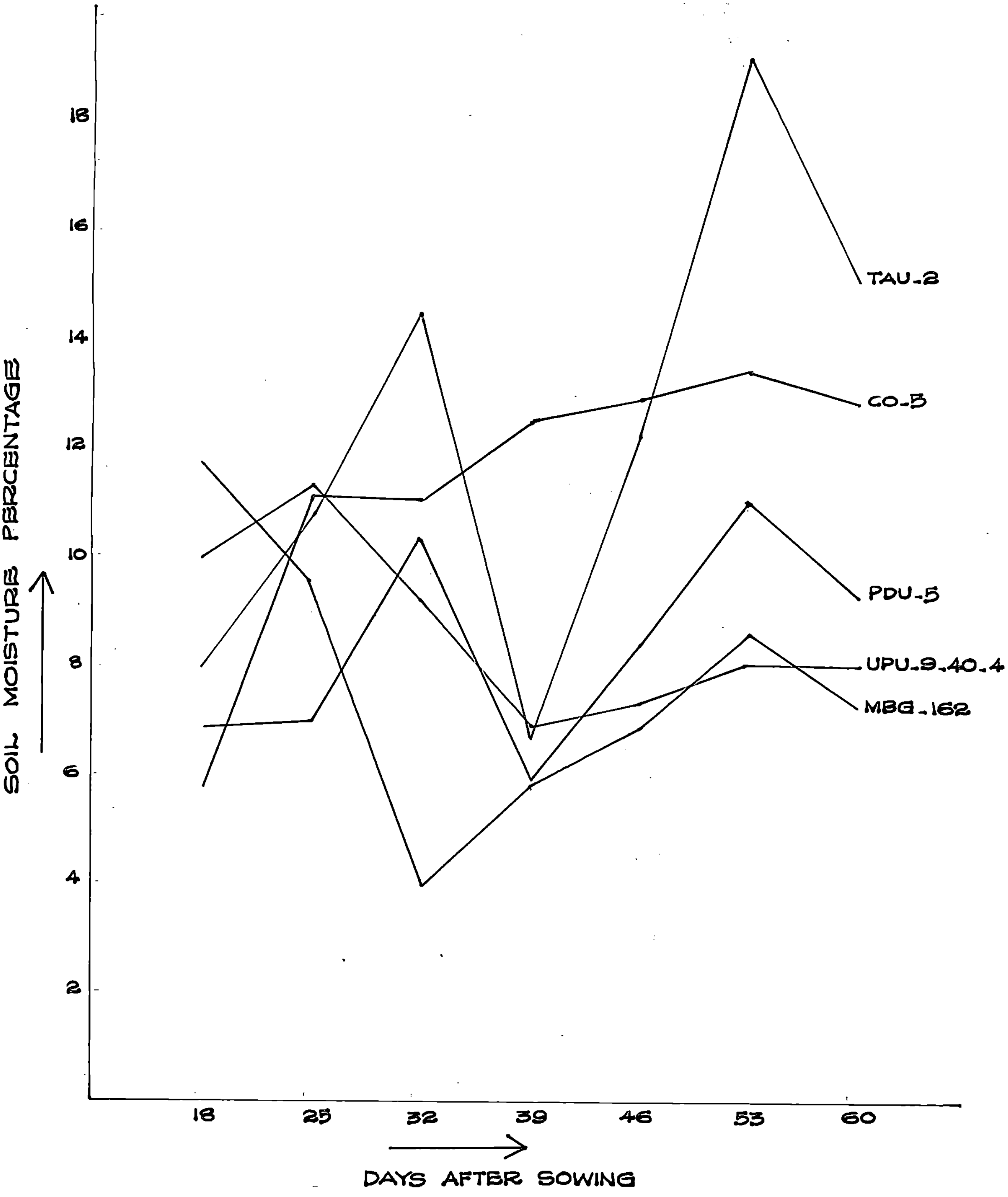


Figure 3. Graphical representation of soil moisture percentage

