

Article

Phenotypic Diversity of Morphological Traits of Pitahaya (*Hylocereus* spp.) and Its Agronomic Potential in the Amazonas Region-Peru

Julio Cesar Santos-Pelaez ¹, David Saravia-Navarro ^{2*}, Julio H. I. Cruz-Delgado ², Miguel Angel del Carpio-Salas ², Elgar Barboza ³ and David Pavel Casanova Nuñez Melgar ²

¹ Estación Experimental Agraria Amazonas, Instituto Nacional de Innovación Agraria (INIA), Ex Aeropuerto, Fundo San Juan, Chachapoyas, Amazonas 01000, Peru; jcsantos18b@gmail.com

² Dirección de Desarrollo Tecnológico Agrario, Instituto Nacional de Innovación Agraria (INIA), Av. La Molina 1981 La Molina, Lima 15024, Peru; cprofrut@inia.gob.pe (J.H.I.C.-D.); miguel_angeldcs@hotmail.com (M.A.d.C.-S.); dcasanova@inia.gob.pe (D.P.C.N.M.)

³ Instituto de Investigación para el Desarrollo Sustentable de Ceja de Selva (INDES-CES), Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Chachapoyas 01001, Peru; ebarboza@indes-ces.edu.pe

* Correspondence: davidsaravian@gmail.com

Table S1. Places of origin of pitahayas in the department of Amazonas, Peru.

Accession ID	Altitude (masl)	Latitude N	Longitude W	District	Province
AC.01	1442	06°02.435'	77°55.983'	Valera	Bongara
AC.02	1434	06°02.454'	77°55.979'	Valera	Bongara
AC.03	1427	05°58.854'	77°58.682'	Jazan	Bongara
AC.04	1432	05°58.845'	77°58.662'	Jazan	Bongara
AC.05	1540	05°54.520'	77°58.103'	Shipasbamba	Bongara
AC.06	1514	06°03.553'	77°55.701'	Olto	Luya
AC.07	1585	06°25.447'	77°31.179'	Huambo	R.Mendoza

Table S2. Descriptive statistics of quantitative descriptors of pitahaya cladode, flower and fruit

