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Natural Variation for Seed Physical and Hydration Parameters in Cowpea (*Vigna unguiculata* L.) in Relation to Hard to Cook Trait

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ABSTRACT

In the present study 15 cowpea genotypes were evaluated for seed physical and cooking quality. Seed length was highest in C-14 (9.66 mm) and lowest value for seed length was recorded in C-6 (6.98 mm). Seed breadth was highest in C-4 (6.98 mm) Coat proportion was highest in case of C-1 (10.23%) and lowest in C-8 (5.36%). Highest value for 100 seed weight was found in C-14 (21.33 g) whereas lowest was found in C1 (8.31 g). Water absorption percentage and hydration coefficient were found highest in C-1 and lowest in C-14. The swelling capacity was found highest in C-14 (0.228) and lowest in C-10 (0.090). Highest bulk density was recorded in C-4 (1.880) least was recorded in C-7(0.946). Four genotypes viz., C-7, C-8, C-11 and C-14 were easy to cook whereas, six genotypes were hard to cook with C-1 and C-9 remaining undercooked. Coat proportion was negatively correlated with cooking time score. Similarly, water absorption was positively correlated with swelling coefficient, hydration coefficient, and bulk density and was negatively correlated with swelling capacity, hydration capacity and cooking time score. Bulk density was negatively correlated with cooking time score. PCA concentrated variability in first three principal components accounting for about 88 % of variation. The PC1 accounted for 53.129 % of variation, and seed breadth, 100-seed weight, seed length, hydration capacity and swelling capacity and cooking time were important. The PC2 accounted for 18.206 % of variation and coat proportion was important. The genotypic scores for principal components indicates that C-8 showed the maximum value for PC 1 followed by C-11 and C-7. For PC2, C-4 had the highest score followed by C-13 and SCP-1.

Key words: *Cowpea, Hydration Capacity, Swelling Capacity, Water Absorption, Cooking Time.*

INTRODUCTION

The seed physical and cooking time are key parameters for farmer acceptability as well as marketability of cowpea varieties. Seed physical parameters that define the visual appearance, water absorption and cooking time are important determinants of farmer acceptability. However, of all the seed quality traits, cooking time is considered the most important[8].

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Two grain traits significantly influence cooking time *viz.* grains which are slow to imbibe water and therefore require a longer cooking time, and grains which imbibe water, but the cotyledons do not soften sufficiently during cooking. The amount of water cowpea seeds absorb during soaking before cooking can be used as reliable indicative of the amount of time required to render them soft and palatable to eat. Hence, the water absorption of a genotype may be a useful and rapid indirect selection method to screen germplasm for cooking time[18]. Cooking time is important in view of the energy requirements associated with cooking and energy being a major issue in developing nations where cowpeas are largely grown and consumed.

A major limitation in legumes including cowpea is its relatively longer cooking time. The cooking time of cowpea seeds ranges from 35 – 120 minutes or more, depending on the variety and type of cooking water used[16]. Cooking renders legumes edible and ensures their acceptable sensory properties[4]. The cooking of cowpea seeds involves certain hydrothermal changes such as gelatinization of starch, denaturation of proteins, solubilisation of some of the polysaccharides, and softening and breakdown of the middle lamella, a cementing material found in the cotyledon[21]. More importantly, in cowpea, cooking also reduces the levels of anti-nutritional factors such as trypsin inhibitors and oligosaccharides such as raffinose, verbasose and stachyose, resulting in improved nutritional quality[22]. However, longer cooking time is associated with some negative effects such as increased energy and time consumption, increase the percentage of leached solids, destruction of heat-labile vitamins and deterioration of protein quality of the cooked product[6,23]. Like other legumes, cowpea is usually soaked prior to cooking to reduce cooking time, and thus grain coat proportion as well as permeability is of paramount importance in view of its potential role in controlling the exchange of water between the grains and their environment[14]. This is attributed to delayed permeability of grains, i.e., grains which require a longer time to imbibe than others because of the low permeability of the grain coat. Uebersax *et al.*[20], implicated the degree and rate of hydration of starch and proteins in ability of grains to imbibe water at a certain rate.