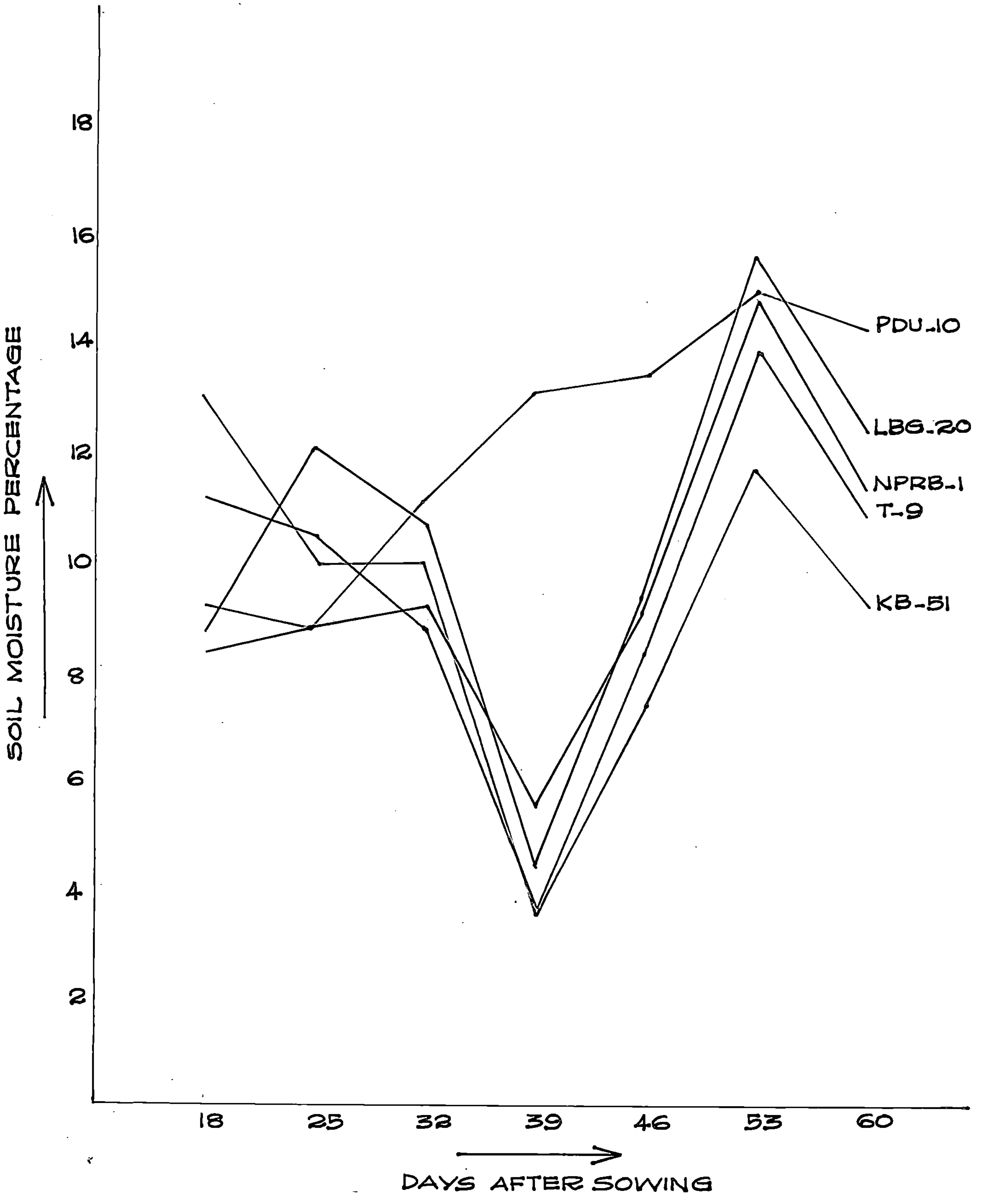


Figure 4. Graphical representation of soil moisture