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Dimensional and Physical Properties of Temperate Highland Rice Varieties

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During the present investigation, eight commonly grown rice varieties of temperate highland regions of Kashmir were selected to study different quality attributes. The dimensional and physical properties of selected rice varieties differed significantly ($p \leq 0.05$). With regard to colour coordinates (L*, a*, b*, chroma and hue angle), all the varieties showed significant ($p \leq 0.05$) variation except b* value. Very high significant ($P \leq 0.01$) correlations were noticed amongst the different dimensional and physical attributes. Based on the nature and magnitude of character association recorded in the present study, the inference drawn was that dimensional properties like length, width, L/W ratio, thickness, equivalent diameter (De), geometric diameter (Dg), arithmetic diameter (Da), area of transverse surface (At), surface area (S) and aspect ratio (Ra); physical properties like 1000 grain weight, bulk density (BD), true density (TD), hardness and chalkiness should be used to formulate the selection indices for development of quality rice for temperate highland regions.

Keywords: Engineering properties, Pearson correlation, Systematic classification, Temperate rice

Introduction

There are more than 20,000 varieties of rice grown across the Indian sub-continent. Due to diverse agro-ecological conditions, there exists an ethnic preference for particular rice varieties in different regions of the country. