V. DISCUSSION

Conserving crop diversity is essential for providing plant breeders the raw materials to improve and adapt crops to meet the emerging challenges in crop production. An insight into the magnitude of variability present in the germplasm maintained is of utmost importance as it forms the basis for any effective crop improvement programme. Besides magnitude, its quantification would indicate the potentiality of the germplasm from the point of view of crop improvement.

The last three decades have witnessed major advances in crop improvement through better appreciation of genetic diversity and its deployment in breeding research. A measure of genetic divergence must reflect the differences in gene frequencies and in the absence of experimental techniques to measure diversity with respect to genes affecting quantitative characters, phenotypic diversity is usually considered to be an indication of underlying genetic differences. Beardmore and Shami (1976) had shown that genetic heterogeneity of population was positively associated with heterogeneity in space and time. This was particularly true within species. Thus, it was thought that geographic diversity was positively associated with genetic diversity. However, this association was found to be not always true. Obviously, geographic diversity, alone cannot be the criterion while selecting parents for hybridization, or can be used as a measure to judge genetic diversity.
The concept of genetic distance has been of vital utility in many contexts and more so in differentiating well defined populations. Several measures of distance have been proposed over the past years to suit various objectives in plant breeding. Bhatt (1973) conducted a comparative study of $D^2$ technique with other breeding methods, with an objective of rationalising the procedure for choosing parents for hybridization. He observed that the application of $D^2$ statistics in finding parents for hybridization to be more efficient than choosing parents on ecogeographic diversity. The inclusion of developmental trait which are more greatly subjected to environmental variation will not effect divergence estimates, as $D^2$ is self weighing (Harlan, 1971). Moreover, the inclusion of large number of variables is expected to increase precision of estimates.

In the present study, a cross section of Indian and African finger millet germplasm obtained from the germplasm unit, All India Co-ordinated Small Millets Improvement Project, University of Agricultural Sciences, Bangalore was utilized for genetic divergence studies. Incidentally, these materials were used for character association and path analysis studies also. The results of various experiments on the above aspects are discussed under the following heads: Variability studies, Pattern of character association and path analysis, Genetic divergence in Indian and African germplasm, Identification of promising germplasm for biotic stresses and domestic use.

5.1 Variability studies:
Selection of desirable genotypes is of prime importance in plant breeding and genotype is normally selected based on its phenotype. As such, a survey of phenotypic variability becomes desirable. The experimental material for the present study was carefully chosen from Africa and India, which have been spatially isolated by the vast Arabian Sea. The materials having no ambiguity about their origin and place of collection were only included in this study in order to exclude the possibilities of gene exchanges between the accessions of the two regions. Thus, it is possible that the pattern of variation expressed by the two groups generally representing the two distinct geographical regions have been the outcome of several evolutionary forces- gene mutations, reconstruction of gene loci, structural rearrangement and introgression through natural hybridization operating in these distinct geographical regions. If this is so, the finger millet might have been evolving independently making each group distinct in its own way, Although the finger millet cultivation dates back to pre-historic times in both Africa and India resulting in accumulation of genetic diversity in local and indigenous land races, a few attempts have been made till today to critically compare the diversity prevalent in materials of African and Indian origin and use this information while selecting material from African collections for use in breeding.

5.1.1 Variability in qualitative characters:

Qualitative characters are a useful criteria for characterization of germplasm accessions, as they show high heritability and stable expression. Further, if qualitative characters show association with yield components, it can serve as a
marker in selection process. The variability for twelve qualitative characters viz., growth habit, pigmentation at node, ear shape, ear size, finger branching, gaps on finger, grains per spikelet, grains covering by glumes, grain colour, grain uniformity, grain shape and synchrony of ear maturity present in African and Indian accessions of finger millets are discussed here.

The study of qualitative characters clearly indicated that the African accessions were more variable than Indian accessions, especially for ear shape, ear size, finger branching, grain covering by glumes, grain colour and shape. Even though there was parallelism between Indian and African accessions for inflorescence shape, the latter exhibited higher frequencies of all classes. The finger branching which is a common phenomenon in African accessions, is of rare occurrence in Indian accessions. Similarly, the frequency of accessions having white grain colour types and with reniform seeds were less in Indian accessions. Among African countries, Zambia showed high variability for inflorescence shape and grain colour. In Indian germplasm, relatively more variability was found for inflorescence shape in collections of West Bengal and Orissa. In many African germplasm, the grains were exposed and devoid of glume cover.

