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ESTIMATION OF GENETIC VARIABILITY IN TURMERIC (*CURCUMA LONGA* L.) GERMPLASM USING AGRO-MORPHOLOGICAL TRAITS

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Abstract

Turmeric is an important medicinal plant and cultivated spice crop in Pakistan. The present study was conducted to determine the extent of genetic variation and relationship among turmeric genotypes using 21 qualitative and quantitative traits. A total of 20 genotypes collected from three eco-geographical areas (Bannu, Haripur and Kasur) of turmeric cultivation in Pakistan were studied under field conditions. In qualitative trait light green leaf color, light orange yellow rhizome color and greenish white flower color were found in abundance in most of the genotypes. The leaves, rhizomes and flowers of turmeric plants collected from Bannu and Haripur were light green, yellow and yellowish-white in color, while those of Kasur area were dark green, dark orange and whitish green in color, respectively. A considerable level of variability was displayed by various genotypes for some of the quantitative traits measured. Pattern of variation among the genotypes was different for different agro-morphological traits. The largest variation was observed for plant height, leaf length, leaf width, total and fresh number of leaves, whereas relatively, a low level of variability was detected in most of the remaining quantitative traits. Agro-morphological data was also analyzed by numerical taxonomic techniques using two complementary procedures: cluster and principal component analysis (PCA). Phenogram based on Euclidean distance coefficients placed 20 genotypes into two main clusters with three sub-groups in the 2nd cluster. Genotypes groups were primarily associated with morphological differences among the collections and secondly with the consumer preference and horticulture use. Principal component analysis re-ordered genotypes into four broad groups that had within cluster similarities and inter-cluster morphological variation. Our study revealed that the evaluated germplasm of turmeric appeared to have narrow genetic base which underwent high level of genetic erosion and selection pressure. This is perhaps due to the use of same ancestors and similar seed source by the farmers for cultivation of crop in selected areas of the country. However, this preliminary study of traditional turmeric landraces from Pakistan provided useful information regarding their horticultural and medicinal potential. The given method of analysis may be helpful in selecting diverse parents and broadening local germplasm base of turmeric for future breeding programs.

Introduction

In the present age of great scientific strides, recognition of the importance of horticultural crops is increasing tremendously, particularly because of new discoveries regarding their hidden properties of dietary and medicinal significance. International literature is increasingly recognizing the importance of various spice crops, especially turmeric for various extraordinary characteristics that it has. Vavilova (1990) reported that the powdered roots of turmeric have been used for making a deep yellow dye for fabrics for hundreds of years, though it does not produce an enduring color-fast tint. It is also used as a coloring material for medicines at times. Turmeric plays an important role in food industry, where this has been conquering the world market as a solution for the substitution of synthetic coloring, besides being used for its medicinal and pharmacological qualities (Scartezzini & Speroni 2000).

Turmeric (*Curcuma longa*) is a plant of the family Zingiberaceae commonly known as ginger family and comprises about 70 species (Smart & Simmonds, 1992). Due to the lack of a comprehensive taxonomic revision, there is still little consensus on the number of species that should be recognized. India is the major producer, consumer and exporter of turmeric in the world. It is found throughout south and south-east Asia with a few species extending to Australia, China and South-Pacific. The highest diversity is concentrated in India and Thailand, with at least 40 species in each area, followed by Burma, Bangladesh, Indonesia and Vietnam. In Pakistan, turmeric is mainly cultivated in Bannu, Haripur and Pubbi area of Khyber Pakhtunkhwa and Kasur, Okara and Sahiwal areas in Punjab province (Daod & Aslam, 1996).

Turmeric has attracted much attention due to its significant medicinal potential (Cousins *et al*., 2007). A compound Curcuminoid, present in turmeric acts as inhibitor of human immune deficiency virus type1 (HIV-1) integrase (Mazumder *et al*., 1995). Turmeric oil is composed of several monoterpene and sesquiterpene compounds such as zingiberene, ar-turmerone and turmerone (Apisariyakul *et al*., 1995). The main biological activities of the oil are carminative, anti-flatulence, antifungal and as an anti-platelet agent (Lee, 2006). Turmeric has been used in traditional medicine as a household remedy for various diseases, including biliary disorders, anorexia, cough, diabetic wounds, hepatic disorders, rheumatism and sinusitis (Ammon *et al*., 1992). In old Hindu medicine, it is extensively used for the treatment of sprains and swelling caused by injury (Ammon & Wahl, 1991). In addition to helping cure some common diseases, turmeric also showed some medicinal properties for the treatment of snake bites (Ratanabanangkoon *et al*., 1993) and as antitumor (Baatout *et al*., 2004). Turmeric also demonstrated

antifungal properties (Afaq *et al*., 2002). It has been reported to possess anti-inflammatory, hepatoprotective, antitumor, antiviral activities (Ammon & Wahl, 1991) and anticancer activity (Polasa *et al*., 1991). The World Health Organization has recommended the use of this spice (Vavilova, 1990). From Pakistan such information has been compiled and reported by Gilani *et al*., (2010) and Shinwari (2010).