percentage

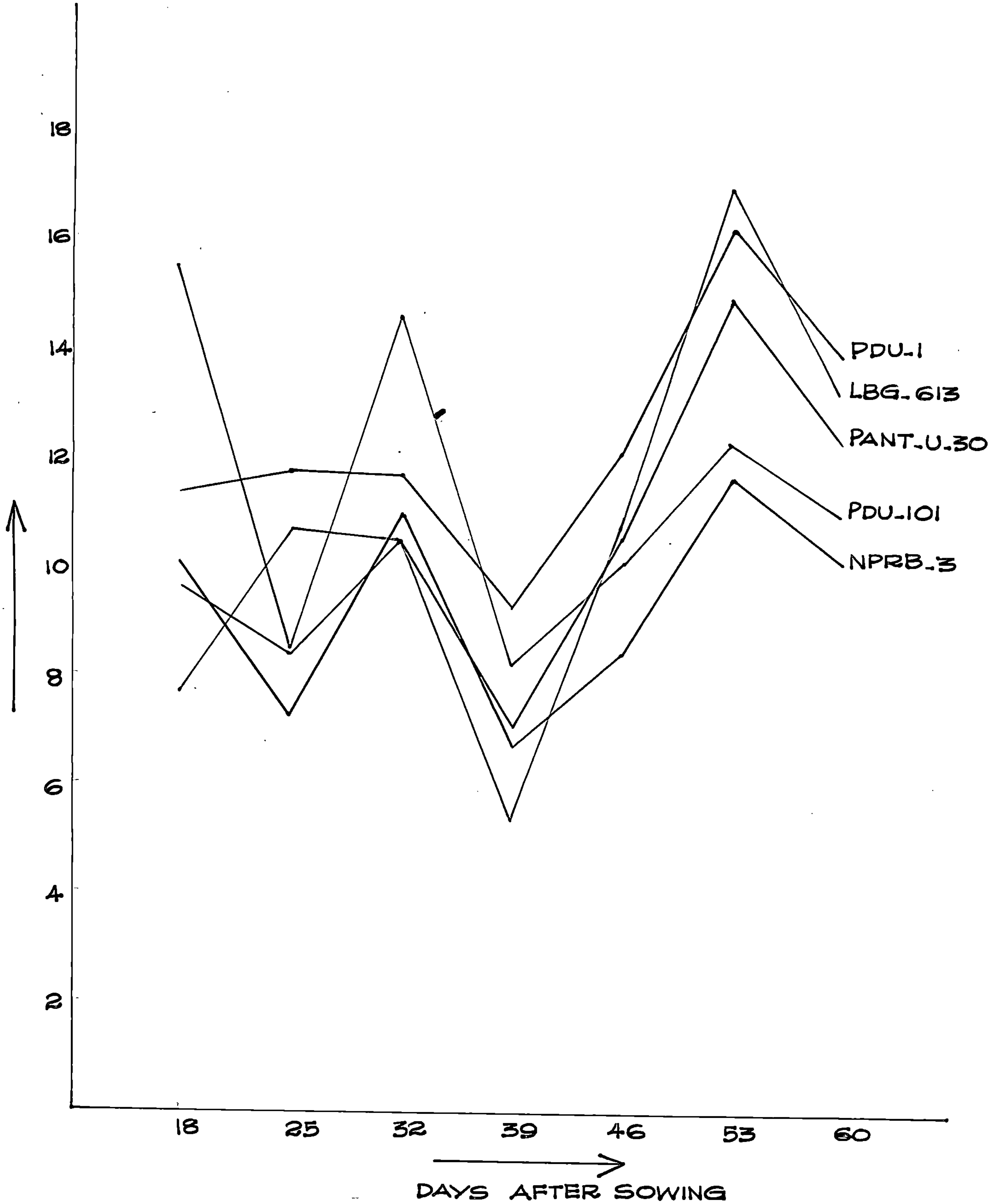
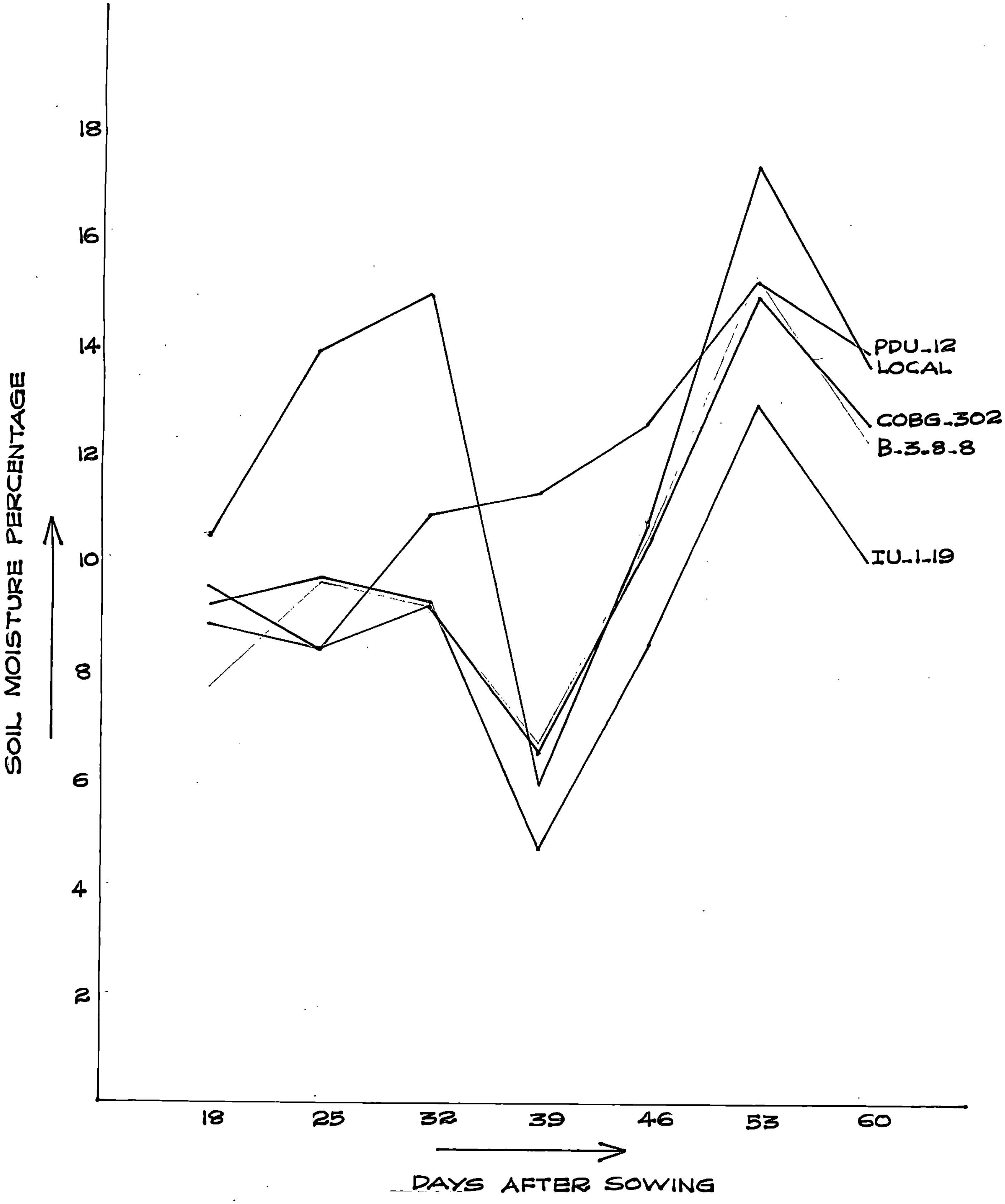