There seems to be some parallelism existing in the prevalence of variation in Indian and African accessions. Malawi in Africa and West Bengal in India had only non pigmented accessions. Similarly, Bihar in India and Uganda and Zimbabwe in Africa had more of pigmented types. Shigeta (1981) and M’buru (1983) also reported similar results in African material. Shigeta (1985) further, reported that
high yield was associated with purple pigmentation in plant parts. Rao (1948) found that pigmented genotypes were more resistant to blast disease. However, no such association is noticed in the present study. Further, many blast resistant varieties developed in India are green in colour.

Ethiopia, Kenya, Zambia and Tanzania in Africa and Andhra Pradesh, Tamil Nadu, Orissa, Gujarat, Himachal Pradesh, Sikkim and NEHR in India had preponderance of green types.

Though inflorescence pigmentation was not considered in the present study: it was generally observed that in the African accessions, yellowish green and purplish green inflorescence colours were noticed in addition to commonly occurring shades – dark green, light green, dark purple, and light purple. In Indian and African materials similar spectrum of variation in inflorescence colour was reported by Kempanna (1975). Invariably plant pigmentation and inflorescence pigmentation was strongly associated – green pigmented plants having green ears and purple pigmented plants having purple ears. Nagai (1959) opined that the nearness to equator and tropical climate have resulted in greater variability for inflorescence colour in African accessions.

The semi-compact and compact inflorescence forms were more in frequency in both African and Indian accessions indicating the operation of natural and/or human selection in favour of these two types. Ayyangar and Rao (1932) reported that the top curved and incurved (the terms for semi-compact and compact) were due to close setting of spikelets and the compact forms are superior yielders.
Obviously in India since the beginning of this century, the finger millet has been receiving more attention of the plant breeders compared to Africa and during this process several high yielding local selections have been bred through human intervention. Droopy ear shape was found in very low frequency in both African and Indian germplasm as this is associated with low grain density and poor yield.

As far as grain colour is concerned all the four colours observed in the present study were not found in equal frequency. It appears that both natural and human selection have not favoured white grain types, at least in India because of their low productivity and high susceptibility to blast disease. However, the light brown colour types were in high frequency in both African and Indian accessions, as this is the most favoured colour with the farmers.

The majority of Indian accessions exhibited either globular or round grains, while it was not so in African material. Reniform grains were seen more in African accessions compared to Indian material. Similarly synchronous ear maturity was more in African germplasm compared to Indian germplasm.

5.1.2. Variability in quantitative characters:

Progress in any crop improvement programme depends on the primary raw material ie, the variability existing in the available germplasm. The utility of the germplasm is decided by the extent of variability and genetic advance present in the material. Grain yield is the key issue in crop improvement and yield is the sum total of many component characters. Therefore, to have a fuller comprehension of the
yield, it is necessary to have an analytical assessment of its component characters. In the present study combined set of 289 accessions from Africa and India were evaluated for the quantitative characters to compare the genetic diversity present in them.

The analysis of variance revealed highly significant differences among the accessions of both the continents for all the 13 characters studied. This suggests that the presence of large variability for all characters under study. The range value which is an indicator of variability was considerably large for all the traits studied, especially in the African accessions, except for productive tillers, finger number, days to 50% flowering and yield per plant. The mean values for most of the characters were higher in African germplasm compared to Indian accessions. However, the mean values were marginally higher in Indian material for productive tillers, finger width and 1000 grain weight.

The high variability among the accessions for all the characters under study is suggestive of their collection from diverse ecogeographic locations.

The range values of different characters reflect the extent of phenotypic variability available in them. This alone will not be sufficient to assess the utility of germplasm in breeding programmes – because, the observed variability includes the genotypic, environmental and genotype X environmental interaction components. Therefore, further partitioning of variability into genetic and environmental components is necessary to judge the ability of this material. The heritable portion of the observed phenotypic variation can be ascertained by studying the
components of variation phenotypic and genotypic coefficients of variation – as suggested by Burton and Devene (1953).

In the present study, the phenotypic and genotypic co-efficients of variation were relatively higher in African accessions for 1000 grain weight, leaf number, flag leaf length and width, and yield per plant, while Indian accessions showed high co-efficients of variability for finger number and finger width. For other attributes, there was not much difference between Africa and Indian accessions. Almost all the traits had relatively close and parallel phenotypic and genotypic co-efficients of variation in both African and Indian accessions, indicating the low effect of environment on these characters. The productive tillers, finger width, culm diameter, finger number in both the groups of accessions showed wider differences in values of genotypic and phenotypic co-efficients of variations, suggesting the vulnerability of these characters to environment. Thus, some traits of both vegetative and reproductive nature were more vulnerable to extraneous factors.

Eventhough, the genotypic co-efficients of variation indicate the extent of genetic variability present for various characters, it does not indicate the heritable variation. This could only be ascertained to some extent from heritability estimates, which in broad sense includes additive and non additive portions of gene effects (Hanson et al., 1956). This parameter is singularly important as it provides a precise measure of genetic variation. The magnitude of heritability is the most important aspect of the genetic constitution of the breeding material, which has close bearing on response to selection (Panse and Khargonkar, 1957).
Days to 50 percent flowering and plant height had the highest broad sense heritability in African as well as in Indian populations. This is in conformity with earlier reports, Ravikumar (1988), and Abraham et al. (1989). Apart from the above characters, grain yield per plant, finger number per ear, finger width, 1000 grain weight, and flag leaf length exhibited high heritability in both African and Indian accessions. High heritability estimates for these characters have also been observed and reported by Abraham et al. (1989), Joshi (1989), Shantha kumar (1997) and Sharma (1998). Culm diameter, leaf number and flag leaf width in the present study showed moderate level of heritability in both African and Indian accessions; while, productive tillers per plant and finger number exhibited moderately high heritability. However, some small differences were observed in heritability values between African and Indian material for characters such as leaf number, finger number and finger width.

Since heritability is also influenced by environment, the information on heritability alone may not help in pin-pointing characters for enforcing selection. Nevertheless, the heritability estimates in conjunction with the predicted genetic advance will be more reliable (Johnson et al. 1955a). Heritability gives information on the magnitude of inheritance of quantitative characters, while genetic advance will be helpful in formulating suitable selection procedures.

High heritability along with high genetic advance were recorded for flag leaf length, finger length, productive tillers and finger number in both African and Indian accessions. The genetic advance values were highest for finger length in both African
and Indian germplasm. High heritability combined with high genetic advance indicates that direct selection could be effective for improving these characters. The lowest genetic advance value was in leaf number followed by days to 50% flowering, flag leaf width and 1000 grain weight.

If high heritability is associated with high genetic advance, the variation could be due to additive gene effects (Panse and Khargonkar, 1957). Similarly, high heritability coupled with low genetic advance and vice versa indicate that the variability is due to non-additive interaction of genes (dominance or epistasis).

The grain yield and plant height exhibited moderate genetic advance and high heritability in both the groups, indicating the role of additive gene effect for these characters. Mishra et al. (1980 a) and Joshi and Mehra (1983) had reported moderate genetic advance for finger length. Low genetic gain and moderate to high heritability were recorded for culm diameter, tiller number flag leaf width, finger number, finger width, and 1000 grain weight in both group of accessions indicating the role of dominant or epistatic gene action. Goud and Lakshmi (1977) for tiller number, Mishra et al. (1980 a) and Joshi and Mehra (1983) for finger number reported similar results.

5.1.3. Pattern of variability in African and Indian finger millet;

The magnitude of variability existing for each character and their genetic architecture in African and Indian accessions were described in the earlier sections of the chapter. It is now imperative to examine the distribution of variation in these
two geographical areas isolated by vast Arabian Sea. This geographical barrier has limited the chances of plant migration and gene exchange. Further, within these two continents, finger millet is grown in different eco geographical regions. However, it is supposed that no two geographical regions would be alike in developmental patterns of their variation. Accordingly to Vavilov (1951) variation is characterised by the interaction product of, firstly of plant communities themselves and secondly of the plant communities and the environmental niche of the region in which they are placed. So, the generalized accounts of variation patterns are less meaningful, as they often do not reflect the true characteristics of the geography, unless they are broken into their geographical entities and a reappraisal is made. Such an attempt is made here with the available data on 13 quantitative characters in two distinct groups of material from Africa and India.

From the pattern of frequency distribution of accessions into distinct classes for various characters under study; it appeared that the African germplasm was more evenly distributed and better represented in all classes compared to Indian germplasm. The absence of representation in certain class intervals especially in higher ranges of Indian germplasm for characters such as plant height (Fig 1), culm thickness (Fig 2), leaf number (Fig 4), flag leaf length and width (Fig 5, 6), peduncle length (Fig 7), finger number per ear (Fig 8), finger length (Fig 9), days to 50% flowering (Fig 11), grain yield (Fig 12) and 1000 grain weight (Fig 13) was most evident. However, large number of Indian accessions was found figuring around mean values and/or skewed towards the positive side. This broadly suggested two things,
(1) African germplasm exhibit wider range of variability for several characters compared to Indian germplasm.