In order to conserve the genetic resources and get consistent variability, genetic studies involving morphological and molecular markers are used to detect relationship and genetic variation among germplasm (Jatoi *et al*., 2006; Jan *et al*., 2011). Few studies on morphological and anatomical characterization of *Curcuma* species and cultivars have been attempted, not much has been done on molecular level (Sasikumar, 2005). Genetic composition of *Curcuma longa* species need to be assessed for efficient maintenance and conservation. Up-to-date there has been no previous report on the use of these methods to elucidate the genetic diversity of *Curcuma longa* in various eco-geographical zones of Pakistan. Objective of this study was to evaluate the pattern of genetic variability and relatedness among various genotypes of turmeric collected from selected areas of Pakistan using agro-morphological traits at intra-specific level. Data will be useful for the sake of efficient management and differentiation of various landraces. It would also be helpful for plant breeders to select readily varied parents which will add new germplasm base for turmeric breeding program in the future.

Materials and Methods

Plant material: Plant materials comprised of 20 genotypes of *Curcuma longa*, collected from different areas of Pakistan. Fresh plants of all genotypes comprising three populations were used in present study for comparison collected from Bannu, Haripur and Kasur, covering almost three ecological zones of turmeric growing area in Pakistan (Table 1).

Table 1. Collection of indigenous turmeric genotypes from selected areas of Pakistan.

Population	No. of genotypes	Genotype code	Area of collection
1.	12	B1 to B12	Bannu district, KPK
2.	5	H1 to H5	Haripur district, KPK
3.	3	K1 to K3	Kasur district, Punjab

Agro-morphological characterization: The sampling was done from September 2009 to February 2010. The research work comprised of two phases conducted under field and laboratory conditions. All the 20 genotypes were characterized for three qualitative and 18 quantitative traits from flowering till maturity and harvest of the crop. Qualitative traits included leaf, rhizome and flower color, whereas quantitative traits comprised of plant height (cm), leaf length (cm), leaf width (cm), leaf petiole length (cm), total leaves number, fresh leaves number, dry leaves number, bract length (cm), bract width (cm), spike length (cm), spike width (cm), peduncle length (cm), ligule length (cm), rhizome length (cm), rhizome width (cm), rhizome branches number, rhizome nodes number, and corolla tube length (cm). Trait selection and measurement techniques were based on standard descriptors for turmeric.

Data analysis: Data were subjected to simple statistical analysis for all the quantitative traits to assess the amount of genetic variation. All recorded morphological traits were also analyzed by numerical taxonomic techniques using principal component analysis (PCA) and cluster analysis (Sneath & Sokal, 1993). To avoid effects due to scaling differences, means of traits were standardize prior to cluster and principal component analysis using Z-scores. Estimates of Euclidean distance coefficients were made for all pairs of genotypes. The resulting Euclidean dissimilarity coefficients were used to evaluate the relationship among the entries with a cluster analysis using complete linkage method NTSYSpc version 2.01 (Roulf, 2002). PCA was also performed with the same data matrix. Scattered plots of first three principal components were produced to provide a graphical representation of the pattern of variation among all the genotypes of turmeric (Statistica, version 6.0).

Results

Genetic diversity based on qualitative and quantitative traits: The turmeric genotypes showed morphological differences in leaf, flower and rhizome color of Bannu, Haripur and Kasur population. The leaves of turmeric plants collected from Bannu and Haripur were light green in color, while leaves of turmeric collected from Kasur area were dark green. Differences in rhizome color were also interesting. Turmeric rhizomes collected from Bannu and Haripur were yellow, while that of Kasur were dark orange in color. Similarly, turmeric flowers collected from Bannu and Haripur were yellowish white, whereas those of Kasur were whitish green in color (Table 2). All others qualitative traits for each turmeric genotypes from three populations remained the same. A considerable level of polymorphism was displayed by various genotypes for some of the quantitative traits measured. Germplasm differed in many traits of agronomic importance including plant height, leaf length, leaves number, etc. Basic statistics for various quantitative traits is given in Table 3. Pattern of variation among the landraces was different for different agro-morphological traits. The largest variation was observed for plant height, leaf length, leaf width, total and fresh number of leaves. The variances for the said traits were 133.3, 37.1, 5.5, 8.6 and 4.2, respectively. Relatively, a low level of variability was detected in most of the remaining quantitative traits. Coefficient of variation (CV%) ranged from 9.1 to 53.2% for various traits. The highest coefficient of variation was observed for number of dry leaves of 20 genotypes, while the lowest level was showed by spike width of germplasm. Based on quantitative traits turmeric genotypes showed variation in plant height, leaf length, but as they were collected from different geographical areas have different environmental conditions so these variations are special.

Table 2. Agro-morphological study of turmeric genotypes based on qualitative traits.

Genotype	Leaf color	Rhizome color	Flower color
B1-B12	Light green	Light orange yellow	Yellowish white
H1-H5	Light green	Light orange yellow	Yellowish white
K1-K3	Dark green	Dark orange yellow	Greenish white

Table 3. Basic statistics for 18 quantitative traits of turmeric genotypes characterized under field condition.

Trait	Mean	Minimum	Maximum	SD	CV(%)	Variance
Plant height (PH)	90.5	70.0	110.0	11.5	12.8	133.3
Leaf length (LL)	45.8	35.0	57.0	6.1	13.3	37.1
Leaf width (LW)	12.6	9.0	18.0	2.3	18.6	5.5
Leaf petiole length (LPL)	6.2	5.0	8.0	0.7	11.2	0.5
Total leaves (TL)	11.9	7.0	17.0	2.9	24.7	8.6
Fresh leaves (FL)	9.4	6.0	13.0	2.1	22.0	4.2
Dry leaves (DL)	2.6	0.0	5.0	1.4	53.2	1.8
Bract length (BL)	6.5	5.0	8.0	0.9	13.3	0.7
Bract width (BW)	4.1	3.0	5.0	0.6	14.4	0.4
Spike length (SL)	12.6	10.5	15.0	1.2	9.2	1.3
Spike width (SW)	4.4	3.8	5.0	0.4	9.1	0.2
Peduncle length (PL)	3.6	3.0	4.3	0.5	13.2	0.2
Ligule length (LgL)	2.7	2.0	3.0	0.3	10.6	0.1
Rhizome length (RL)	7.9	6.0	10.0	1.1	14.3	1.3
Rhizome width (RW)	3.1	2.5	3.6	0.3	10.4	0.1
Rhizome branches (RB)	6.1	4.0	7.0	0.9	15.6	0.9
Rhizome nodes (RN)	7.1	5.0	8.0	0.9	12.8	0.8
Corolla tube length (CTL)	1.3	1.0	1.5	0.2	16.4	0.0