Descriptor	AC.01	AC.02	AC.03	AC.04	AC.05	AC.06	AC.07	Mean	P-value	CV %
Cladode										
Length of segment (mm)	3.97 (cd)	4.39 (cd)	4.33 (cd)	5.34 (b)	3.54 (d)	4.62 (c)	6 (a)	4.59	<0.0001	16.02
Width (mm)	38.48 (b)	28.33 (c)	36.21 (b)	23.42 (c)	23.11 (c)	27.81(c)	47.47(a)	32.11	<0.0001	26.45
Distance between areoles (mm)	54.06 (b)	54.11 (b)	47.89 (bc)	51.05(bc)	47.44(bc)	42.6(c)	62.69 (a)	51.4	0.0001	16.84
Arch height (mm)	38.74 (b)	23.96 (c)	37.41 (b)	18.86 (c)	19.5 (c)	22.9 (c)	56.09 (a)	31.06	<0.0001	23.26
Length spine (mm)	4.34 (a)	3 (c)	4.34 (a)	3.42 (bc)	3.29 (bc)	3.6 (b)	4.39 (a)	3.76	<0.0001	13.12
Flower										
Length of pericarpel (mm)	202.62 (b)	199.7 (b)	167.58 (d)	166.11 (d)	203.11 (b)	176.51 (c)	232.22 (a)	192.55	<0.0001	3.62
Width of pericarpel (mm)	28.93 (b)	22.93 (c)	23.37 (c)	21.78 (c)	29.91 (b)	22.74 (c)	35.28 (a)	26.42	<0.0001	12.45
Length of perianth (mm)	169.36 (b)	189.96 (b)	153.22 (c)	150.46 (c)	183.21 (b)	126.46 (d)	200.93 (a)	167.65	<0.0001	5.58
Length of style (mm)	291 (b)	321.1 (a)	266.22 (c)	235.8 (d)	289.73 (b)	191.13 (e)	321.1 (a)	273.72	<0.0001	5.13
Flower: number of stigma lobes (mm)	27.22 (a)	20.7 (c)	26.4 (a)	21 (c)	26.12 (a)	19.8 (c)	23.3 (b)	23.5	<0.0001	8.31
Fruit										
Fruit: length (mm)	90.82 (b)	98.14 (b)	93.43 (b)	96.58 (b)	96.37 (b)	92.82 (b)	118.09 (a)	98.03	<0.0001	6.92
Fruit: width (mm)	57.31 (bc)	59.93 (d)	66.72 (b)	59.93 (cd)	81.8 (a)	60.28 (cb)	80.73 (a)	66.67	<0.0001	7.62
Number of bracts	37.6 (a)	37.9 (a)	39 (a)	36.8 (a)	38 (a)	42.2 (a)	26.5 (b)	36.85	<0.0001	12.58
Fruit weight (g)	234.02 (c)	212.69 (c)	246.8 (c)	198.91 (c)	392.96 (b)	210.92 (c)	451.93 (a)	278.31	<0.0001	18.5
Fruit Pulp weight (g)	126.08 (c)	163.81 (b)	117.71 (c)	120.24 (c)	297.61 (a)	115.6 (c)	292.5 (a)	176.22	<0.0001	20.5
Length of apical bracts (mm)	15.6 (c)	17.37 (b)	14.92 (c)	17.71 (b)	14.13 (c)	23.18 (a)	15.75 (c)	16.95	<0.0001	9.29
Thickness of peel (mm)	110.02 (bc)	95.02 (cd)	125.89 (b)	78.16 (d)	95.45 (cd)	91.9 (cd)	201.39	113.97	<0.0001	18.87
Seed width (mm)	1.42 (c)	1.52 (c)	1.39 (c)	1.57 (c)	2.04 (b)	1.42 (c)	2.76 (a)	1.73	<0.0001	12.29
Seed length (mm)	3.67 (b)	3.53 (b)	3.64 (b)	3.54 (b)	3.66 (b)	3.38 (b)	4.56 (a)	3.71	<0.0001	6.29
Sweetness (°Brix)	15.73 (a)	14.76 (a)	15.78 (a)	15.15 (a)	15.25 (a)	15.27 (a)	15.82 (a)	15.39	0.1068	6.01

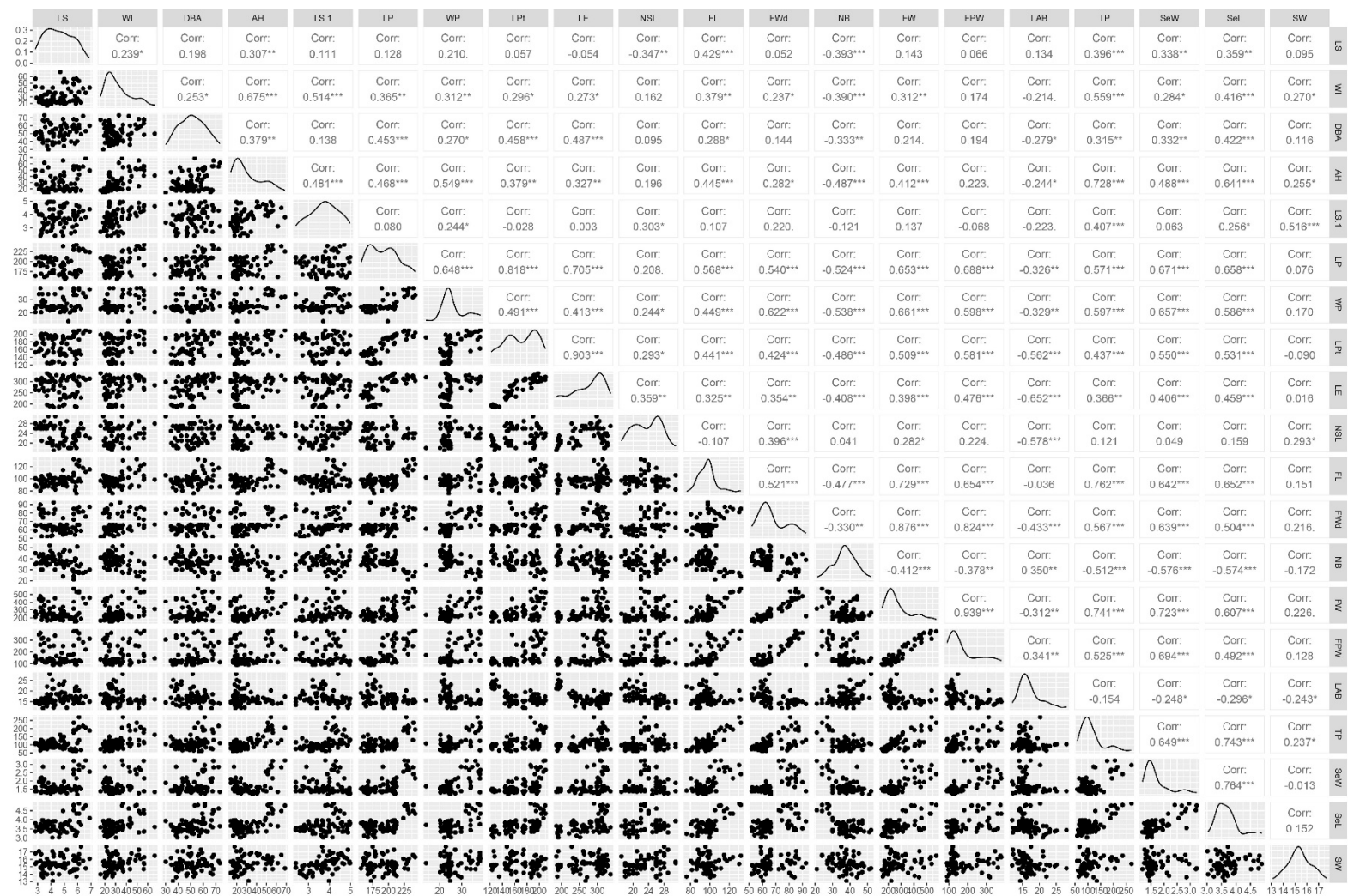


Figure S1: Correlogram of the quantitative descriptors for the seven dragon fruit accessions in the Amazon region.

Table S3. Contribution to variance of quantitative variables in PCA and the accumulated variance for each component.

Principal Component Analysis (Contribution)			
	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	8.69678668	43.4839334	43.48393
comp 2	2.355713499	11.7785675	55.2625
comp 3	2.158845255	10.79422628	66.05673
comp 4	1.661751785	8.30875892	74.36549
comp 5	0.834618885	4.17309442	78.53858
comp 6	0.731629128	3.65814564	82.19673
comp 7	0.628564394	3.14282197	85.33955
comp 8	0.516966577	2.58483289	87.92438
comp 9	0.420228479	2.1011424	90.02552
comp 10	0.410642804	2.05321402	92.07874
comp 11	0.364985872	1.82492936	93.90367
comp 12	0.297486008	1.48743004	95.3911
comp 13	0.246835459	1.2341773	96.62527
comp 14	0.17745732	0.8872866	97.51256
comp 15	0.146720303	0.73360152	98.24616
comp 16	0.132774825	0.66387413	98.91004
comp 17	0.091779154	0.45889577	99.36893
comp 18	0.071971714	0.35985857	99.72879
comp 19	0.05102537	0.25512685	99.98392
comp 20	0.003216489	0.01608245	100

Contribution					
Variable	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
LS	1.0137	19.0078	1.8216	1.7687	14.4002
WI	3.2892	4.9618	8.4450	1.7504	12.0055
DBA	2.6340	0.0139	0.2456	16.3914	5.1155
AH	5.3236	5.6455	5.3062	2.5605	8.6080
LS.1	0.9785	4.4509	26.6410	0.8066	0.6768
LP	7.9966	1.4478	1.2843	1.6214	0.9877
WP	6.8480	0.0000	0.0024	0.9421	0.0011
LPt	6.3749	7.5600	0.8809	8.9170	0.6295
LE	5.0153	10.9442	0.0117	11.1382	0.0003
NSL	1.0167	12.9963	15.3959	2.2533	1.2227
FL	6.3146	4.3968	4.2321	1.1082	0.0002
FWd	6.3352	1.8495	0.0396	16.5527	0.1924
NB	5.1244	1.5572	0.2576	4.4208	12.2262
FW	8.2249	0.2286	1.1847	12.5601	0.0443
FPW	6.8270	2.9312	4.6594	9.4544	0.5219
LAB	2.6969	13.1452	7.1841	1.2530	8.6047
TP	7.8361	5.6527	0.0968	0.6232	4.0946
SeW	7.6638	0.3281	4.7187	0.2355	0.0133
SeL	7.8000	1.6196	0.0779	0.6319	0.1969
SW	0.6866	1.2629	17.5147	5.0105	30.4581

Table S4. Contribution to variance of quantitative and qualitative variables in FAMD and the accumulated variance for each component.