(2) The Indian germplasm inspite of showing narrow range have higher mean values because of larger concentration of accessions around mean or positive side of mean.

Many of the above characters are having agronomic significance and selection has been practiced. So, there is a possibility of greater human intervention in India to select favorable types to suit the specific climatic region and cropping pattern need. When viewed from economic angle, Indian accessions differed somewhat bringing some level of distinctness to them. Unlike, Indian accessions, the African accessions distributed normally. However, for finger length both the continents showed a skewness towards left (Fig. 9), indicating that in nature shorter fingers are more favored. Further, the association of short and broad fingers with yield is discussed elsewhere in this chapter.

The Indian germplasm, by and large were characterized by earliness, narrow and small leaves, medium long, broad fingers, medium plant height, thin stems and moderate to high tillering. On the other hand, African accessions were characterized by longer maturity duration, late flowering, tall, stout in stature, possessing long and broad flag leaves. Hilu and de Wet (1976 a) reported that African accessions were tall, robust and erect whereas low land races were medium in height and erect. He opined that the nearness to equator with associated eco-geographical factors might have favoured the evolution of tall forms in Africa.
In conclusion, it can be stated that between the two continents there was parallelism in respect of certain characters and distinctness in respect of some other characters as far as variability is concerned.

### 5.1.4 Screening of Indian and Afrian Germplasm for Blast Disease.

It is believed that in nature both host and pathogen survived together in a complex equilibrium and neither dominated. So, the wild plants rarely have epidemic diseases. It is well known that in the primary centre of origin, the dominant genes are found for several biotic and abiotic stresses. Keeping this in view in the present study, the African and Indian accessions were screened for blast disease caused by fungus, *Pyricularia grisea*, as this disease is prevalent in all ragi growing regions of the world.

The disease grades for both neck and finger blast were higher in Indian accessions. Only one accession from Tanzania showed resistant reaction for the disease. The African accessions exhibited higher level of resistance and tolerance for blast suggesting greater utility of African germplasm in resistance breeding for blast disease.

**Character associations and path analysis ;**

### 5.2.1. Character Associations

Understanding of the interaction of characters among themselves and with the environment has been of great use in plant breeding. Correlation studies
provide information on the nature and extent of association between any two pairs of metric characters. From this, it would be possible to bring about genetic upgradation in one character by selection of the other of a pair. Grafius (1959) opined that there may not be any gene for yield as such, but operates only through its components. Obviously, knowledge about character associations will surely help to break the genetic barriers of yield.

With a view to determine the extent and nature of relationship prevailing among yield contributing characters, an attempt has been made here to study the character association separately in African, Indian and in the combined set of accessions; both at phenotypic and genotypic levels. In general, the phenotypic correlation co-efficient values were higher than the genotypic values. This indicates that strong intrinsic associations are somewhat masked at phenotypic level due to environmental effect. Higher genotypic correlation values than phenotypic values between pairs of characters have been reported by Johnson et al. (1955) in soyabean, Agarwal et al. (1967) in wheat, and Gangaprasad (1988) in proso millet. The higher genotypic values whenever observed are contributed to the relative stability of the genotypes (Davis et al. 1961 and Carlson and Moll, 1962).

In the study of character associations of the 13 characters considered 9 characters showed highly significant correlation with yield, in both African and Indian germplasm. The important characters positively and significantly influencing yield were days to 50% flowering, finger length, flag leaf length and width, plant height and number of leaves. Contrary to expectation the character
productive tillers which showed strong positive association with yield in African germplasm did not show any relationship in Indian and combined set. On the other hand, finger width significantly influenced seed yield suggesting that Indian germplasm is a good source of diversity for improving finger width.

