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ASSESSMENT OF PHENOTYPIC VARIABILITY IN ENSET (ENSETE VENTRICOSUM (WELW) CHEESMAN) ACCESSIONS USING MULTIVARIATE ANALYSIS

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ABSTRACT
Enset (Ensete ventricosum) is a perennial, banana-like crop, endemic to Ethiopia that produces pseudostem and a starchy belly corm pulped for food, feed and fiber. This study was carried out to ascertain the value and magnitude of genetic diversity among 240 Enset accessions based on their morpho-agronomic traits. A considerable level of polymorphism was observed among Enset accessions for the majority of the morphological characters measured. The accessions were grouped in to five clusters. Cluster and principal component analyses were used to classify Enset accessions on the basis of phenotypic traits. Phenotypically all the cultivars were classified into five major groups. The highest inter-cluster distance (133.95) was observed between clusters II and III.Hence, crossing between accessions included in these clusters may give high heterotic response. The first nine principal components (PCs) with Eigen values greater than one explained 99.98% of the observed variation. Generally, the PC analysis confirmed high diversity of the Enset accessions since the entire variation cannot be explained in terms of few PCs. This in turn, indicates the involvement of the number of traits in contributing towards the overall observed diversity. Regardless of the limitation in estimating total genetic variation, the current study indicated that agro morphological traits were helpful for preliminary characterization and can be used as a broad-spectrum approach to assess genetic diversity among morphologically distinguishable Enset accessions. The distribution of accessions is characterized by high level of endemism which has implications for the conservation of Enset diversity. It is suggested that high land areas owing to the high concentration of diverse and unique landraces there should be given a high priority for collection and in situ germplasm conservation.

Keywords: Cluster analysis, Diversity, Enset ventricosum , Multivariate analysis, Phenotypic variability, Principal component analysis.

1. INTRODUCTION
Enset (Ensete ventricosum (Welw.) Cheesman) belongs to the order Schistaminae the family musaceae. The Musaceae family is subdivided into the genera Musa and Ensete [1]. Enset was considered as member of the genus Musa as it strongly resembles banana morphologically [2] and because of this some of the species names formerly given to Enset were Musa Ensete and Musa ventricosum [3].

Enset systems is one of the four major agricultural systems in Ethiopia feeding about 13 million people, more than 20% of the population residing in the southern Ethiopian highlands. Enset (Ensete ventricosum) is a perennial, banana-like crop, endemic to Ethiopia that produces psuedostem and a starchy belly corm pulped for food, feed and fiber. The Ethiopian [4] indicates that 3,020.143 km2 of land is covered by enset crop and about 6.9 million quintals of enset yields were produced in 2010/11 production season.

Enset provides year-round food, fiber, animal feed and medicine [5, 6]. The main food types obtained from enset are kocho, bulla and amicho [7]. Kocho is the fermented starch that is obtained from decorticated (scraped) leaf sheaths and grated corms. Bulla, a starchy liquid, is obtained during scraping of leaf sheaths and grating of corms. The thick liquid is allowed to dry and this produces a white powder rich in starch. Amicho or boiled corm pieces, is consumed in a similar manner to other root and tuber crops [5].

There are many Enset accessions in different agro ecologies. Farmers classify their land races and give them different names based on several attributes that distinguish the land races from one another. The names given by farmers to the different Enset accessions separate the land races linguistically, phenotypically and in terms of their utilization value. They often plant the different accessions they have in mixture.

Despite the existence of sufficient variability, and diverse uses, the current knowledge about its biology, variety development and agronomy are neither complete nor conclusive. This lack of information is a major hindrance to exploit the wealth of Enset diversity in Ethiopia. Information on phenotypic variation and its geographical distribution is important for genetic conservation, plant breeding and efficient utilization of plant genetic resources [8]. Tabogie, et al. [9] and Tsegaye and Westphal [10] reported a wide phenotypic variation among Enset accessions across a broad set of agro-ecological zones in southern Ethiopia. Thus, initiating a breeding program, with this security crop but neglected or underutilized crop contributes a magnificent role for its diversity maintenance, conservation, collection, improvement, cultivation and utilization. When initiating a breeding program with any crop having genetic variation, it is important to gather information on the traits of agronomic importance [11].