Cluster analysis: Phenotypic data of turmeric genotypes were also analyzed by numerical taxonomic technique using cluster analysis. Euclidian dissimilarity coefficients were calculated for all the genotypes of turmeric from their morphological data. Dissimilarity coefficient of 20 genotypes ranged between 2.6 to 12.4 (Table 4). H2 and B5 were the closest genotypes with the lowest dissimilarity index of 2.6 followed by pairs of genotypes 'B10 and B11', 'B5 and B10', 'B5 and B11', 'B8 and B11', 'B4 and B10', and 'B2 and B9' having Euclidean distance of 3.0, 3.1, 3.2, 3.2, 3.3 and 3.4, respectively. Genotypes 'B1 and B12', 'B1 and H3', 'B1 and K2', 'B7 and B12', 'B1 and H1', 'B1 and H5', 'B7 and H3', and 'B12 and K3' exhibited the greatest dissimilarity with Euclidean distances of 12.4, 11.8.,11.7, 10.2, 10.1, 9.6, 9.4, and 9.4 respectively. Most of the genotypes of turmeric from Pakistan had comparatively lower Euclidian dissimilarity among themselves; however they exhibited more dissimilarity indices with course genotypes. Genotypes B1, B12, and H3 exhibited the maximum Euclidian distances of all the other turmeric genotypes used (Table 4).

Table 4. Euclidian distances based on 18 agro-morphological traits showing the variability among turmeric genotypes.

Genotype*	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	H1	H2	H3	H4	H5	K1	K2	K3
B1	0.0																			
B2	8.2	0.0																		
B3	5.5	4.1	0.0																	
B4	8.1	5.6	4.8	0.0																
B5	7.4	4.2	3.8	3.5	0.0															
B6	8.4	5.0	4.6	4.8	5.0	0.0														
B7	4.8	5.7	3.6	5.6	4.6	5.9	0.0													
B8	5.6	5.5	3.7	5.4	4.8	4.9	4.9	0.0												
B9	5.8	4.9	4.3	6.3	5.7	5.9	3.4	4.7	0.0											
B10	6.5	5.1	3.5	3.3	3.1	4.2	4.7	4.0	5.7	0.0										
B11	5.7	4.6	3.7	4.7	3.2	4.9	4.2	3.2	4.8	3.0	0.0									
B12	12.4	7.3	8.5	5.8	6.5	6.1	10.2	8.3	9.9	6.8	7.5	0.0								
H1	10.1	5.7	6.3	4.2	4.7	5.4	8.2	6.6	8.2	4.4	5.9	3.7	0.0							
H2	8.5	4.4	4.7	3.7	2.6	6.0	5.2	6.2	5.8	4.2	4.9	7.1	4.9	0.0						
H3	11.8	5.7	7.5	6.4	5.7	5.8	9.4	7.4	9.1	6.8	6.8	3.6	4.4	6.6	0.0					
H4	8.2	4.4	5.6	4.9	4.4	4.6	5.9	5.6	5.2	4.9	4.2	6.0	5.2	5.3	5.8	0.0				
H5	9.6	5.9	6.8	4.5	4.3	5.1	7.3	6.9	7.6	5.0	5.3	4.6	4.5	5.5	5.3	3.6	0.0			
K1	7.8	5.4	5.5	5.2	5.6	5.1	6.7	4.4	5.4	4.5	4.1	6.6	5.0	6.1	6.7	4.1	6.1	0.0		
K2	11.7	6.2	7.6	5.7	5.2	5.4	8.8	7.7	9.1	6.0	6.7	3.5	4.2	6.0	2.7	5.8	4.3	7.0	0.0	
K3	4.6	6.5	4.7	5.1	5.0	5.9	3.8	4.4	5.2	3.8	4.1	9.4	7.3	6.2	9.3	5.8	6.2	6.2	8.6	0.0

*B1-B12 (genotypes from Bannu, KPK), H1-H5 (genotypes from Haripur, KPK), K1-K3 (genotypes from Kasur, Punjab).