CIAT has developed a cooking time evaluation protocol that is based on a cooking time index derived from a bardrop cooker[10]. It is laborious and time consuming especially for large number of samples. In view of substantial experimental evidences about usefulness of hydration parameters of dried legume seeds, It has been suggested that the amount of water cowpea absorbs during soaking before cooking can be a reliable indicative of the amount of time required to render them soft and palatable to eat. Hence, the water absorption of a genotype may be a useful and rapid indirect selection method to screen germplasm for cooking time in cowpea and common bean[7,9]. The principal component analysis (PCA) is one of Multivariate Analysis methods that identifies decisive traits for genotypic differentiation[13]. PCA enables us understand the impacts and connections among different traits by elucidating their importance and explaining their roles. It helps in identification of biological relationships among traits[1], reduce associated-traits to a few factors[11] and characterise correlations among traits. PCA has the potential of enhancing our knowledge of causal relationship of variables and can help to know the nature and sequences of traits to be selected for breeding program[12]. The present study was undertaken to assess the variation in seed physical and hydration characteristics in cowpea landraces of Kashmir valley in relation to hard to cook trait as well as identify key factors that define cooking quality.

MATERIALS AND METHODS

Experimental set up

Fifteen genotypes of cowpea including 14 local landraces and one released variety (Shalimar Cowpea-1) as check were evaluated. Seeds were properly dried and stored for 2 weeks in plastic boxes to equilibrate the moisture content. The samples for various seed quality traits were drawn from these working samples for further processing.

Seed physical parameters

Seed length and breadth: Seed length and breadth was measured using vernier calliper and averaged across 10 representative seeds for each genotype.

Seed dry weight: Seed dry weight was calculated on a randomly drawn sample of 100 sun dried seeds and averaged across 3 samples.

Bulk density: The bulk density of the cowpea seeds was calculated using the standard method of Shimelis and Rakshit[17]. 50 g of the sample seeds were transferred to a measuring cylinder, which had 100 ml distilled water at 20ºC. Seed volume (ml/ g seeds) was obtained after subtracting 100 ml from the total volume (ml). The bulk density was then calculated and recorded in g/ml.

Coat proportion: The proportion of seed coat (the ratio in weight between seed coat and cotyledon plus seed coat, after removing the seed coat from the cotyledon and keeping them for 48 h at 60ºC). Seed coat proportion was determined on 20 seeds per genotype, as the ratio in weight between coat and cotyledon expressed in percentage, after removing the seed coat from the cotyledons.

Hydration parameters

Seed water absorption parameters were calculated as per the procedure of Bishnoi and Khetarpaul[3]. The moisture contents of the dry cowpea samples were equilibrated to each other before analysis of water absorption by storing them for 2 weeks in sealed plastic containers at ambient temperatures and relative humidity.

Water absorption percentage: The percent water absorption was determined by first soaking 100 seeds for 24 h in deionised water at room temperature and dividing the difference in weight before and after soaking by the dry weight of the 100-seed sample.

Swelling capacity: Seeds, weighting 50 g, were counted, their volume noted and soaked overnight. The volume of soaked seeds were noted in a graduated cylinder[3]. Swelling capacity (SC) was calculated as change in volume per number of seeds.

Swelling capacity (ml/seed) = (Va - Vb)/N

Where Vb and Va is the volume (ml) of cowpea seeds before and after soaking.

Hydration capacity: Seeds, weighting 50 g, were counted and soaked overnight. After the water was drained, the soaked seeds were blotted dry and weighted. Hydration capacity (Hc) was calculated as change in weight per number of seeds.

Hydration capacity (g/seed) = (Ma – Mb)/N

Where Mb and Ma is the weight (g) of cowpea seeds before and after soaking

Swelling coefficient: Swelling coefficient was determined using the Youssuf's[24] method. The swelling coefficient was calculated as the percentage increase in volume of cowpea after soaking:

Swelling coefficient (%) = (V a/ V b) × 100

Where Vb and Va is the volume (ml) of cowpea seeds before and after soaking.

Hydration coefficient: Hydration coefficient was determined using the Youssuf's[24] method. The raw cowpea seeds were soaked in distilled water for 24 hours and the volume of the bean seeds was estimated before and after soaking by determination of displaced water. The hydration coefficient was calculated as the percentage increase in weight of cowpea.

Hydration coefficient (%) = (Ma/ Mb) × 100

Where Mb and Ma is the weight (g) of cowpea seeds before and after soaking

Cooking time score

The cooking time score was evaluated following the method described by Carvalho *et al.*[5], with modifications. Fifty seeds were soaked for 90 minutes and placed in falcon tubes filled with 50 ml of distilled water tightly covered with lid, and cooked in a cooker with 3.5 litre capacity filled with water upto 3/4th of its capacity. The cooking was allowed for forty minutes. The softness/hardness (cookability) of the beans was determined subjectively by pressing the cooked beans between the thumb and forefinger[21].

Scale	Designation	Description
1	Undercooked	Grain is difficult or not able to smash and cotyledon feels hard
2	Slightly undercooked	Grain is less difficult to smash and cotyledon feels slightly hard
3	Average cooked	Grain is firm but smashes easily and cotyledon feels soft
4	Slightly overcooked	There is little resistance to smash grain and cotyledon feels mushy
5	Overcooked	Grain is easily pressed into a mush

RESULTS AND DISCUSSION

Variability for seed physical traits and hydration parameters

The data pertaining to variability and mean performance of seed physical traits is presented in Table 1 and 2. Out of 15 genotypes, 12 genotypes were black and 3 were brown. This is probably due to the fact that black colored cowpea is predominantly grown in Kashmir valley. In terms of seed shape nine genotypes were rhomboidal, three were globose, two ovoid and one kidney shaped. The eye colour was white in 12 and rest three had black eyes with varied degree of pattern, with only three having Holstein eye pattern. Seed length was highest in C-14 (9.66 mm) ,followed by C-8 (9.15 mm) and C-7 (9.07 mm) whereas least value for seed length was recorded in C-6 (6.98 mm). Similarly for seed breadth the highest value was observed in C-4 (6.98 mm) ,followed by C-11 (6.93 mm) and C-8(6.83) and least value recorded in C-10 (4.70 mm). The length breadth ratio was highest in case of C-4 (1.74) followed by C-10 (1.67) and C-2 (1.65) and lowest in case of C-8 (1.34). Coat proportion was highest in case of C-1 (10.23%) followed by C-9 (9.78%) while as lowest value was recorded in case of C-8 (5.36%). Highest value for 100 seed weight was found in C-14 (21.33 g), followed by C-11 (16.86 g) and C-8 (16.14 g) whereas least 100 seed weight was found in C1 (8.31 g). For seed length, 11 genotypes had higher values than the check variety Shalimar Cowpea-1 while as for seed breadth and 100 seed weight five and six genotypes had higher values than the check variety respectively. The mean performance of 15 genotypes for hydration parameters and cooking traits is presented in table 3. Water absorption percentage was found highest in C-1(127.71 %), followed by C-4 (124.468 %) and C-13 (123.91 %) and lowest in C-14 (96.713 %). The swelling capacity measured as ml/seed was found highest in C-14 (0.228), followed by C-11 (0.190) and C-8 (0.180) and lowest in C-10 (0.090). Similarly, highest value for hydration capacity (g/seed) was recorded in C-14 (0.206), followed by C-11(0.201), followed by C-8(0.180) and least was found in C-3(0.096). Swelling coefficient (%) was highest in C-4 (370.00), followed by C-3 (320.00) and C-5(242.857) and lowest in C-12 (160.00). Similarly, out of the 15 genotypes hydration coefficient (%) was highest in C-1 (227.711), followed by C-4 (224.468) and C-13 (223.913) and lowest in case of C-14 (196.713). Highest value for bulk density, measured as (g/ml), was recorded in C-4 (1.880), followed by C-3 (1.740) and C-8 (1.238) and least was found in C-7(0.946). Tresina and Mohan[19] have reported hydration capacity of 0.03 g/seed and hydration index of 0.9 for cowpea and swelling capacity and swelling index values as 0.053 mL/seed and 0.001 mL/seed, respectively for cowpea. Out of the 15 genotypes evaluated, four genotypes viz., C-7, C-8, C-11 and C-14 were easy to cook whereas, six genotypes were hard to cook with C-1 and C-9 remaining undercooked. Hamid *et al.*[7] evaluated two cowpea varieties for cooking traits and reported that bulk density was found significantly higher for black cowpea than red cowpea. Black cowpea had significantly shorter cooking time (29.77 min) than Red cowpea (64.67 min). Water uptake ratio, hydration capacity and swelling capacity were significantly higher for red cowpea than black cowpea. Similar results have been also reported by Bhokre and Joshi[2]. Sofi *et al.*[18] and Iram Saba *et al.*[9] evaluated diverse lines of common bean for seed physical and water absorption traits and found wide variation in different traits studied.