Genetic divergence is an important factor in any crop improvement program for obtaining high yielding variety [12]. Selection of parents based on genetic divergence is a pre-requisite in a hetrosis breeding program [13]. Likewise, Marker and Krupakar [14] stated that assessment of genetic divergence is an essential pre-requisite for identifying potential parents for hybridization. Thus, precise information on the nature and degree of genetic divergence helps plant breeders in choosing the diverse parents for purposeful hybridization. Knowledge on genetic divergence is, therefore, fundamental to identify and organize the available genetic resources aiming at the production of promising cultivars [15]. Genetic divergence can be determined by multivariate analysis, a procedure that is widely used in different crops for parent selection [16]. The study aimed to determine the level of germplasm variation and to identify and classify groups of accessions with different genetic diversity.

2. MATERIALS AND METHODS

2.1. Description of the Research Area

The Areka research station is located at 7° 09′ N and 37° 47′ E and at an elevation ranging from 1,750 to 1,800 meters above sea level (masl). The Areka Agricultural Research Center is located in the Wolayta zone and is one of the research centers of the Southern Agricultural Research Institute. Areka has an average rainfall of 1,539 mm and a minimum and maximum mean temperature of 14.5 and 25.8°C, respectively. The soil is silty loam with a pH of 4.8 to 5.6 and low to medium organic matter content (2.65-5.67%) (Esayas 2003 unpublished).

Experimental materials

A total of 240 Enset accessions which were collected from Wolaita, Kembata, Hadiya, Sidama, Gamo Gofa, Gurage and Dawro zones were included in this study. Corms of these Enset accessions were buried at the experimental field of the Areka Agricultural Research Center during the 1999-2000 rainy seasons for sucker production. One year after sucker multiplication, four suckers of similar size were taken from each accession and planted using a spacing of 3 m × 1.5 m between rows and plants, respectively. An accession was represented by a non-replicated plot consisting of four individual plants. A total of 22 quantitative traits were used for characterization.

2.2. Statistical Analysis

All recorded agro-morphological traits were analyzed by SAS techniques using cluster and principal component analyses. To avoid effects due to scaling differences, means of each trait were standardized prior to cluster and principal component analyses using Z-scores. Clustering of accessions was done according to Tocher's method as described by Rao [17]. Estimates of Euclidean distance coefficients were produced for all pairs of cultivars. The consequential Euclidean dissimilarity coefficient matrices were used to estimate the relationships between the cultivars with a cluster analysis using average linkage clustering analysis method (UPGMA) using SAS/PC Version 9.0 [18]. Principal component analysis was also performed with the same data matrix. The estimates of phenotypic and genotypic correlation were obtained by using the formula given by Singh and Chaudhary [19].

3. RESULT AND DISCUSSION

3.1. Phenotypic Variation

Basic statistics for 22 quantitative traits is presented in Table 1. A reasonable amount of genetic variation was displayed for the traits evaluated. All traits showed above 10% coefficient of variance and the highest 147.45 % was recorded for bulla yield per hectare per year. Plant height had a wide range of 2.33 -7.65 m with mean height of 5.50 ±0.05, and 16.43 % coefficient of variance. Leaf sheath weight before decortication from 10 to 144 kg/plant with mean of 57.58 ±1.26 and coefficient of variance was observed as 43.87; fermented squeezed kocho yield per plant from 2.75 to 51.0 kg with mean of 18.19 ±0.42 and coefficient of variance was observed as 46.77%.