Factor Analysis of Mixed Date (Contribution)						
eigenvalue		percentage of variance		cumulative percentage of variance		
comp	1	20.986672	39.597494		39.59749	
comp	2	10.323612	19.478513		59.07601	
comp	3	6.748766	12.733521		71.80953	
comp	4	3.847602	7.259625		79.06915	
comp	5	3.127273	5.900515		84.96967	
Contribution						
Variable		Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
LS		0.0014	3.6536	1.9368	2.3707	0.3180
WI		1.1596	0.4517	3.7299	0.3681	0.3833
DBA		0.4656	1.2172	0.4475	1.0246	3.5774
AH		1.9331	0.8556	4.2468	0.1444	0.2840
LS.1		1.0433	0.2690	4.8453	0.4020	0.2378
LP		1.9608	2.7415	0.4280	5.3099	0.0735
WP		2.3368	1.2677	0.0384	0.0354	0.1566
LPt		1.8115	1.1310	0.4879	5.3723	3.5090
LE		1.6441	0.3679	0.2642	6.1519	2.9342
NSL		2.1562	2.6896	0.1240	0.0077	0.3822
FL		0.7499	5.1077	0.0171	0.4368	0.1888
FWd		2.7724	0.3742	1.9979	1.6835	0.6076
NB		0.9020	2.7919	0.4158	0.0588	1.7771
FW		2.5652	1.7046	1.4464	0.7432	0.9859
FPW		1.8143	1.9330	4.4021	0.0910	0.2860
LAB		2.1559	0.4835	0.2284	0.0083	5.0972
TP		2.0830	2.4454	1.4513	0.1227	1.6205
SeW		1.6383	4.1622	0.5893	0.5791	0.0001
SeL		1.9280	2.9332	0.3766	0.1227	0.0806
SW		0.4595	0.0428	0.9634	0.6777	0.1413
ACCESION		4.7425	9.5449	14.5710	25.3300	30.6084
YSRC		4.3630	0.7289	0.0190	0.0673	0.0406
TS		0.0000	0.0000	0.0000	0.0000	0.0000
MR		1.4647	6.5055	0.2087	0.0074	0.0029
IGGA		4.3630	0.7289	0.0190	0.0673	0.0406
MCS		4.3885	1.8643	1.5321	8.2571	5.7030
FBS		4.6809	9.3908	14.2550	0.9154	0.2376
SA		4.3630	0.7289	0.0190	0.0673	0.0406
C		4.6532	9.0697	0.7362	0.2471	0.1366
IRCB		1.4647	6.5055	0.2087	0.0074	0.0029
PC		4.3630	0.7289	0.0190	0.0673	0.0406
SMC		4.5627	5.2662	6.3348	0.8996	0.2328
SPSC		0.0000	0.0000	0.0000	0.0000	0.0000

CSL	1.5436	5.7584	0.7071	0.2385	0.1304
PARS	4.3630	0.7289	0.0190	0.0673	0.0406
PBTP	1.5209	0.5890	1.8368	11.1323	1.4103
MCMB	4.4913	2.6781	2.8638	14.6307	21.0211
CP	4.3630	0.7289	0.0190	0.0673	0.0406
CF	4.3649	0.9183	14.1223	11.7568	17.5501
AC	4.3635	0.9125	14.0725	0.4634	0.0792