At genotypic level, only a limited number of characters number of characters – culm diameter, days to 50% flowering and 1000 grain weight showed positive significant association with yield. The relationship of culm diameter on yield was highly significant but negative especially in the Indian accessions as it affected productive tillers negatively and significantly. But, association of culm diameter with number of leaves, flag leaf length and width, and days to 50 % flowering was significant and positive. Character association similar to above have been reported earlier in finger millet – Rao and Pardasarathi (1968 b) observed correlation of yield with leaf number, Chaugale et al. (1982) and Shashidhar et al.(1989) with biomass and harvest index; Sastry (1982) with stover weight, Shanthakumar (1988) with ear weight and Subramanion et al. (1977) and Shanthappa (1980) with 1000 grain weight. The results indicated that yield increased whenever there was increase in plant height, culm diameter, 1000 grain weight, finger width and length. These can be considered as a criteria for selection for higher yield especially both in African and Indian accessions as these characters were mutually and positively associated with seed yield.

Besides positive association with yield, the characters plant height and culm diameter showed significant positive association with most other characters.
However, the association of culm diameter with productive tillers and days to 50 per cent flowering was negative and significant. These findings agree with the earlier reports of various workers. The positive association of various characters with yield reported earlier were days to flowering (Patnaik, 1968), days to maturity (Dhagat et al. 1972), Abraham et al. (1989), plant height (Dhagat et al. 1972), Mahudeswaran and Murugesan, 1973, Goud and Lakshmi 1977, Ravikumar 1988, Culm diameter (Mchizuki et al. 1979), tiller number (Samathvam, 1961), Rao and Paradasarathi, 1968a, Chaudhari and Acharya, 1973, Raj et al. 1973, Goud and Lakshmi, 1977 and Subramanian et al 1977, Shanthappa 1980, Ravikumar 1988, Shanthakumar 1988, Abraham et al. 1989), finger number and length (Rao and Paradasarathi 1968 b, Subramanian et al. 1977, Shanthakumar 1988, Ravikumar 1988). However, Ravikumar (1988) observed negative association between yield and days to 50 per cent flowering. Similarly, Agloia et al. 1979) reported negative association between days to maturity and seed yield. Both the characters, days to 50 per cent flowering and days to maturity were negatively associated with spikelet density, grain density and recovery percentage. The positive association of yield with days to 50 per cent flowering in the present study implies a limitation of combining yield with early maturity. Further, productive tiller number, plant height flag leaf length and width, and finger length can be used as selection criteria as these characters are directly and positively associated with yield.

It is evident from the foregoing discussion that in both Indian and African accessions, the association of grain yield with other characters was more or less similar although the relative strength between different characters in Indian and
African accessions differed. The character productive tiller which showed strong positive association in African finger millet did not show similar association in Indian accessions and *vice versa* for finger width. So, it may be possible through hybridization between African and Indian finger millets to alter and reconstruct genotypes with combination of more number of characters having stronger association with yield and thereby achieve higher yield levels.

### 5.2.2 Path Co-efficient Analysis:

The correlation co-efficient measures the relationship existing between pairs of characters. But, a dependant character is an interaction product of many mutually associated component characters and a change in any one components will disturb the whole network of cause and effect system. The path co-efficient analysis, a statistical device developed by Wright (1921), which takes into account the cause and effect relationship between the variables is unique in partitioning the association into direct and indirect effects through other independent variables to yield or any such dependant variable. The path co-efficient analysis also measures the relative importance of casual factors involved. This is simply a standardized partial regression analysis, wherein total correlation value is sub divided into a casual scheme. Li (1956) emphasized the importance of path diagram which facilitates the understanding of the nature of cause and effect system. In the present study, the path co-efficient analysis was done at genotypic level separately for African, Indian and combined set of accessions taking thirteen characters and the results are discussed below.
Direct and Indirect effects of yield components on yield

The study of contribution of various yield components to final seed yield in different sets of germplasm – African, Indian and combined set - revealed certain similarities and differences in the direct and indirect effects on yield.

By and large in all the 3 sets of germplasm, two characters namely days to 50 per cent flowering and 1000 grain weight commonly figured exerting high positive direct effect on yield though there were differences in the relative strength in different sets of germplasm. Closer scrutiny of results further revealed that in Indian sub set, no other character directly influenced yield in a substantial way except to some extent productive tillers and finger length. However, there was fair degree of indirect effect of number of leaves, and flag leaf width through culm diameter on yield. The culm diameter also showed fairly large indirect but negative effect through days to 50 % flowering.

In African germplasm, in addition to days to 50 % flowering and 1000 seed weight, two more characters culm diameter and productive tillers influenced yield through their direct positive effects. In fact, the direct positive effect of culm diameter on yield was the highest followed by 1000 grain weight. Seed yield in African collections was also indirectly influenced by number of leaves through flag leaf length, flag leaf width and culm diameter.