Differences between maximum and minimum values for other characters were also big. The wide range in each of the traits studied offers broad opportunities for selecting parents of interest in breeding programs to develop varieties suitable for different agro-ecologies of the country and for different purposes. The broad range noted in phenology as depicted from the days to maturation (2.1 to 7.6 year) for instance, offers great flexibility for developing varieties suitable for various agro-ecological zones of the country that greatly differ in the length of the growing period and/or for use in various cropping systems. Considering the differences in the number of genotypes the ranges and means found in the current study were not very different from what was reported by Tabogie, et al. [9] who studied the variability in 88 accessions of Enset and reported wide ranges of 3.2 to 6.7 years to maturity, 3.0 to 7.7 m for plant height, 2.0 to 5.0 m for leaf length, 41.0 to 97.0 cm for leaf width, 5.0 to 21 leaves per plant, 9.5 to 22.8 leaf sheathes per plant and 2.69 to 24.71 t ha-1 yr-1 of Kocho yield. Tsegaye and Westphal [10] reported a maximum kocho yield of 19, 33 and 26 t ha-1yr-1 from Enset plants transplanted once, twice and thrice, respectively.

3.2. Cluster Analysis

The 240 accessions of Enset were grouped in to five clusters based on 22 characters (Table 2). The random distribution of the accessions was evident from different clusters. Cluster I was the largest, having 195 accessions indicating the overall genetic similarity among it, the accessions are mostly from Kembata/Hadiya, GamoGoffa and Sidama areas. Cluster II contained 36 accessions out of which eleven are from kembata collections and some from Gurage (5), Wolaita (5), Sidama (6), GamoGoffa (5) and four accessions from Dawro. Cluster III contained only 7 accessions collected from Kembata/Hadiya, Gurage, Sidama, and Dawro. Cluster IV which contained one accessions collected from Gamo Gofa, had taller plants with a height of 7.2 m. Accessions of this cluster had intermediate maturity time (5.2 year). Cluster V contained only one accession. It was intermediate in plant height (6.2 m) and had highest corm weight (88 kg). It was observed that accessions from different areas of southern parts of the country have been grouped in to the same cluster and also accessions collected from the same area have been distributed over clusters. The trend agrees with the result reported by Tabogie, et al. [9] who found out that accessions from different zones were grouped in the same cluster and accessions from similar zones were distributed in different clusters. Our findings was also comparable those reported by Tsegaye and Westphal [10] and Negash, et al. [20]. This is in agreement with Singh, et al. [21] grouping pattern which did not show relationships between genetic divergence and geographical diversity. Likewise, Sirohi and Dar [22] reported that changing of genetic material, genetic drift, natural variation and artificial selection other than ecological and geographical diversifications are the causes of genetic divergence.

The mean performance of each cluster for all traits is presented in Table 3. Based on cluster means, greater ranges of mean values among the cluster were recorded for different characters. The result is in agreement with Tabogie, et al. [9] who reported a wide range of variation in different characters of Enset. Cluster I consisted of 195 (81.25%) accessions out of 240 accessions evaluated. Accessions in this cluster are relatively early to late maturity group (2.1 – 7.6 years) with a mean maturity time of 4.8 years and are intermediate in their un squeezed kocho yield per plant (4.75 – 42.5 kg) with mean of 59.67 kg, which separated this cluster from rests of the clusters.

The distance between clusters was very small for III and V (35.38) followed by I and II (41.95) and IV and V (44.65). Maximum distances were recorded between clusters II and III (133.95) followed by clusters I and III (119.67) and between II and V (98.78) (Table 4). Crossing of genotypes from those clusters with big inter cluster distance is expected to produce more genetic variability and desirable genotypes than those with smaller inter cluster distances. It has been well established fact that more genetically diverse parents used in hybridization program, greater will be the chances of obtaining high heterotic hybrids and broad spectrum variability in segregating generations [23]. It has also been reported that the most productive hybrids may come from high yielding parents with high with a high genetic diversity [14]. Therefore, crossing genotypes for example, from clusters II with that of III, I with III and II with V will end up with genotype having more genetic variability for the desired characters and is expected to manifest heterosis.