Figure 5. Graphical representation of soil moisture percentage



etc. in that order. The top ranking five varieties were thus identified as tolerant to drought.

V Soil moisture analysis

The mean data on soil moisture percentage measured at weekly intervals from sowing to harvest are presented in Table 10 and graphically represented in Figures 2 to 5.

The analysis of variance on soil moisture percentage did not show any significant difference between plots (Table 3). However, variation in soil moisture percentage was observed at critical stages of crop growth viz. flowering and pod filling. The results presented in Table 10 indicated that the plants had suffered severe stress during the flowering stage. It is evident from the results presented in Figures 2 to 5 that the varieties MBG-162, PDU-5, KB-51, T-9, LBG-20, NPRB-1, LBG-613 and IU-1-19 had received only less than six per cent soil moisture at 32-39 days after sowing. These varieties were found to come to flowering during these days when they experienced maximum soil moisture stress. It is evident from these results that out of the eight varieties which experienced maximum stress, two varieties viz. PDU-5 and T-9 were found to be superior in yield and other drought tolerant parameters (Table 4).

DISCUSSION

DISCUSSION

In the present study twenty genotypes of blackgram were evaluated for yield, yield components and drought tolerant paremeters. The results are discussed hereunder.

Days to first flowering (Earliness)

Early maturity is considered as a desirable character for improving the drought resistance of crop plants [Fanous (1967) in pearl millet and Ojomo (1971) in cowpea]. Among the twenty genotypes tested in the present study, T-9, NPRB-3, UPU-9-40-4, PDU-5, LBG-613, Local, KB-51, PDU-12 and NPRB-1 were found to be early in flowering. The earliness of these varieties show their potentiality for drought tolerance as suggested by Saxena and Sheldrake (1977) in chickpea.