Seed length was positively correlated with seed breadth, 100 seed weight, swelling capacity, hydration capacity and cooking time score but was negatively correlated with water absorption, swelling coefficient, hydration coefficient and bulk density (Table 4). Seed breadth was positively correlated with 100 seed weight, swelling capacity hydration capacity, cooking time score. Seed breadth was negatively correlated with water absorption %, swelling coefficient, hydration coefficient, and bulk density. Coat proportion was negatively correlated with cooking time score. The negative correlation between the traits as reported above is due to the fact that seeds with thicker seed coats are invariably impermeable to water and impede water imbibition by dry seeds during soaking process (Sofi et al, 2014). 100 seed weight was positively correlated with swelling capacity, hydration capacity cooking time score and was negatively correlated with water absorption %, swelling coefficient , hydration coefficient, bulk density. Water absorption % was positively correlated with swelling coefficient, hydration coefficient, and bulk density and was negatively correlated with swelling capacity, hydration capacity and cooking time score. Swelling capacity was positively correlated with hydration capacity, swelling coefficient, bulk density, cooking time score and was negatively correlated with hydration coefficient .Hydration capacity was positively correlated with cooking time score and was negatively correlated with swelling coefficient ,hydration coefficient ,bulk density . Swelling coefficient was positively correlated with hydration coefficient, bulk density and was negatively correlated with cooking time score. Bulk density was negatively correlated with cooking time score. Similar results have been reported by Sofi *et al*.[18] and Iram Saba *et al*[9].

Principal Component analysis

In the present study, PCA concentrated variability in first three principal components. Total variance explained with the three PC's was about 88% and the variance explained with rest of the seven PC is irrelevant. The criteria followed for selecting the number of principal components (PC) to be included in the final analysis was based on the values of Eigen values of PC[13]. Table 5 shows the factor loadings for three principal components identified on the basis of Eigen values. The fact that Eigen values are above one indicates that the evaluated principle component weight values are reliable[15]. Latent roots (Eigen values) were 6.375, 2.185 and 1.996 for PC-1, PC-2 and PC-3 respectively accounting for about 87.971 %. In the PCA, the value and sign of each trait in a PC are important in determining their effectiveness for selection process. The sign of factors' coefficients in each factor represents the relationship between these characters. The PC1 accounted for 53.129 % of variation, and traits such as seed breadth, 100-seed weight, seed length, hydration capacity and swelling capacity and cooking time were important (Table 6). The PC2 accounted for 18.206 % of variation and coat proportion was important. Similarly, the PC3 accounted for 19.96% of variation and traits like swelling coefficient and bulk density were important. In terms of the trait contributions to different PC's (Table 6), the largest contribution to PC1 was by 100-seed weight (14.901%) followed by seed breadth (14.608%) and hydration capacity (14.521%). For PC 2 largest contribution was by hydration capacity and water absorption (17.009%) followed coat proportion (15.176%) and for PC3 it was by bulk density (31.513%) followed by swelling coefficient (28.495%) and lowest by hydration capacity (0.013%). The genotypic scores for principal components (Table 7) indicates that C-8 (1.747) showed the maximum value for principal component 1 followed by C-11 (1.580), C-7 (1.518),C-7 (1.056), while as most of the other accessions including SCP-1 had negative values. For PC2, C-4 (2.356) had the highest score followed by C-13 (0.663) and SCP-1 (0.612). On the basis of principal component analysis, 100-seed weight, seed breadth, hydration capacity, swelling capacity and cooking time score were important traits identified, whereas, the genotypes C-7, C-8 and C-11 had positive values for both PC 1 and PC 2, C-12 and C-14 had positive values for PC 1 but negative values for PC 2, C-4, C-13, C-3 and SCP-1 had negative values for PC 1 and positive values for PC 2, while as rest of the genotypes had negative values for both the PC's (Fig. 1).