3.3. Association between Quantitative Traits

Correlation study of different combinations of quantitative traits within the cultivars, some of the characters exhibited positive correlations, while other showed negative associations with one another (Table 5).The association indicated that squeezed kocho yield per hectare per year was positively correlated with twelve other characters except maturity time, bulla yield per plant and fiber yield per plant. Furthermore, kocho yield per hectare per year for instance showed positive correlation with plant height (0.6**), pseudostem circumference (0.58**), leaf length (0.54**), leaf sheath weight before decortications (0.73**), leaf sheath weight after decortications (0.77**) and central shoot weight before grating (0.65**). This is in agreement with Tabogie, et al. [9] who reported that kocho yield was positively and significantly correlated with plant height, pseudostem circumference, leaf sheath number, and leaf sheath weight. Moreover Mekiso [24] who indicated that plant height and pseudo stem circumference had positive correlation. In general, most of the characters were positively correlated with one another except maturity time and fiber yield per plant. Characters which are positively correlated phenotypically are useful in conventional breeding techniques because selection or breeding for one character will improve or influence the other character.

3.4. Principal Component Analysis (PCA)

Using Eigen value greater than one as a measure for significance of a principal component (PC), nine PCs extracted about 99.98 % of the total variance of the 240 Enset accessions (Table 6). Of these, the first three PCs, explained about 94.3 of the gross population variance. About 78.9% of the total variation accounted for by the first PC alone was due mainly to variations in leaf sheath weight before decortication, unfermented kocho yield and leaf sheath after decortication. Likewise, the second PC accounting for about 9.66 % of the total variance of the accessions originated mainly from variations in corm weight before grating, fermented unsqueezed kocho yield per plant, unfermented kocho yield and fermented squeezed kocho yield per plant. Variations in leaf sheath before decortication, unfermented kocho yield, fermented squeezed kocho yield per plant, and fermented unsqueezed kocho yield per plant constructed a large part of the total variance explained by the third PC. Generally, the PC analysis confirmed high diversity of the Enset accessions since the entire variation cannot be explained in terms of few PCs. This in turn, indicates the involvement of the number of traits in contributing towards the overall observed diversity. Similar results indicating the contribution of several of the traits to the overall variation observed was also obtained in other studies with Enset accessions [10, 20]. This variation offers ample opportunities for the genetic improvement of the crop through breeding.

4. CONCLUSION

As a concluding remark, the large number of Enset accessions recorded and the nature of diversity indicate that the region is rich in terms of Enset accessions diversity in Ethiopia. The diversity of Enset is not spread evenly across the region. Some areas in the region pass high varietal diversity while others are characterized by relative varietal paucity. The household characteristics, geographical distance and ethnic differences are responsible for this variation. The distribution of accessions is characterized by high level of endemism which has implications for the conservation of Enset diversity. It is suggested that high land areas owing to the high concentration of diverse and unique landraces there should be given a high priority for collection and in situ germplasm conservation.

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Table- 1. Descriptive statistics for 22 quantitative agronomic traits of Enset accessions.