Phenogram based on Euclidian distance coefficients using 18 quantitative traits placed 20 genotypes into two main clusters (Fig. 1). First cluster consisted of a total of four genotypes; three of them belonging to the Bannu (B1, B7 and B9) and a single genotype (K3) from Kasur area. These genotypes were characterized by the tallest plant, large leaf size, longer petiole, greater leaves number, larger bract size, longer spikes, longer rhizomes, the highest ligule length, the highest rhizome branches and nodes, higher corolla tube length, large peduncle length, and with only exception of low corolla tube length in genotype B7. The second cluster comprised of a total of 16 genotypes and could be further subdivided into three sub-groups. First sub-group was composed of seven genotypes, six of them belonged to Bannu (B2, B3, B6, B8, B10, B11), while a single genotype (K1) belonging to Kasur. These genotypes were characterized for longer ligules, higher rhizome length, low rhizome width, lower corolla tube length, high in rhizome branch number, larger in spike width, except low rhizome length in genotype B6 and low ligule length in B2 genotype. Second sub-group of cluster-2 contained a total of five genotypes, two genotypes B4 and B5 belonging to Bannu and three genotypes H2, H4, and H5 belonged to Haripur. They displayed the highest peduncle length, ligule length, rhizome branches number, rhizome width, lower bract width, minimum rhizome nodes number, except lowest corolla tube length in genotype H2 and H5 belonging to Haripur. Third sub-group consisted of four genotypes, B12, H1, H3 and K2 belonging to all three populations of Bannu, Haripur and Kasur. They were characterized by the shortest plant height, the lowest leaf size, petiole length, leaves number, spike length and width, corolla tube length, peduncle length, rhizome nodes number and with the highest rhizome branch number in H1, as well as maximum rhizome node number, and highest corolla tube length in genotype H3. Genotypes groups were primarily associated with morphological differences among the collections and secondly with the horticulture use. Phenotypically most of the genotypes belonging to the three populations were different in some traits therefore they were scattered into separate groups.

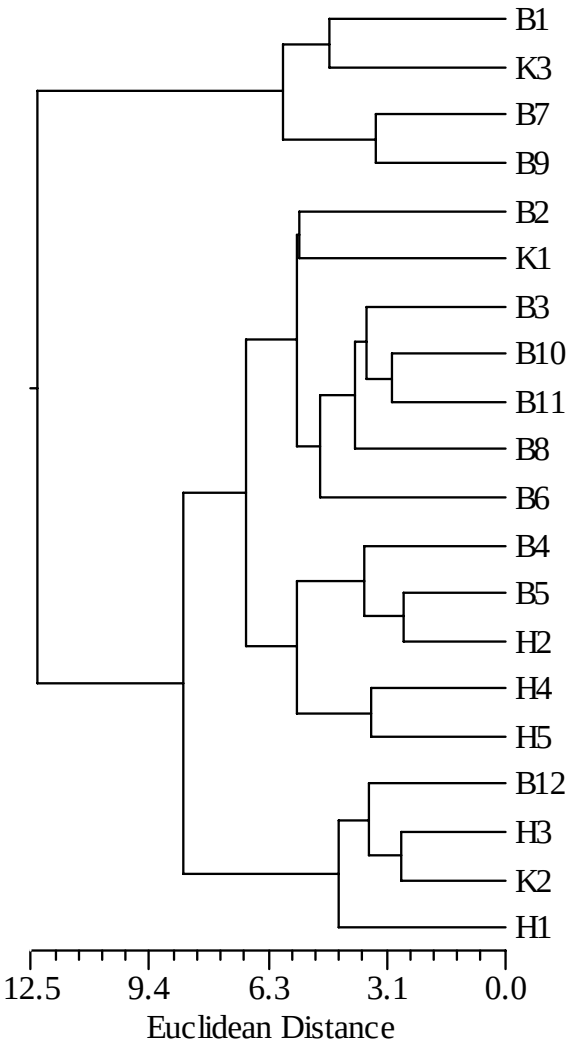

Fig. 1. Cluster analysis showing the relationships among turmeric genotypes using 18 quantitative traits.

Principal component analysis (PCA): The first five principal components (PCs) with eigenvalues greater than one accounted for 87.5% of the variability amongst 20 turmeric genotypes (Table 5). The first principal component (PC1) accounted for 54.7% of total variation. The quantitative traits that contributed more positively to PC1 included plant height, leaf length, leaf width, leaf petiole length, total number of leaves, fresh leaves, dry leaves, bract length, bract width, spike length, spike width, peduncle length, ligules length, rhizome length, rhizome width, rhizome branches number, rhizome nodes number and corolla tube length. Principal component 2 (PC2) had 10.2 % of the total morphological variability. Total leaves number, dry leaves number, bract length, bract width and spike width contributed positively to PC2, whereas peduncle length, ligules length, rhizome length, rhizome width, rhizome branches number and corolla tube length were negatively associated with PC2 (Table 5; Fig. 2). Principal component 3 (PC3) exhibited 9.9% of the total variation in phenotypic traits and was heavily and positively associated with plant height, ligule length, rhizome nodes number and corolla tube length, whereas dry leaves number, peduncle length, rhizome length, rhizome width and rhizome branches number were negatively associated with PC3. The first two PCs were plotted to observe the relationship between 20 genotypes of turmeric (Fig. 3). There was no clear separation of the genotypes in the PCs into different groups. Instead various genotypes of three populations were interspersed and had a wider spread across two principal components. This separation was based on several important morphological differences amongst the turmeric genotypes.