The varieties T-9, UPU-9-40-4, PDU-5, Local, KB-51 and NPRB-1 were found to be good in yielding ability also. This result confirms the findings of Singh _et_ _al_. (1985) in Brassica; Ali _et_ _al_. (1986) in pearl millet and Sivakumar and Singh (1987) in chickpea that earliness is directly associated with productivity under drought conditions. The flowers and pods of early varieties would experience less drought and be less likely to abscise than would late flowers and pods and this might be the reason for the higher grain yield recorded by them under moisture stress condition.

Number of leaves and leaf area

Number of leaves and leaf area per plant were found to be not much affected by moisture stress condition of the soil. The varieties COBG-302, T-9, Local, TAU-2 and KB-51 recorded comparatively higher leaf area where as LBG-613, PDU-101, PDU-1, MBG-162, UPU-9-40-4, PANT-U-30, PDU-5 and NPRB-1 recorded moderate values.

Reduction in functional leaf area has been reported as an adaptation mechanism to conserve water by Thangavelu _et al_. (1967) in sorghum; Nagarajah and Schulze (1983) in cowpea and Hoogenboom _et al_. (1987) in soybean. However, moderate to high leaf area under water stress recorded by the varieties COBG-302, T-9, Local, TAU-2, KB-51, LBG-613, PDU-101, PDU-1, MBG-162, UPU-9-40-4, PANT-U-30, PDU-5 and NPRB-1 may be attributed to their potentiality for drought tolerance as suggested by Bascur _et al_. (1985) in french bean.

Stomatal distribution

The varieties which recorded higher yields in the present study viz. UPU-9-40-4, TAU-2, NPRB-1, PDU-5, Local, T-9, KB-51, PDU-1 and COBG-302 were found to have a comparatively lower number of stomata per microscopic field. This result is in agreement with the findings of Ali and Naidu (1982) in maize. The lower number of stomata recorded by these varieties might be an indication of their likely drought tolerance as suggested by Rojas et al. (1983) in sugarcane.

Grain-filling period

The duration of grain-filling is related to yield in many crops. The varieties which had longer grain-filling period were found to be low in yielding ability where as varieties with short to medium grain-filling period recorded comparatively higher yields. This result is in confirmity with the earlier reports of Bruckner (1986) in wheat whereas the findings of Asana et al. (1968) and Omara (1987) in barley were contrary to the present result.

Root characters

The ability of a plant to absorb water is associated with its root system characters. In the present study, no significant difference between varieties for root length was observed. However, varieties with a higher root length may be able to withstand drought by absorbing water from deeper layers of soil [Babalola (1980) in cowpea and Kavitha (1982) in blackgram]. It is also evident that, in addition to length a better spread of roots enabled the plants to tolerate drought and yield satisfactorily. The varieties UPU-9-40-4, TAU-2, NPRB-1, PDU-5, Local, T-9, KB-51 and COBG-302 had comparatively better root length and spread. These varieties can occupy a larger soil volume for water and this might be the reason for the comparatively higher grain yields in them as suggested by Hurd (1974) in wheat.

Root/shoot ratio

According to Begg and Turner (1976) and Levitt (1980) a high root/top ratio is an effective means of adaptation of plants to drought conditions. But contrary to this, root/shoot ratios, though found significant were not high in the present study. This indicates that mechanisms other than reduction in shoot growth might be the reason for the relative drought tolerance of blackgram genotypes.

Proline content

Proline accumulates in leaves of plants subjected to moisture stress. Varietal differences in free proline accumulation was observed in the present study which is in conformity with the findings of Barnett and Naylor (1966) in Bermuda grass. The varieties TAU-2, PDU-5, PDU-101, PDU-10, UPU-9-40-4, COBG-302, T-9, NPRB-3 and LBG-20 recorded higher amount of free proline in their leaves. This indicates their potential for drought tolerance as suggested by Mehkri et al. (1977) in groundnut and Pandey (1982) in wheat. The varieties TAU-2, PDU-5, UPU-9-40-4, COBG-302 and T-9 were found to have higher grain yield also. This suggests that varieties which can accumulate proline can withstand the adverse effects of drought better than others and can give substantially good yields.

Yield and yield components

Among the twenty genotypes tested UPU-9-40-4 had the highest grain yield per plant under the moisture stress conditions prevailed followed by TAU-2 and NPRB-1. The varieties PDU-5, Local, T-9, KB-51, PDU-1 and COBG-302 also recorded comparatively higher grain yields. This indicates the ability of these genotypes for drought tolerance as suggested by Turner (1979) and Levitt (1980).