Traits	Mean ± SE	Minimum	Maximum	Variance	SD	CV(%)
MT (yr.)	4.22 ±0.05	2.1	7.55	1.28	1.13	26.82
PH (m)	5.50 ±0.05	2.33	7.65	0.81	0.9	16.43
PSH(m)	1.74 ±0.02	0.88	2.9	0.1	0.32	18.28
PSC(m)	1.17 ±0.01	0.58	2.04	0.04	0.21	17.98
LN	10.05 ±0.10	4.5	17	3.79	1.95	19.36
LL(m)	3.37 ±0.03	0.73	4.71	0.36	0.6	17.8
LW(m)	0.70 ±0.01	0.37	3.68	0.04	0.21	30.66
LSN	18.36 ±0.19	11	48.5	12.92	3.59	19.57
LSBD (Kg)	57.58 ±1.26	10	144	639.24	25.28	43.87
LSAD (Kg)	28.10 ±0.64	3	67	155.73	12.48	44.39
CSBG (Kg)	14.61 ±0.30	2	60.5	33.45	5.71	39.56
COBG (Kg)	27.14 ±0.64	5	88	177.43	13.32	49.05
BA (Kg)	0.29 ±0.01	0.11	1.44	0.07	0.26	88.85
FL(m)	1.14 ±0.01	0.11	1.72	0.07	0.27	23.76
FA (kg)	0.30 ±0.01	0.11	1.39	0.04	0.21	67.56
USQKA (kg)	26.90 ±0.57	4.75	83.5	134.03	11.58	43.04
SQKA (Kg)	18.19 ±0.42	2.75	51	72.5	8.51	46.77
UFK (t ha^{-1} yr^{-1})	38.18 ±0.81	7.1	95.51	270.98	16.46	43.06
USQKB (t ha^{-1} yr^{-1})	14.79 ±0.35	1.92	42.34	51.93	7.2	48.67
SQKB(t ha^{-1} yr^{-1})	9.87 ±0.24	1.29	25.32	24.16	4.91	49.69
BB(t ha^{-1} yr^{-1})	0.49 ±0.03	0.01	7.08	0.52	0.72	147.45
FB(t ha^{-1} yr^{-1})	0.16 ±0.006	0.04	0.99	0.01	0.11	67.11

Maturity Time, PH=Plant Height PSH=Pseudostem Height, PSC=Pseudostem Circumference, LN=Leaf Number, LL=Leaf length, LW=Leaf Width, LSN=Leafsheath Number, LSBD=Leafsheath Weight Befor Decortication, LSAD=Leafsheath Weight After Decortication, CSBG=Central Shoot Weight Before Grating, COBG=Corm Weight Before Grating, BA=Bulla Yield Per Plant, FL=Fiber length, FA=Fiber Yield Per Plant, USQKA= Fermented Unsqueezed Kocho Yield Per Plant, SQKA= Fermented Squeezed Kocho Yield Per Plant, UFK=Unfermented Kocho Yield, USQKB= Fermented Unsqueezed Kocho Yield Per Hectare Per Year, SQKB= Fermented Squeezed Kocho Yield Per Hectare Per Year, BB= Bulla Yield Per Hectare Per Year, FB= Fiber Yield Per Hectare Per Year

Table-2. Region of collection and distribution of 240 Enset accessions over five clusters by regions of origin

Collection region	No. of accessions	Clusters				
		1	2	3	4	5
Gurage	30	24	5	1		
Kembata/hadiya	72	58	11	3		
Wolaita	36	31	5	-		
Sidama	41	32	6	2		1
Dawro	27	22	4	1		
Gamogoffa	34	28	5	-	1	
Total no. Of accessions in cluster	240	195	36	7	1	1

Table-3. Cluster means of 240 Enset accessions evaluated at Areka for 22 traits

Traits	I	II	III	IV	V
MT	4.8	3.94	4.74	3.93	4.09
PH	6.03	7.2	4.61	6.18	5.52
PSH	1.73	2.24	1.53	1.91	1.76
PSC	1.53	1.55	0.98	1.37	1.16
LN	11.67	11.12	8.73	11.3	10.07
LL	3.77	4.42	2.79	3.81	3.4
LW	0.77	0.87	0.61	0.81	0.7
LSN	20	21.12	15.67	21.4	18.2
LSBD	93.67	123.94	29.68	86.41	54.1
LSAD	50.27	58.41	14.96	42.43	26.12
CSBG	22.33	26.6	9.39	18.9	14.39
COBG	75.17	49.32	19.71	34.82	25
BA	0.2	0.22	0.27	0.33	0.29
FL	1.4	1.41	1	1.15	1.18
FA	0.2	0.26	0.42	0.27	0.27
USQKA	59.67	54.25	15.64	35.73	25.99
SQKA	40.17	37.94	10.13	24.49	17.56
UFK	68.4	74.91	20.99	55.14	36.39
USQKB	28.23	30.41	7.59	20.76	14.33
SQKB	18.67	20.91	4.89	13.96	9.63
BB	0.37	0.71	0.2	0.92	0.45
FB	0.1	0.18	0.18	0.16	0.16