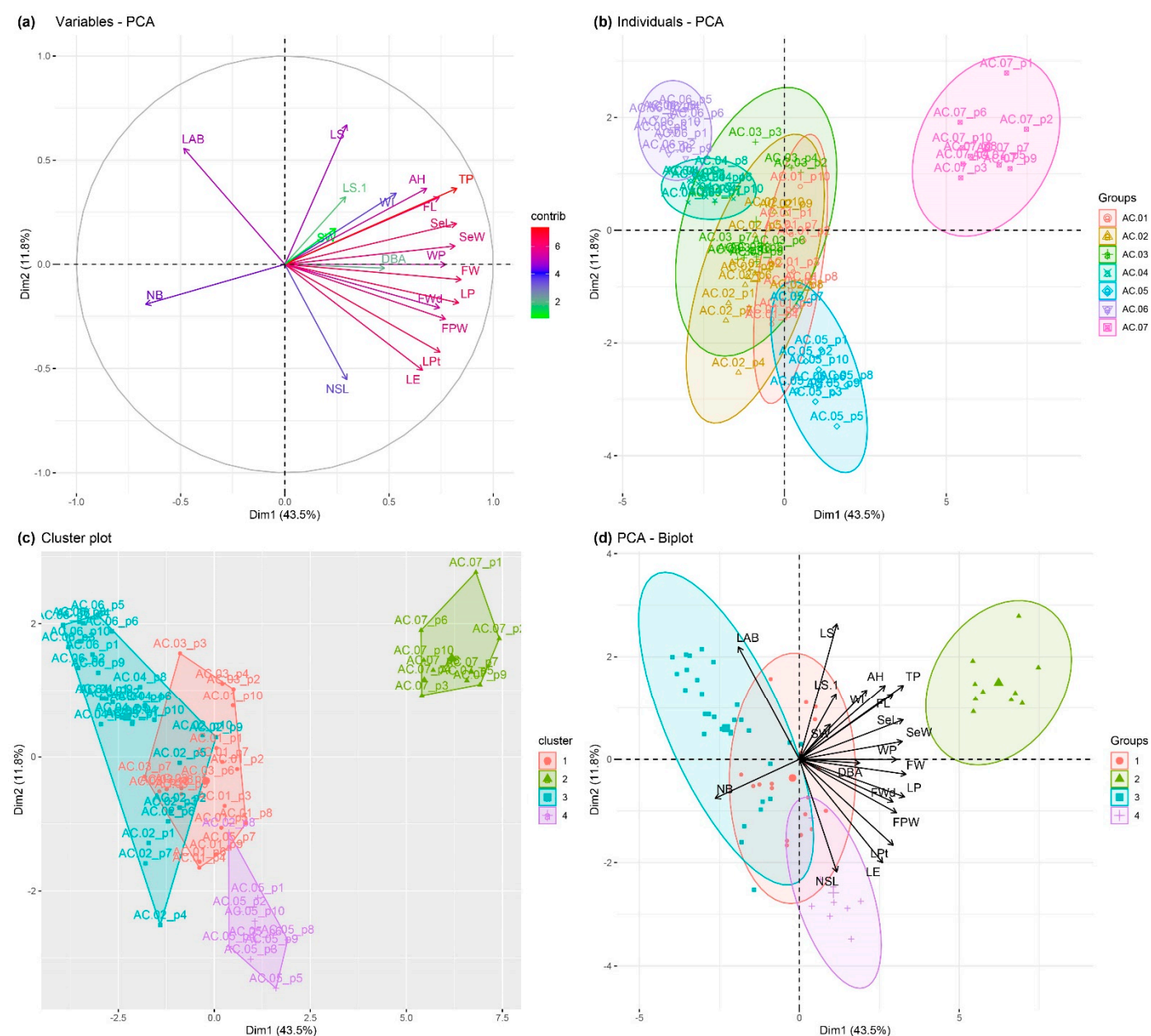


Figure S2. Multivariate analysis graphs. Principal components analysis (PCA) by variables (a) for the quantitative variables, individuals - PCA with groups by access (b). Clustering by k-means (c) and PCA biplot by four clusters with quantitative data (d).