Discussion

To analyze the degree of genetic diversity among indigenous turmeric landraces, twenty genotypes were used as experimental material and were studied for three qualitative and 18 quantitative traits. Qualitative characters are important for plant description and mainly influenced by the natural selection, socio-economic scenario and consumers performance. Some of the *Curcuma* species are well characterized, but others are difficult to distinguish. The overall appearance of many

species of *Curcuma* is very similar as they differ in small morphological details (Sirirugsa, 1996; Padua *et al*., 1999). Light green leaf color was present in 17 genotypes (85%) belonging to Bannu and Haripur, whereas only three genotypes (15%) from Kasur area exhibited dark green leaf color. Syamkumar & Sasikumar (2007) also pointed out dark green and light green color of leaf in turmeric. Breeding for green color of leaf has been suggested as a method of increasing yield in cereal crops. Increasing light penetration into canopy has been suggested as one way of obtaining higher yield. Duncan (1971) showed that increased penetration of light into canopy would increase photosynthetic rate and perhaps enhance yield. Light orange yellow color of rhizome was present in 17 genotypes belonging to Bannu and Haripur, while rhizomes of three genotypes from Kasur were dark orange yellow colored. Such two types of rhizome colors in *Curcuma longa* had also been reported by Syamkumar & Sasikumar (2007). Our findings were also very near to the work of Chaveerach *et al*., (2008) who reported that in *Curcuma zedoaroides* rhizome color externally pale greenish and silver glance, internally pale yellow in dry season and pale green to yellow in rainy season. Greenish white color of flower was present in 17 genotypes (85%) belonging to Bannu and Haripur, whereas only three (15%) genotypes from Kasur area showed yellowish white colored flowers.

Table 5. Variation among turmeric genotypes accounted for first five principal components.

Traits	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
Eigenvalues	9.8	1.8	1.8	1.2	1.0
Cumulative eigenvalues	9.8	11.7	13.5	14.7	15.8
Variance (%)	54.7	10.2	9.9	6.9	5.8
Cumulative variance (%)	54.7	64.8	74.8	81.7	87.5
Traits			**Eigenvectors**		
Plant height	0.939	0.060	0.173	-0.051	-0.114
Leaf length	0.974	0.048	0.074	-0.098	0.001
Leaf width	0.962	0.027	0.040	0.026	-0.032
Leaf petiole length	0.955	0.043	-0.021	0.072	0.011
Total leaves	0.864	0.121	-0.048	-0.300	0.168
Fresh leaves	0.723	-0.029	0.059	-0.579	0.122
Dry leaves	0.774	0.305	-0.193	0.229	0.179
Bract length	0.928	0.109	0.086	0.204	0.029
Bract width	0.865	0.139	0.002	0.329	0.131
Spike length	0.975	-0.011	0.025	-0.115	-0.063
Spike width	0.870	0.180	-0.046	0.117	-0.242
Peduncle length	0.770	-0.157	-0.107	-0.059	-0.123
Ligule length	0.104	-0.439	0.780	0.085	0.158
Rhizome length	0.472	-0.713	-0.236	-0.112	0.024
Rhizome width	0.238	-0.810	-0.335	-0.197	-0.144
Rhizome branches	0.315	-0.488	-0.125	0.716	-0.002
Rhizome nodes	0.027	0.067	0.359	-0.003	-0.880
Corolla tube length	0.059	-0.168	0.873	-0.004	0.207

To analyze the degree of genetic diversity among indigenous turmeric germplasm from Pakistan, twenty genotypes were also studied for 18 quantitative traits. Morphological and agronomical traits of the collected genotypes facilitate in identification and selection for desirable trait (Amanullah & Hatham, 2000). Morphological characterization is considered as first step in the description and classification of crop germplasm (Smith & Smith, 1989). Our findings were similar to the work of Chaveerach *et al*., (2008) who reported that in *Curcuma sattayasaii* and *C. zedoaroides* plant height ranged from 70–100 cm. For crop improvement in turmeric, plant height and number of leaves determines the yield potential of the genotype (Narayanpur & Hanamashetti, 2003). Therefore plant height is the single most important morphological character on which selection for yield could be made. Reduction in plant height may improve their resistance to lodging and reduce substantial yield losses associated with this trait (Abbasi *et al*., 1995). A breakthrough in plant breeding was attained with the development of semi-dwarf cultivars characterized by lodging resistance, nitrogen responsive and erect leaves. The success of the green revolution is directly related to the intensive use of these dwarf varieties (Hirano *et al*., 1992). The semi dwarf plant type has been extensively utilized in the improvement of crop cultivars throughout the world.

Our results were very near to the work of Chaveerach *et al*., (2008) who reported 30-50cm long leaf sheaths in *Curcuma sattayasaii*, while 25-40cm long and green leaf sheaths in *C. zedoaroides*. They also reported similar results in *Curcuma sattayasaii* leaf blades which ranged between 30-45×7-13 cm, while in *C. zedoaroides* 70-100×15-18 cm in length. Rattan *et al*., (1988) reported that multiple regression analysis using morphological characters indicated that the final yield of ginger could be predicted by taking into consideration of plant height, number of leaves and breadth of last fully opened leaf at 90^{th} and 120^{th} day after planting. Chaveerach *et al*., (2008) reported that in *Curcuma sattayasaii* petiole length ranged between 15 and 35cm, while in *C. zedoaroides* petioles ranged from 8 to 12cm long or more and was similar to our findings.