The direct effects of number of leaves, finger width and peduncle length on yield were negative and fairly large.
In the combined set also flag leaf width in addition to 1000 grain weight and days to 50% flowering exerted large positive direct effect on yield. However, the direct effect of number of fingers on yield was highly negative. The other characters exerting limited direct effects were, culm diameter, productive tillers and finger length. But culm diameter also indirectly and negatively affected yield through days to 50% flowering and 1000 grain weight in a substantial way and to a lower extent through number of fingers.

The above observations of the present study is by and large in conformity with several earlier studies on Path analysis. The direct role of productive tillers, grain weight and finger length on yield is well known (Prabhakar and Prasad 1983; Ravikumar 1988; Dhanakodi 1988; Chaudari 1989; Reddy et al. 1994 and Shanthakumar and Gowda 1997).

The significant finding of the present study being that characters contributing directly to yield differ in Indian and African germplasm. In Indian subset only two characters such as days to 50 per cent flowering and 1000 seed weight showed high positive direct effect. On the other hand, in African subset culm diameter and productive tillers in addition to 1000 seed weight and days to 50% flowering directly contributed to the yield. Such differences in two different sets of germplasm is obvious as the nature and direction of selection while selecting varieties have been different. In Indian germplasm breeding and selection for earliness has been important in order to escape late season drought and this might be the reason for larger direct effect on yield. Since the number of characters
directly contributing to yield is more in African germplasm; involvement of African germplasm in recombination breeding might be highly rewarding and this might help in bringing together more characters which directly contributing to yield and productivity.

5.3. Genetic divergence in Indian and African germplasm:

Quantification of genetic diversity existing within and between groups of germplasm is important and particularly useful in proper choice of parents for realizing higher heterosis and obtaining useful recombinants. Several methods have been advocated by various workers to estimate the genetic divergence in crop plants (Murthy and Quadri, 1966; Bhatt, 1970; Hussaini, 1973, Hilu and de Wet, 1976b). Of the several methods available, Mahalanobis’ generalized distance estimated by $D^2$ statistic (Rao 1952) is a unique tool for discriminating populations considering a set of parameters together rather than inferring from indices based upon morphological similarities, eco-geographical diversity and/or phylogenetic relationships.

The antiquity of finger millet cultivation in Africa and India and vast spatial isolation of these two continents suggests that some racial differentiation might have taken place bringing distinction in African and Indian finger millet as the gene flow and migration are not frequented between the two groups. The earlier studies by Hussaini (1973), Kempanna (1975), Hilu and De Wet (1976b), Swamynath (1978), Seetharam (1983) and Naik et al. (1993) are suggestive of distinction in morphological variation in the finger millet of African and Indian origin. In the
present study for quantifying diversity in a cross section of 140 African and 149 Indian accessions of finger millet, 13 morphological characters were considered and their fitness was assessed by using the concept of Mahalanobis’ generalized distance ($D^2$).

The range of $D^2$ values (15.00 to 5579.61) in African and (13.72 to 4431.86) in Indian accessions indicated the availability of extreme diversities in both the groups of material. Nevertheless, the African accessions exhibited relatively more diversity than Indian accessions. Based on $D^2$ values the accessions segregated into thirteen, fifteen and sixteen clusters in African, Indian and Combined set of accessions respectively, when Tocher’s method (Rao 1952) of grouping was adopted for forming clusters.

The clustering pattern in the combined set showed the joint presence of Indian and African accessions in 10 out of 16 clusters formed. In other words, the entries did not remain isolated as separate entities representing the diversified geographic regions of their origin but grouped in clusters possessing entries from heterogenous origin. Such an overlapping of African and Indian accessions was seen in clusters I to X (Table 46). This may be due to the existence of similar ecological niches from where these accessions might have been collected. Such a congregation accessions from different geographical areas in the same cluster has been reported by many workers [Arunachalam and Ram 1967; Mehndiratta and Sidhy 1972; Govil and Murthy 1973 and Nath et al. 1985] in sorghum, Sinha et al. 1977, Kanwal et al 1983; Ratho 1984; Pande and Gorai 1987; De and Rao 1987 in rice; Jain et al. 1981;
and Shimizu et al. 1983 in ragi; Sheriff 1984, in foxtail millet and Siddaraju 1990 in proso millet. It is generally opined that even the temperature, rainfall and cropping pattern could influence the plant characters in the absence of gene exchange and migration.