MT=Maturity Time, PH=Plant Height PSH=Pseudostem Height, PSC=Pseudostem Circumference, LN=Leaf Number, LL=Leaf length, LW=Leaf Width, LSN=Leafsheath Number, LSBD=Leafsheath Weight Befor Decortication, LSAD=Leafsheath Weight After Decortication, CSBG=Central Shoot Weight Before Grating, COBG=Corm Weight Before Grating, BA=Bulla Yield Per Plant, FL=Fiber length, FA=Fiber Yield Per Plant, USQKA= Fermented Unsqueezed Kocho Yield Per Plant, SQKA= Fermented Squeezed Kocho Yield Per Plant, UFK=Unfermented Kocho Yield, USQKB= Fermented Unsqueezed Kocho Yield Per Hectare Per Year, SQKB= Fermented Squeezed Kocho Yield Per Hectare Per Year, BB= Bulla Yield Per Hectare Per Year, FB= Fiber Yield Per Hectare Per Year

Table 4. Pair wise generalized square distance (D^2) of five clusters formed by distance analysis of 240 Enset accessions

Cluster	I	II	III	IV	V
I	1				
II	41.95	1			
III	119.67	133.95	1		
IV	53.19	54.69	79.8	1	
V	87.63	98.78	35.38	44.65	1

Table- 5. correlation coefficient for selected traits of Enset accessions at Areka

Character	SQKB	MT	PH	PSH	PSC	LN	LL	LW	LSN	LSBD	LSAD	CSBG	COBG	BA	FL	FA
SQKB	1															
MT	0.43															
PH	0.6**	-0.24	1													
PSH	0.32**	0.02	0.77**	1												
PSC	0.58**	0.009	0.58**	0.4**	1											
LN	0.47**	-0.52	0.43**	0.23**	0.35**	1										
LL	0.54**	-0.23	0.87**	0.65**	0.57**	0.45**	1									
LW	0.38**	-0.16	0.3**	0.18**	0.34**	0.18**	0.03	1								
LSN	0.48**	-0.28	0.36**	0.22**	0.37**	0.44**	0.37**	0.18	1							
LSBD	0.73**	-0.21	0.7**	0.49**	0.72**	0.41**	0.68**	0.36**	0.55**	1						
LSAD	0.77**	-0.25	0.67**	0.44**	0.71**	0.4**	0.64**	0.41**	0.49**	0.91**	1					
CSBG	0.65**	-0.28	0.51**	0.32**	0.61**	0.41**	0.53**	0.27**	0.36**	0.66**	0.71	1				
COBG	0.39**	0.39**	0.45**	0.46**	0.61**	0.06	0.4*	0.14	0.15	0.51**	0.51**	0.39**	1			
BA	-0.12	-0.15	0.05	0.04	-0.01	0.12*	0.04	-0.02	0.002	0.03	0.05	0.05	-0.05	1		
FH	0.4**	-0.02	0.33	0.2**	0.2	0.11*	0.31*	0.11	0.14	0.27**	0.22**	0.13	0.17	-0.57**	1	
FA	-0.27	0.24**	-0.23	-0.11	-0.15	-0.2	-0.21	-0.05	-0.22	-0.24	-0.24	-0.2	-0.09	0.15	-0.2	1

**&*-significant at 1% & 5%, respectively. SQKB= squeezed kocho yield per hectare per year, MT=Maturity Time,

PH=Plant Height PSH=Pseudostem Height, PSC=Pseudostem Circumference,

LN=Leaf Number, LL=Leaf length, LW=Leaf Width, LSN=Leafsheath Number, LSBD=Leafsheath Weight Befor Decortication, LSAD=Leaf sheath Weight After Decortication,

CSBG=Central Shoot Weight Before Grating, COBG=Corm Weight Before Grating, BA=Bulla Yield Per Plant, FL=Fiber length, FA=Fiber Yield Per Plant,