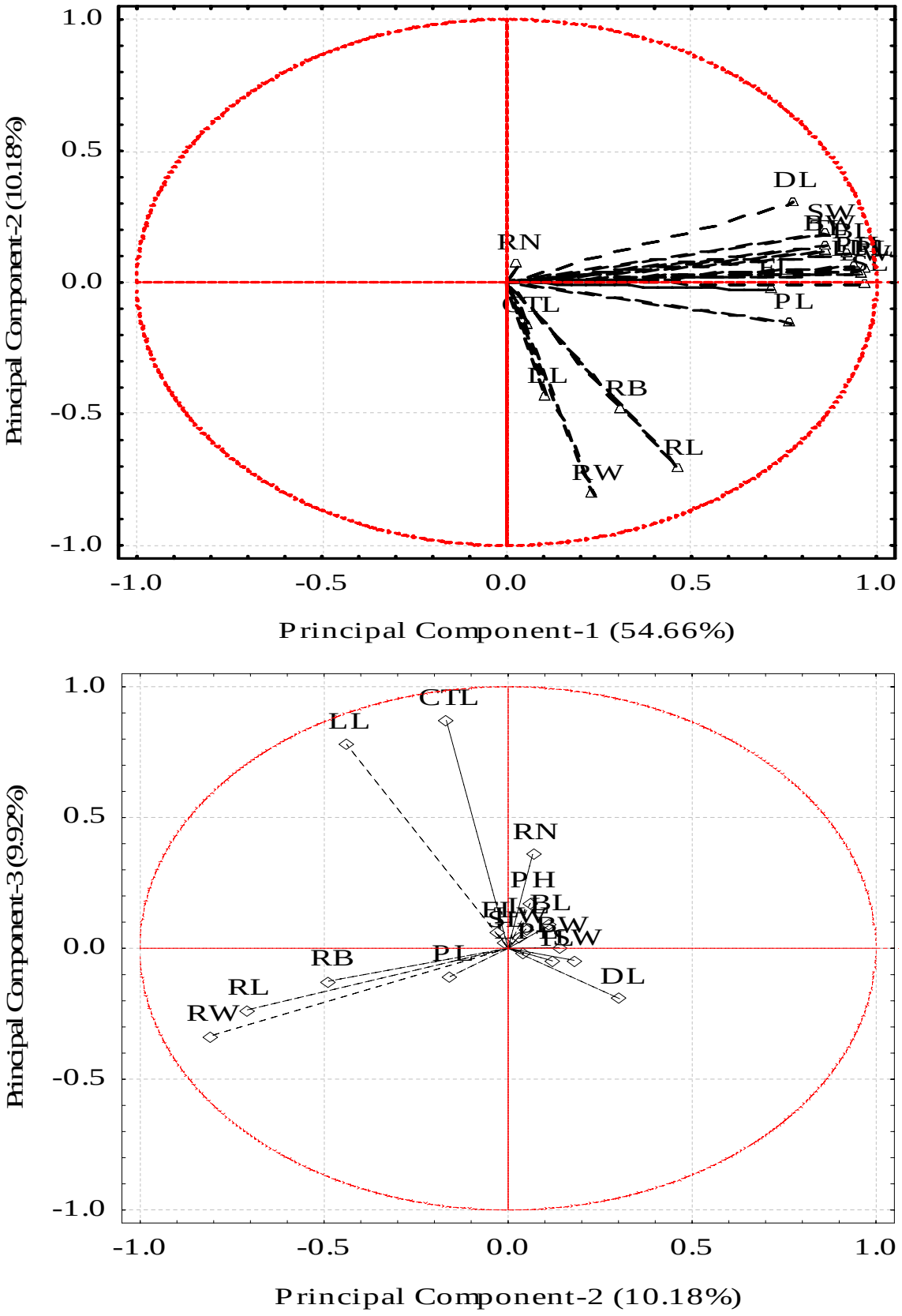

Fig. 2. Scattered diagrams of first three principal components showing the contribution of various traits in the separation of various genotypes of turmeric from Pakistan.

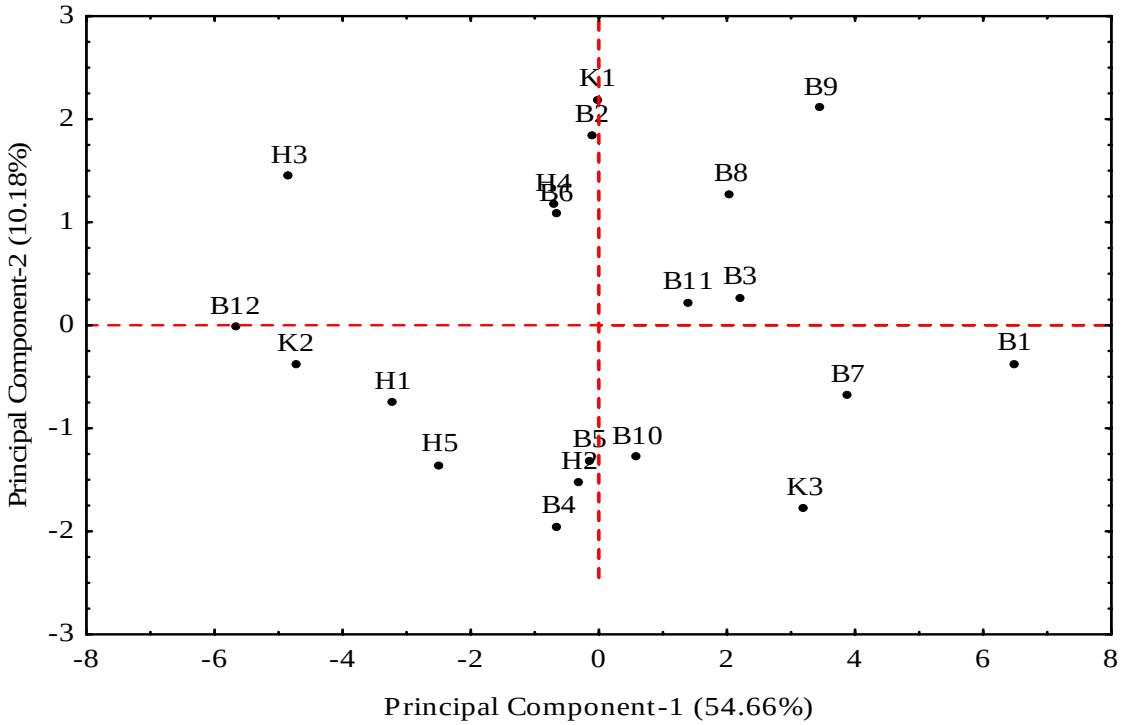

Fig. 3. Scattered diagram of first two principal components based on mean values of 18 quantitative traits in 20 genotypes of turmeric from Pakistan.