Among the yield components, number of pods per plant was found to be adversely affected by moisture stress condition of the soil. This is in agreement with the findings of Summerfield et al. (1976) in cowpea and Vijayakumar (1980) and Kavitha (1982) in blackgram. The other yield components viz. number of grains per pod, grain-size and weight were not much affected by moisture condition of the soil. The severe stress experienced by the plants during the flowering stage might be the reason for the reduction in number of pods noticed in the present investigation as suggested by Singh and Tripathi (1972) in soybean.

Variability

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

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

The difference between the genotypes were highly significant for 10 out of 17 characters. The estimates of variance components indicated only little difference between phenotypic and genotypic variances for the characters viz. grain-filling period, days to maturity, root/shoot ratio, number of grains per pod, hundred seed weight and grain size (Table 5). This indicates that variations observed in these characters were mainly due to genetic causes and that environment had only negligible influence over them and there is better scope of improvement of these characters through selection.

On the other hand, the characters viz. days to first flowering, number of leaves per plant, leaf area, root spread, free proline content of leaves, haulm yield per plot, grain yield per plot and number of pods per plant showed wide difference between phenotypic and genotypic variance denoting the greater influence of environment over them.

Genetic parameters

High genotypic coefficient of variation observed for leaf area, root/shoot ratio, free proline content of leaves and grain yield per plot indicates the presence of high degree of genetic variability and better scope for the improvement of these characters through selection.

The characters viz. days to first flowering, number of leaves per plant, grain-filling period, days to maturity, root spread, number of pods per plant, number of grains per pod, hundred seed weight and grain size showed low genotypic coefficient of variation indicating the low amount of variability in these characters and thereby limiting the scope for their improvement through selection.

The low genotypic coefficient of variation observed in this study for days to maturity agrees with the findings of Pillai (1980) and for number of grains per pod agrees with the findings of Soundarapandian *et al*. (1975) in blackgram.

Number of pods per plant showed a low genotypic coefficient of variation in the present investigation, as against observations by Singh *et al*. (1972), Veeraswamy *et al*. (1973), Soundarapandian *et al*. (1975) and Sagar *et al*. (1976) in blackgram; Lal and Haque (1972) in soybean and Shoram (1983) in pigeon pea.

The low genotypic coefficient of variation observed for hundred seed weight is contrary to the results of Lal and Haque (1982) in soybean.

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

In the present study, days to maturity, grain-filling period and hundred seed weight recorded high heritability values indicating that they are less influenced by environment. High heritability recorded for days to maturity is in agreement with the findings of Pillai (1980) and Sarkar *et al*. (1984) in blackgram; Empig *et al*. (1970) in greengram; Singh and Mehndiratta (1969) and Radhakrishnan and Jebaraj (1982) in cowpea. However, moderate heritability for this trait was recorded by Sreekumar *et al*. (1979) in cowpea. Regarding hundred seed weight, high heritability values were observed by Goud *et al*. (1977) and Pillai (1980) in blackgram; Singh and Mehndiratta (1969) in cowpea and Khorgade *et al*. (1985) in chickpea.

Moderate values of heritability were recorded for leaf area, root/shoot ratio, free proline content of leaves, number of grains per pod and grain size. Moderate heritability recorded for number of grains per pod is in agreement with the findings of Sreekumar *et al*. (1979) in cowpea. However, high heritability values for this trait was recorded by Goud *et al*. (1977) and Patel and Shah (1982) in blackgram; Sreekumar and Abraham (1979) in greengram and Khorgade *et al*. (1985) in chickpea.

Low heritability values were observed for days to first flowering, number of leaves per plant, root spread, haulm yield per plot, grain yield per plot and number of pods per plant. The low heritability value recorded for grain yield was in conformity to the findings of Pillai (1980) in blackgram; Singh and Mehndiratta (1969) in cowpea and Empig *et al*. (1970) in greengram. The low heritability value observed for number of pods per plant is in agreement with the findings of Pillai (1980) in blackgram.

Heritability values alone may not provide a clear predictability of the breeding value. Heritability in conjunction with genetic advance is more effective and reliable in predicting the resultant effect of selection, than heritability alone (Johnson et al., 1955). Moderately high heritability and appreciable genetic advance were recorded by leaf area,root/shoot ratio and free proline content of leaves. High heritability along with high genetic advance indicate the role of additive gene action for the character concerned as suggested by Panse (1957).