The study of generalized distance ($D^2$) among African and Indian accessions separately also brought out the overlapping of accessions from different countries or states in different clusters. Ten clusters, viz., Cluster I, II, III, IV, V, VI, VII, VIII, IX and X out of the total thirteen clusters formed in African accessions showed overlapping of accessions of different countries. In Indian material also twelve clusters viz., I, II, III, IV, V, VI, VII, VIII, IX, X, XI and XII out of the fifteen clusters formed, included accessions from different states. Another reason attributed for coming together of entries from different geographical regions in the same cluster is unidirectional selection practiced by plant breeders of different locations (Singh and Bains 1968). But, Murty and Arunachalam (1966) were of the opinion that such wide adaptability would be possible due to factors like heterogeneity, genetic architecture of populations, past selection history, developmental traits and degrees of general combining ability. It appears that varieties having same geographical origin might differ and may possess wide divergence factors, since rapid ecotype differentiation will be taking place even in the absence of reproductive isolation (Bennet 1970).

The inclusion of accessions from different regions in one and the same cluster indicates the absence of discernable relationship between genetic and
geographic diversity. The grouping of varieties of different geographic origin in the same cluster could also be expected because of the free exchange of material from one region to another in the past, at least in Indian sub-continent. Arunachalam and Ram (1967) and Govil and Murthy (1973) in sorghum; Sheriff (1982) in foxtail millet and Naik et al. (1992) in finger millet; observed similar overlapping of accessions from different areas in the same cluster.

It was noted in the clustering pattern of the combined set, 3 clusters, Viz. Cluster XI, XII and XIII were exclusively African and 3 clusters XIV, XV and XVI were exclusively Indian. This suggests that some of the African and Indian accessions are distinct from one another. It is possible that these accessions have been probably confined to a narrow geographical area having a distinct ecology and such long temporal and spatial isolation might have given them distinctness in specific attributes making them vastly different from the rest. Similar clustering pattern was observed by Hussaini (1973) in African finger millet.

A few accessions in the present study formed solitary clusters. The formation of solitary clusters may be due to total isolation preventing the gene flow or intensive natural/human selection for diverse adaptive gene complexes. Three each of such clusters were seen in African subset (XI, XII and XIII) and Indian sub set (XIII, XIV and XV). The accessions of solitary clusters in African set came from Tanzania (GE 5004); Burundi (GE 5016); and Muzambique (GE 5015). Similarly in Indian set they were from Punjab (GE 305), Rajasthan (GE 329) and Uttar Pradesh
Thus, it is obvious that these accessions distinctly differ for one or more morphological characters from the rest.

**5.3.1 Intra – Cluster and Inter Cluster Distances :**

The intra – cluster distances in any cluster was less than the inter cluster distance even between the two closely related clusters (Tables 41, 43 and 45). The range of inter cluster distances of African clusters (17.1 – 62.2) was relatively more than Indian clusters (16.4 - 58.5) indicating the higher presence variability in the former.

The number of accessions in each cluster and their composition vastly varied. It was from 1-30 in African set; 1-37 in Indian set and 3-48 in the combined set. It was also evident from the distribution of accessions, That accessions coming from one country/state were found in many clusters. For eg. in African set, Zambian accessions were found in 7 out of 13 clusters formed followed by Zimbabwe and Ethiopia in five clusters each and Kenya and Uganda and Tanzania in 4 clusters each. Similarly in Indian set, the germplasm of Madhya Pradesh and Orissa were found distrituted in 6 clusters each out of 15 clusters followed by Karnataka and Uttar Pradesh each in 5 clusters and TamilNadu germplasm in 4 clusters. Such wide distribution of accessions of one region in many clusters reflects the large diversity present in them and these regions being likely hotspots for diversity become preferred regions for further collection.
The farthest clusters in African set were I and X, VII and X, and III and XIII. Similarly in Indian set the farthest clusters were VII and XIII, VII and XV and VII and XI. Generally the farthest clusters were formed by solitary or a fewer number of accessions. But, the clusters having farthest intercluster distances are supposed to be more diverse than the closer clusters.