High heritability with appreciable genetic advance was reported for turmeric rhizome yield, crop duration, number of leaves, number of primary fingers, yield of secondary fingers and plant height (Yadav & Singh, 1996). The morphology of *C. domestica* [*C. longa*] from Tanegashima (Japan), Taiwan, Indonesia and Java were compared, and *C. domestica* was also compared with *C. zedoaria*. In the appearance from Tanegashima and Indonesia, there were correlations between the leaf number and the weights of above or below ground parts or weight of the main tuber (Aoi, 1992). Our findings were very similar to the work of Chaveerach *et al*., (2008) who reported that in *Curcuma sattayasaii* and *C. zedoaroides* bract size ranged between 4-5 ×3.2-3.5cm and 4.2-5×3.2-3.5 cm, respectively. Preter (2001) also reported same range of 10 to 15cm of spike length in turmeric. Our results were very near to the work of Chaveerach *et al*., (2008) who reported that in *Curcuma sattayasaii* inflorescence length ranged between 16 and 17cm, while in *C. zedoaroides* it varied from 15 to 18cm. Similar to our results, Chaveerach *et al*., (2008) also reported 30-31cm longer peduncle in *Curcuma sattayasaii*. Similar to our findings, Chaveerach *et al*., (2008) reported very short ligules in *Curcuma sattayasaii*, ranging between 2–3 mm long, while in *Curcuma zedoaroides* it was also very short, 2-3 mm long, which was contrary to our findings. The rhizome of turmeric is fleshy, oblong, tapered at either end, and from 5 to 10 centimeters (2-3 inches) in length and about 2.5 centimeters (1 inch) wide (Schonbeck & Frey 2005). Our findings were similar to the work of Chaveerach *et al*., (2008) who reported that in *Curcuma sattayasaii* main rhizome ranged from 8-10cm long and 1.5-2.5cm in diameter, secondary rhizome cylinder 1.0-1.5cm in diameter, horizontal, externally brownish yellow, internally deep orange-yellow, and fragrant, while in *C. zedoaroides* primary rhizome ranged from 10-12×3-5cm, while secondary rhizome, 8-10×2.5-3cm in length. Chaveerach *et al*., (2008) reported similar findings that in *Curcuma sattayasaii* and *C. zedoaroides* corolla tube ranging between 2.0-2.3cm in length.

Our study revealed that the evaluated genotypes of turmeric germplasm appeared to have narrow genetic base which have undergone high level of genetic erosion and selection pressure by the farming communities. This is perhaps due to the utilization of same ancestors and seed source by the farmers for the cultivation of crop in three selected areas of Pakistan. This preliminary investigation of traditional turmeric landraces from Pakistan provided useful information regarding their horticultural use and medicinal potential. The given technique of analysis can be helpful to select diverse parents and widen indigenous gene-pool of turmeric for future breeding programs.

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References

Abbasi, F.M., M.A. Sagar, M. Akram and M. Ashraf. 1995. Agronomic and quality traits of some elite rice genotypes. *Pak. J. Sci. Ind. Res*., 38: 9-10.

Afaq, F., V.M. Adhami and N. Ahmad. 2002. Botanical antioxidants for chemoprevention of photo carcinogenesis. *Front Biosci*., 7: 784-92.

Amanullah and M. Hatam. 2000. Performance and distinguishing characters of promising black-bean germplasm. *Sarhad. J. Agri*., 16: 467-476.

Ammon, H.P. and M. Wahl. 1991. Pharmacology of *Curcuma longa*. *Planta Med*., 57: 1-7.

Ammon, H.P.T., M.I. Anazodo, H. Safayhi, B.N. Dhawan and R.C. Srimal. 1992. Curcumin: a potent inhibitor of leukotriene B4 formation in rat peritoneal polymorph nuclear neutrophils (PMNL). *Planta Med*., 58: 26.

Aoi, K. 1992. The characteristics and cultivation methods of the medicinal plant *Curcuma domestic*. *Agric. Hort*., 67: 401-406.

Apisariyakul, A., N. Vanittanakorn and D. Buddhasuk. 1995. Antifungal activity of turmeric oil extracted from *Curcuma longa* L. (Zingiberaceae). *J. Ethno-Pharmacol*., 49: 163-169.

Baatout, S., H. Derraji, P. Jacquet, D. Ooms, A. Michaux and M. Mergeay. 2004. Effect of *Curcuma* on radiation induced apoptosis in human cancer cells. *Int. J. Oncology*, 24: 321-329.

Chaveerach, A., R. Sudmoon, T. Tanee, P. Mokkamul, N. Sattayasai and J. Sattayasai. 2008. Two new species of *Curcuma* (Zingiberaceae) used as cobra-bite antidotes**.** *J. Syst. Evol*., 46: 80-88.

Cousins, M., J. Adelberg, F. Chen and J. Rieck. 2007. Antioxidant capacity of fresh and dried rhizome from four clones of turmeric (*Curcuma longa* L.) grown *In vitro*. *Indus. Crops Prod*., 25: 129-135.