High heritability and low genetic advance were recorded for grain-filling period, days to maturity and hundred seed weight; while moderately high heritability and low genetic advance were observed for number of grains per pod and grain size. Similar reports of high heritability and low genetic advance for days to maturity was made by Singh and Mehndiratta (1969) and Radhakrishnan and Jebaraj (1982) in cowpea and for number of grains per pod by Sreekumar and Abraham (1979) in greengram and Patel and Shah (1982) in blackgram. Contrary to the present finding of high heritability and low genetic advance for hundred seed weight Singh and Mehndiratta (1969) observed high heritability and high genetic advance in cowpea. High heritability and low genetic advance observed in the present study is attributed to the role of non-additive genes in the expression of these characters (Panse, 1957).

Low heritability and low genetic advance were observed for days to first flowering, number of leaves per plant, root spread, haulm yield per plot, grain yield per plot and number of pods per plant indicating that these characters are highly influenced by environmental factors. The present finding regarding number of pods per plant differs from the findings of Soundarapandian *et al*. (1975) in blackgram; Sreekumar and Abraham (1979) in greengram and Radhakrishnan and Jebaraj (1982) in cowpea.

Correlation studies

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

In the present study, leaf area, free proline content of leaves, number of pods per plant, number of grains per pod, hundred seed weight and grain size exhibited positive genotypic correlation with grain yield. The positive genotypic correlation observed for grain yield with number of pods per plant, number of grains per pod and hundred seed weight agrees with the findings of Sammons *et al*. (1981) in soybean and Kavitha (1982) in blackgram. The positive genotypic correlation recorded between grain yield and leaf area is in agreement with the findings of Mehrotra et al. (1968) in maize and Kavitha (1982) in blackgram.

Days to first flowering, number of leaves per plant, grain-filling period, days to maturity and root/shoot ratio showed negative genotypic correlation with grain yield. The negative genotypic correlation recorded between grain yield and days to first flowering agrees with the findings of Saxena et al. (1979) in chickpea and Ali et al. (1986) in pearl millet. This indicates that early maturing varieties perform well under drought conditions. The negative genotypic correlation of grain yield with days to maturity and number of leaves per plant conforms to the reports of Kavitha (1982) in blackgram.

Grain yield showed negative genotypic correlation with grain-filling period which is in agreement with the findings of Bruckner (1986) in spring wheat and contradictory to the findings of Asana et al. (1968) in wheat and Omara (1987) in barley.

Selection index

A selection index was formulated to increase the efficiency of selection, taking into account the important characters contributing to yield and drought tolerance. Levitt (1980) and Kirkham (1981) suggested yield as the ultimate criterion in selection for drought tolerance. However, selection index was found to be relatively more efficient than direct selection for yield which is probably due to the low heritability for yield in the present study.

Based on the index values, the top ranking five varieties viz. TAU-2, PDU-5, T-9, COBG-302 and PDU-101 were identified as drought tolerant.

SUMMARY

SUMMARY

An experiment on the evaluation of potential for drought tolerance in twenty genotypes of blackgram was conducted at the Department of Plant Breeding, College of Agriculture, Vellayani during Rabi 1988.

The varieties were grown in a field trial in Randomised Block Design with three replications and evaluated for yield and various other characters associated with drought tolerance. Data were collected on seventeen characters viz. days to first flowering, number of leaves per plant, leaf area, number of stomata per microscopic field, grain-filling period, days to maturity, root length, root spread, root/shoot ratio, free proline content of leaves, haulm yield per plot, grain yield per plot, grain yield per plant, number of pods per plant, number of grains per pod, hundred seed weight and grain size.

The following are the important results obtained in this investigation.

1. Analysis of variance revealed significant differences among the treatments for 10 out of 17 characters studied.

2. The number of days to first flowering was found to be reduced in general for all the varieties under the low

soil moisture condition. This will help the plants to escape drought and perform better, as indicated by the seed yield of varieties which flowered early.

3. The number of leaves and leaf area was not much affected by soil moisture stress. Among the varieties studied, the varieties possessing moderate leaf area were found to give better yields.

4. A short to medium grain filling period was found to be advantageous under moisture stress as such varieties recorded higher grain yields than others.