In general, the inter-cluster spatial pattern was not consistent with the geographical distribution of accessions. However, the African accessions were more randomly distributed across the clusters in the combined set compared to Indian accessions. The Indian accessions belonging to divergent and distant ecological regions clustered together. Such a grouping of genotypes from different locations has been attributed to the free exchange of breeding material from one location to another (Verma and Mehta, 1976) and/or due to the unidirectional selection practiced by breeders of different locations (Singh and Bains, 1968). It was also noted that the accessions from one geographic or ecological region were found scattered in different clusters. Geographical diversity may not always be related to genetic diversity (Timothy 1963 in maize and Arunachalam and Ram 1967 in Sorghum). Furthermore, the Indian finger millets has been subjected to more of intense human selection than African material.

It may be summed up that large genetic diversity exists in both groups of African and Indian germplasm selected for this study for almost all the important characters. This suggests that finger millet germplam of both regions are required in crop improvement. The two groups have characters mostly over lapping but
distinct and differing for a few attributes of breeding value. The involvement of African germplasm in Indian breeding programmes and vice versa will be surely rewarding.

The choice of parents is of paramount importance for making progress in plant breeding programmes. Selection of parents based on the extent of genetic divergence has been rewarding in different crops (Moll et al, 1962; Murthy and Arunachalam, 1966 and Bhatt 1970). In the present study, it was observed that considerable amount of genetic diversity is present in Indian and African finger millet for yield and yield attributes. The accessions from Africa and India do differ for certain key characters in spite of overlapping in many characters. The accessions in solitary clusters appear to be distinct from the rest and might be useful in breeding.

5.3.2 Identification of promising germplasm:

One of the objectives in the present study was to identify promising accessions in both sets of germplasm for possible utilization in crop improvement programmes. After careful scrutiny of material in the field as well as data, a couple of accessions showing superior performance for yield and important yield attributes such as short plant height, higher number of productive tillers, more fingers, long fingers, early flowering and high grain yield have been identified (Table 47). They could be used in recombination breeding programmes.
Table 47: Promising germplasm accessions of both Indian and African origin for different characters

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Characters</th>
<th>Accession Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Plant height (≤ 60cm)</td>
<td>Short: GE 5015 (43.5), GPU 26 (53.2), GE 4764 (54.5), GE 580 (59), GE 5016 (59.8).</td>
</tr>
<tr>
<td>2.</td>
<td>More Productive tillers (≥ 7)</td>
<td>GE 172(7), GE 210(7), GE 304(7), GE 314(7), GE 618(7), GE 4678 (7), GE 4914 (7), GE 5012(7), GE 5027(7), GE 5032 (7), GE 5039 (7), GE 357(8), GE 5122(9).</td>
</tr>
<tr>
<td>3.</td>
<td>More Fingers (≥ 10)</td>
<td>GE 140(10), GE 583(10), GE 810(10), GE 894(12), GE 1035(10), GE 4715(10), GE4889(12).</td>
</tr>
<tr>
<td>4.</td>
<td>Long Fingers (≥ 10cm)</td>
<td>GE 262(10), GE 4682(12), GE 4809(10), GE 4833(10), GE 4841(11), GE 4859(11), GE 4894(10).</td>
</tr>
<tr>
<td>5.</td>
<td>Earliness (≤ 50 days to flowering)</td>
<td>Early: GE 313(45), GE 753(46), GE 157(47), GE 305(48), GE 362(48), GE 469(48), GE 833(48), GE 1045(48), GE 1050(48), GE 1582(48), GE 302(49), GE 544(49), GE 840(49), GE 894(49), GE 1009(49), GE 68(50), GE 847(50).</td>
</tr>
<tr>
<td>6.</td>
<td>Yield per plant (≥ 20g)</td>
<td>GE 342(21.8), GE 4670(21.8), GE 156(22.8), GE 256(23.8), GE 294(24.3), GE 141(34.4).</td>
</tr>
</tbody>
</table>
|   | Neck blast immune  
|   | Neck blast resistant  
|   | (0.0 to 2.0 %)  | GE 2, GE 112, GE 139, GE 202, GE 210, GE 314, GE 329, GE 358, GE 461, GE 565, GE 4724. |
|   | Finger blast immune  
|   | (0.0 %)            | GE 152, GE 156, GE 220, GE 256, GE 4765, GE 4785, GE 4859, GE 4864, GE 4865, GE 4990, GE 4902, GE 4913, GE 4914, GE 4915, GE 4922, GE 4927, GE 4928, GE 4951, GE 4952, GE 4966, GE 4968, GE 4969, GE 4977. |
|   | Finger blast resistant  
|   | (0.0 to 2.0 %)  | GE 170, GE 172, GE 174, GE 210, GE 412, GE 833, GE 1580, GE 4722, GE 4905, GE 4909. |