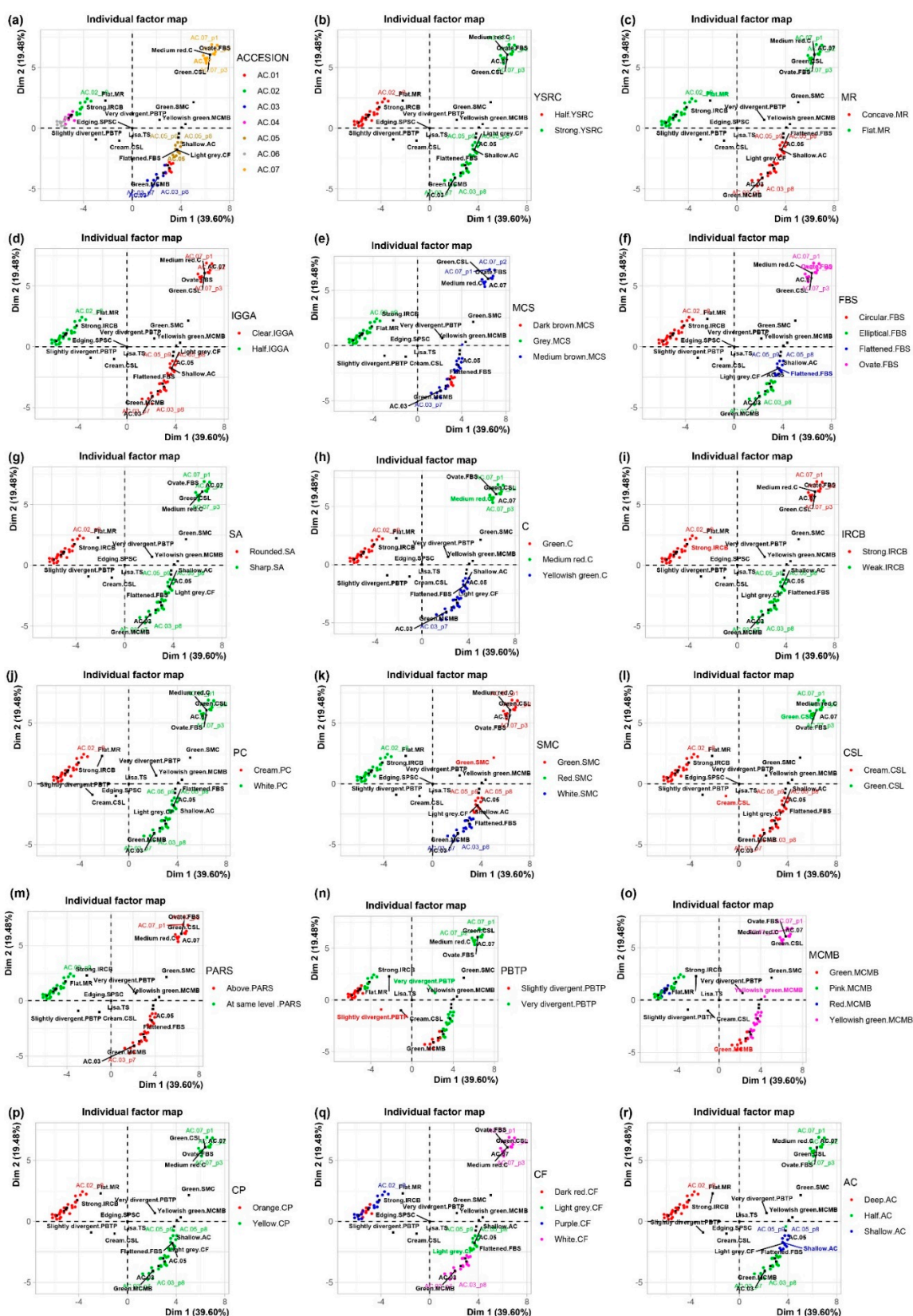


Figure S3. Multivariate analysis graphs. Factor analysis of mixed data (FAMD) with qualitative and quantitative data, grouped by accession (a) Young stem: reddish color (b), Margin of rib (c), Intensity of grey color of areoles (d), Main color spine (e), Flower bud: shape (f), Shape of apex (g), Color (h), Intensity of red color of bract (i), Petal: color (j), Sepal: main color (k), Flower: color of stigma lobe (l), Position of anthers about stigma (m), Position of bracts towards the peel (n), the Main color of middle bracts (o), Color of flower (p), Color of flesh (q), and Apical cavity (r).