Daod and Aslam. 1996. Source of income from fruits and vegetables. *Proceedings of National Workshop on Horticultural Crops and their Importance in Pakistan*. 1(1): 3.

Duncan, W.G. 1971. Leaf angle, leaf area, and canopy photosynthesis. *Crop Sci*., 11: 482-485.

Gilani, S.A., Y. Fuji, Z.K. Shinwari, M. Adnan, A. Kikuchi and K.N. Watanabe. 2010. Phytotoxic studies of medicinal plant species of Pakistan. *Pak. J. Bot*., 42: 987-996.

Hirano, H., A. Nakamura, F. Kikuchi and S. Komatsu. 1992. Protein encoded by genes linked with semi dwarfing gene in rice. *Jap. Agric. Res. Quart*., 25: 223-229.

Jan, H.U., M.A. Rabbani and Z.K. Shinwari. 2011. Assessment of genetic diversity of indigenous turmeric (*Curcuma longa* L.) germplasm from Pakistan using RAPD markers. *J. Med. Plants Res*., 5: 823-830.

Jatoi, S.A., A. Kikuchi, S.S. Yi, K.W. Naig, S. Yamanaka, J.A. Watanabe and K.N. Watanabe. 2006. Use of rice SSR markers as RAPD markers for genetic diversity analysis in Zingiberaceae. *Breed. Sci*., 56: 107-111.

Lee, H.S. 2006. Antiplatelet property of *Curcuma longa L*. rhizome derived ar-turmerone. *Bioresour. Technol*., 97: 1372-1376.

Mazumder, A., K. Raghavan, J. Weinstein and Y. Pommier. 1995. Inhibition of human immunodeficiency virus type-1 integrase by curcumin. *Biochem. Pharmacol*., 49: 1165-1170.

Narayanpur, V.B. and S.I. Hanamashetti. 2003. Genetic variability and correlation studies in Turmeric (*Curcuma longa* L.). *J. Plantation Crops*, 31: 48-51.

Padua, L.D., N. Bunyapraphatsara and R.H.M.J. Lemmens. 1999. Plant Resources of South-East Asia No. 12(1): Medicinal and Poisonous Plants 1. Leiden: Backhuys Publishers.

Polasa, K., T.C. Raghuram and T.P. Krishna. 1991. Turmeric (*Curcuma longa* L.) induced reduction in urinary mutagens. *Food Chem. Toxic*., 29: 699-706.

Preter, K.V. 2001. Handbook of Herbs and Spices. 1: 298.

Ratanabanangkoon, K., C. Cherdchu and P. Chudapongse. 1993. Studies on the cobra neurotoxin inhibiting activity in an extract of *Curcuma* sp. (Zingiberaceae) rhizome. *SE Asia J. Trop. Med. Public Health*, 24: 178-185.

Rattan, R.S., B.N. Korla and N.P. Dohroo. 1988. Performance of ginger varieties under Solan condition of Himachal Pradesh. In: *Proceedings of National Seminar on Chilies, Ginger and Turmeric, Hyderabad* (Eds.): G. Satyanarayanan M.S. Reddy, M.R. Rao, K.M. Azam and R. Naidu. Spices Board, Cochin and Andra Pradesh Agricultural University, Hyderabad. pp. 71-73.

Roulf, F.J. 2002. *NTSYS–pc: Numerical Taxonomy and Multivariate Analysis System*. Version 2.01. Exter Publishing Ltd., Setauket, NY.

Sasikumar, B. 2005. Genetic resources of Curcuma: diversity, characterization and utilization. *Plant Genet. Res*., 3: 230-251.

Scartezzini, P. and E. Speroni. 2000. Review on some plants of Indian traditional medicine with antioxidant activity. *J. Ethnopharmacol*., 71: 23-43.

Schonbeck, J., and R.J. Frey. 2005. Turmeric. In: Longe JL (Ed.), The Gale Encyclopedia of Alternative Medicine. Farmington Hills, Mich: Thomson/Gale.

Shinwari, Z.K. 2010. Medicinal plants research in Pakistan. *J. Med. Plants Res*., 4: 161-176.

Sirirugsa, P. 1996. The genus *Curcuma* of Thailand. In: (Eds.): T.L. Wu, Q.G. Wu and Z.Y. Chen. *Proceedings of 2nd Symposium on the Family Zingiberaceae*. Zhongshan University Press, Guangzhou. pp.39-46.

Smart, J. and N.W. Simmonds. 1992. *Evolution of Crop Plants*. Longman, Edinburgh. 333p.

Smith, J.S.C. and O.S. Smith, 1989. The description and assessment of distances between inbred lines of maize: The utility of morphological, biochemical and genetic descriptors and a scheme for the testing of distinctiveness between inbred lines. *Maydica*, 34: 151-161.

Sneath, P.H.A. and R.P. Sokal. 1993. *Numerical Taxonomy: The Principles and Practices of Numerical Classification.* W.H. Freeman & Co., San Francisco, USA. 573p.

Syamkumar, S. and B. Sasikumar. 2007. Molecular marker based genetic diversity analysis of Curcuma species from India. *Scientia Horticulturae*, 112: 235-240.

Vavilova, N.I. 1990. Turmeric a new spice and medicinal plant. *Skogo-Instituta-Rastenievodstva-imeni.* 4: 77-79.

Yadav, D.S and R. Singh. 1996. Studies on genetic variability in turmeric (*Curcuma longa*). *J. Hill Res*., 9: 33-36.

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