Table 6. Eigen vectors and Eigen values of the first nine principal components (PC) of 22 quantitative traits of 240 Enset accessions from Southern Ethiopia

Traits	Eigen vector								
	Prin1	Prin2	Prin3	Prin4	Prin5	Prin6	Prin7	Prin8	Prin9
MT (yr)	-0.0078	0.0647	-0.0519	0.0101	-0.063	0.0578	0.0157	-0.0330	-0.0878
PH (m)	0.0184	0.0015	-0.0013	0.0007	0.0093	-0.007	-0.009	-0.0007	0.11515
PSH(m)	0.0044	0.0051	-0.0050	-0.0004	0.0037	0.0016	-0.000	-0.0161	0.03516
PSC(m)	0.0045	0.0030	-0.0015	-0.0023	0.0001	0.0070	0.0032	0.00737	0.01199
LN	0.0243	-0.0439	0.04264	-0.0059	0.1121	-0.021	0.1489	0.05104	0.96149
LL(m)	0.0117	-0.0009	-0.0028	-0.0008	0.0117	0.0080	0.0016	-0.0065	0.08786
LW(m)	0.0023	-0.0016	0.00183	0.0015	-0.007	-0.001	-0.002	0.00581	0.00018
LSN	0.0549	-0.0603	-0.0174	0.0825	0.1943	-0.117	0.9510	0.00495	-0.1703
LSBD (Kg)	0.6913	-0.2151	-0.6225	0.1278	0.2336	0.0088	-0.123	-0.0365	-0.0078
LSAD (Kg)	0.3375	-0.0839	0.01395	-0.1146	-0.891	0.0118	0.1806	-0.0360	0.07289
CSBG (Kg)	0.1207	-0.0376	0.17633	-0.1184	0.1409	0.9267	0.0860	-0.0175	-0.0124
COBG (Kg)	0.2282	0.8172	-0.0901	-0.4606	0.1112	-0.1034	0.0428	0.01984	0.01685
BA (Kg)	0.0001	-0.0036	0.00045	-0.0120	0.0013	-0.002	0.0003	-0.0246	0.01529
FL(m)	0.0021	0.0028	-0.0003	0.0168	0.0009	-0.001	-0.005	0.02187	0.00992
FA (kg)	-0.0014	0.0010	-0.0015	-0.0021	-0.001	0.0002	-0.005	-0.0072	-0.0085
USQKA (kg)	0.2801	0.3109	0.32832	0.4682	-0.009	0.0449	-0.014	-0.5565	0.02563
SQKA (Kg)	0.1975	0.2727	0.13889	0.4292	-0.090	0.1016	-0.002	0.63655	-0.0282
UFK (t ha^{-1} yr^{-1})	0.4205	-0.2997	0.52778	-0.4974	0.1643	-0.161	-0.057	0.11741	-0.0878
USQKB (t ha^{-1} yr^{-1})	0.1709	-0.076	0.35043	0.2017	0.1507	-0.244	-0.091	-0.2237	-0.0152
SQKB(t ha^{-1} yr^{-1})	0.1168	-0.0162	0.19899	0.2089	0.0743	-0.118	-0.061	0.45311	-0.0154
BB(t ha^{-1} yr^{-1})	0.0068	-0.0213	0.00778	-0.0392	-0.011	-0.011	0.0096	-0.0854	0.023
FB(t ha^{-1} yr^{-1})	-0.0002	-0.0021	0.00111	-0.0018	0.0014	-0.001	-0.003	-0.0014	-0.0030
Eigen value	**1241.82**	**152.022**	**90.4502**	**44.361**	**14.591**	**13.061**	**8.221**	**5.582**	**2.381**
Percent of total variance explained	**0.789**	**0.0966**	**0.0575**	**0.0282**	**0.0093**	**0.0083**	**0.0052**	**0.0035**	**0.0015**
Cumulative percent of total variance explained	**0.789**	**0.885**	**0.943**	**0.971**	**0.98**	**0.9885**	**0.9937**	**0.997**	**0.9998**