Table 1: Variability parameters for 10 seed physical and water absorption traits in cowpea

Trait	**Mean ± SE**	**Range**	**CV %**
Seed length (mm)	8.087 ± 0.22	6.980 – 9.660	10.523
Seed breadth (mm)	5.371 ± 0.22	4.490 – 6.980	16.067
Length breadth ratio	1.518 ± 0.034	1.340 – 1.740	8.672
Coat proportion (%)	7.829 ± 0.359	5.360 – 10.230	17.737
100 Seed weight (g)	11.71 ± 1.01	8.31- 21.33	33.390
Water absorption (%)	115.30 ±2.10	96.71-127.71	7.068
Swelling capacity (ml/seed)	0.123 ± 0.01	0.07 – 0.23	34.959
Hydration capacity (g/seed)	0.133 ± 0.01	0.096 – 0.206	27.819
Swelling coefficient (%)	234.300 ± 13.10	160.00- 370.00	21.681
Hydration coefficient (%)	215.300 ± 2.10	196.71 – 227.71	3.785
Bulk density (g/ml)	1.223 0.06	0.946 – 1.880	20.605
Cooking time score	2.867 ±0.35	1-5	47.296

Table 2: Seed physical parameters of 15 cowpea genotypes

Genotype	Seed colour	Seed shape	Eye colour	Eye pattern	Seed length (mm)	Seed breadth (mm)	Length/ breadth ratio	Coat proportion (%)	100-seed weight (g)
C1	Black	Rhomboidal	White	Absent	7.56	4.87	1.55	10.23	8.31
C2	Black	Rhomboidal	White	Absent	7.89	4.79	1.65	8.31	10.12
C3	Black	Rhomboidal	White	Absent	7.05	4.58	1.54	9.26	8.73
C4	Black	Rhomboidal	White	Absent	7.10	4.69	1.51	6.52	9.42
C5	Black	Ovoid	White	Absent	8.56	4.92	1.74	8.34	8.41
C6	Black	Rhomboidal	White	Absent	6.98	4.49	1.55	6.93	8.86
C7	Black	Globose	White	Absent	9.07	6.67	1.36	6.87	14.22
C8	Brown	Globose	Black	Holstein	9.15	6.83	1.34	5.36	16.14
C9	Black	Kidney	White	Absent	8.48	4.97	1.70	9.78	11.51
C10	Black	Rhomboidal	White	Absent	7.88	4.70	1.67	8.55	8.72
C11	Brown	Rhomboidal	Black	Holstein	8.56	6.13	1.39	6.27	16.86
C12	Black	Globose	White	Absent	8.58	5.64	1.52	6.81	13.63
C13	Black	Rhomboidal	White	Absent	7.66	5.07	1.51	7.18	9.24
C14	Brown	Ovoid	Black	Holstein	9.66	6.98	1.38	8.45	21.33
SCP-1	Black	Rhomboidal	White	Absent	7.13	5.24	1.36	8.57	10.12
SE mean	-	-	-	-	0.22	0.22	0.03	0.36	1.01

Table 3: Mean performance for hydration parameters and cooking time score for 15 cowpea genotypes