5. The significant difference observed for root spread indicated that besides length a better spread of roots enabled the plants to survive better by utilizing the residual moisture from a larger soil volume under stress conditions.

6. A low root/shoot ratio was recorded.

7. Among the yield components studied, number of pods per plant was found to be adversely affected by the moisture stress condition of the soil but an increase in grain number and size made up for the fewer pods.

8. An increasing trend for free proline content of leaves was observed, which enabled the plants to survive better

and give good yields by increasing the bound water content of cells under soil moisture stress condition.

9. Genotypic coefficient of variation was maximum for free proline content of leaves and minimum for days to first flowering. For characters like grain-filling period, days to maturity, root/shoot ratio, number of grains per pod, hundred seed weight and grain size, there was only little difference between phenotypic and genotypic variance. But for characters viz. days to first flowering, number of leaves per plant, leaf area, root spread, free proline content of leaves, haulm yield per plot, grain yield per plot and number of pods per plant, there was wide difference between phenotypic and genotypic variance indicating higher environmental influence.

10. Heritability estimate was maximum for days to maturity while number of pods per plant recorded the least value. Characters like grain-filling period and hundred seed weight also exhibited high heritability indicating lesser environmental influence on these characters.

11. Genetic advance was maximum for free proline content of leaves followed by root/shoot ratio. Moderate to high heritability coupled with appreciable genetic advance was recorded by leaf area, root/shoot ratio and free proline content of leaves. High heritability and low genetic advance were recorded for grain-filling period,

days to maturity and hundred seed weight, while moderately high heritability and low genetic advance were observed for number of grains per pod and grain size. Low heritability and low genetic advance for days to first flowering, number of leaves per plant, root spread, haulm yield per plot, grain yield per plot and number of pods per plant were also recorded.

12. The correlation study has revealed that leaf area, free proline content of leaves, number of pods per plant, number of grains per pod, hundred seed weight and grain size showed high positive correlation with yield. This indicates the influence of these characters as the important components of yield.

13. Days to first flowering and days to maturity were found to show a negative correlation with yield indicating that early maturing varieties perform well under soil moisture stress condition.

14. Grain-filling period was found to be negatively correlated with yield indicating that varieties with a short grain-filling period can complete maturity before the soil dries out.

15. Root spread was found to be positively correlated with yield showing that, under moisture stress conditions a better spread of roots enables the plant to survive better.

16. A selection index based on yield, yield components and important drought tolerant parameters was found to be relatively more efficient than direct selection for yield.

17. Thus it can be concluded from the present study that an ideal plant type for drought prone area should have early maturity, moderate leaf area, fewer number of stomata, short to medium grain-filling period, high root length and spread, moderate number of pods and maximum grain number per pod and grain size.

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* Original not seen.

POTENTIAL FOR DROUGHT TOLERANCE IN BLACKGRAM (*Vigna mungo* L. Hepper)

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ABSTRACT OF A THESIS
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ABSTRACT

An investigation was carried out in the Department of Plant Breeding, College of Agriculture, Vellayani to evaluate the drought tolerance potential of twenty genotypes of blackgram under moisture stress situation. The variability present in the population was studied and a selection index was worked out to identify desirable genotypes from undesirable ones.

The varieties were evaluated for yield, yield components and other drought tolerant parameters in a field trial in Randomised Block Design with three replications. The varieties tested showed significant difference for most of the drought tolerant parameters. Genotypic coefficient of variation was maximum for free proline content of leaves and minimum for days to first flowering.

Days to maturity, grain-filling period and hundred seed weight exhibited high heritability indicating lesser environmental influence on these characters. Moderate to high heritability and appreciable genetic advance was recorded by leaf area, root/shoot ratio and free proline content of leaves.

The correlation study has revealed that leaf area, free proline content of leaves, root spread, number of pods per plant, number of grains per pod, hundred seed weight

and grain size showed positive correlation with grain yield. Days to first flowering, days to maturity and grain-filling period were found to be negatively correlated with grain yield.

A selection index based on yield, yield components and drought tolerant parameters like leaf area, grain-filling period, root/shoot ratio and free proline content of leaves was found to be relatively more efficient than direct selection for yield. Based on index values, five genotypes were found to be drought tolerant.

It can be concluded from the present study that an ideal plant type in blackgram for drought prone area should have early maturity, moderate leaf area, fewer number of stomata, short to medium grain-filling period, high root length and spread and moderate number of pods having maximum grain number and size.