Genotype	Water absorption %	Swelling capacity (ml/seed)	Hydration capacity (g/seed)	Swelling coefficient (%)	Hydration coefficient (%)	Bulk density (%)	Cooking time score
C1	127.711	0.100	0.106	233.333	227.711	1.106	1
C2	115.841	0.115	0.117	235.294	215.841	1.188	3
C3	110.345	0.110	0.096	320.000	210.345	1.740	2
C4	124.468	0.135	0.117	370.000	224.468	1.880	2
C5	116.666	0.100	0.098	242.857	216.666	1.200	2
C6	115.909	0.085	0.102	200.000	215.909	1.035	2
C7	114.788	0.130	0.163	186.666	214.788	0.946	5
C8	111.801	0.180	0.180	238.461	211.801	1.238	5
C9	102.608	0.120	0.118	220.000	202.608	1.150	1
C10	117.241	0.090	0.102	212.5000	217.241	1.087	3
C11	119.643	0.190	0.201	226.666	219.643	1.120	5
C12	111.029	0.075	0.151	160.000	211.029	1.088	3
C13	123.913	0.095	0.114	218.750	223.913	1.150	2
C14	96.713	0.228	0.206	232.558	196.713	1.238	4
SCP-1	120.792	0.100	0.122	217.647	220.792	1.188	3
SE mean	2.10	0.01	0.01	13.11	2.10	0.06	0.35

Table 4: Correlation between seed physical, hydration parameters and cooking time score in 15 cowpea genotypes

Trait	Seed length (mm)	Seed breadth (mm)	Length breadth ratio	Coat proportion (%)	100-seed weight (g)	Water absorption (%)	Swelling capacity (ml/seed)	Hydration capacity (g/seed)	Swelling coefficient (%)	Hydration coefficient (%)	Bulk density (g/ml)	Cooking time score
Seed length (mm)	-	0.847**	-0.264	-0.239	0.813**	-0.602**	0.631**	0.766**	-0.404	-0.602**	-0.401	0.617**
Seed breadth (mm)		-	-0.735**	-0.455	0.916**	-0.437	0.755**	0.926**	-0.312	-0.437	-0.290	0.827**
Length breadth ratio			-	0.517	-0.636*	0.024	-0.557	-0.718**	0.068	0.024	0.023	-0.702**
Coat proportion (%)				-	-0.379	-0.117	-0.281	-0.500	0.055	-0.117	0.012	-0.650*
100-seed weight (g)					-	-0.607**	0.853**	0.971**	-0.238	-0.607**	-0.189	0.740**
Water absorption %						-	-0.449	-0.416	0.179	1.000**	0.057	-0.208
Swelling capacity (ml/seed)							-	0.835**	0.194	-0.449	0.127	0.619**
Hydration capacity (g/seed)								-	-0.240	-0.416	-0.212	0.818**
Swelling coefficient (%)									-	0.179	0.948 **	-0.263
Hydration coefficient (%)										-	0.057	-0.208
Bulk density (g/ml)											-	-0.256
Cooking time score												-

Table 5: Eigen values (Latent roots) and rotated component loadings (values of principal component traits of cowpea)

Trait	PC 1	PC2	PC3
Seed length (mm)	**0.853**	0.311	-0.021
Seed breadth (mm)	**0.965**	-0.082	-0.083
Length breadth ratio	**-0.665**	0.539	0.134
Coat proportion (%)	-0.464	**0.576**	0.279
100 Seed weight (g)	**0.975**	0.013	0.123
Water absorption (%)	-0.571	**-0.610**	-0.483
Swelling capacity (ml/seed)	**0.806**	-0.220	0.398
Hydration capacity (g/seed)	**0.962**	-0.158	-0.016
Swelling coefficient (%)	-0.319	-0.549	**0.754**
Hydration coefficient (%)	-0.571	**-0.610**	-0.483
Bulk density (g/ml)	-0.281	-0.499	**0.793**
Cooking time score	**0.836**	-0.303	-0.235
Eigen value	6.375	2.185	1.996
% variation	53.129	18.206	16.636
Cumulative variance (%)	53.129	71.335	87.971

Table 6: Contribution of traits (%) to the principal components

TRAITS	PC-1	PC-2	PC-3
Seed length (mm)	11.423	4.425	0.021
Seed breadth (mm)	14.608	0.309	0.343
Length breadth ratio	6.946	13.297	0.901
Coat proportion (%)	3.380	15.176	3.909
100 Seed weight (g)	14.901	0.007	0.754
Water absorption (%)	5.109	17.009	11.668
Swelling capacity (ml/seed)	10.202	2.212	7.954
Hydration capacity (g/seed)	14.521	1.150	0.013
Swelling coefficient (%)	1.595	13.812	28.495
Hydration coefficient (%)	5.109	17.009	11.668
Bulk density (g/ml)	1.238	11.378	31.513
Cooking time score	10.967	4.215	2.761

Table 7: Genotype wise scores for principal components for 10 seed physical and hydration parameters in cowpea

Genotypes	PC-1	PC-2
C1	**-0.957**	0.464
C2	**-0.522**	-0.141
C3	**-0.677**	0.545
C4	0.201	**2.356**
C5	**-0.904**	-0.340
C6	**-0.736**	0.053
C7	**1.056**	-0.365
C8	**1.747**	0.166
C9	-1.077	**-1.732**
C10	**-0.846**	-0.293
C11	**1.580**	0.510
C12	0.027	**-0.827**
C13	-0.321	**0.663**
C14	1.518	**-1.672**
SCP-1	-0.087	**0.612**

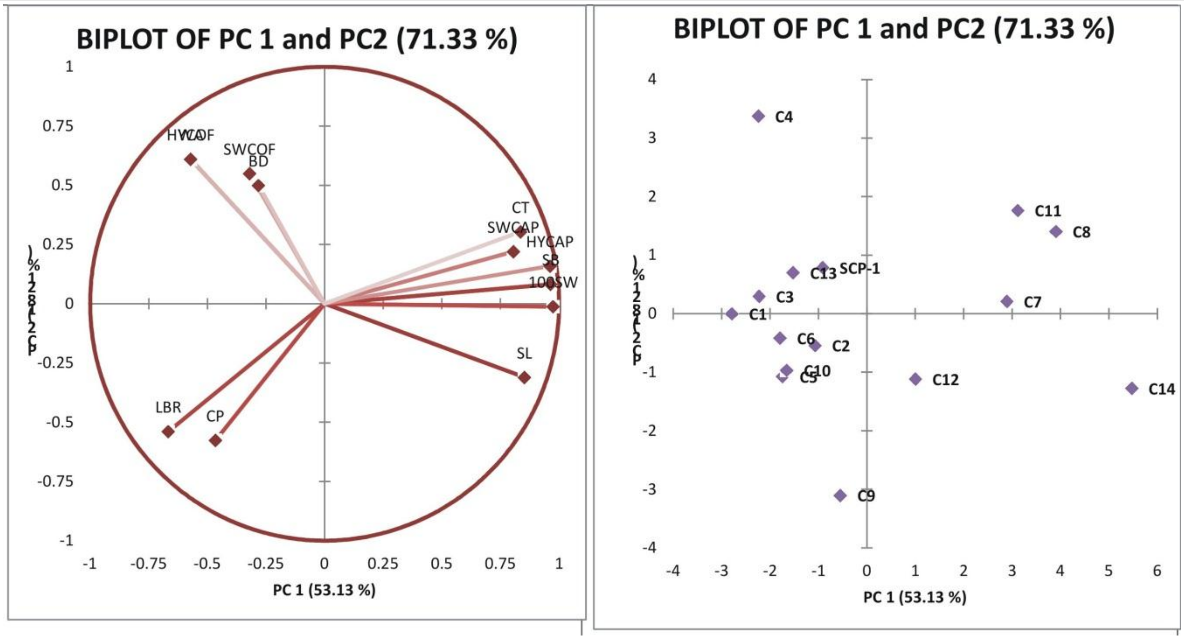

Fig. 1: Genotype v/s trait biplot for seed physical and water hydration parameters

CONCLUSION

Hydration parameters can be used as effective and reliable indicators of cooking quality and identification of hard to cook trait. These parameters can be used to screen large germplasm sets especially in view of laborious methods of direct cooking protocols.

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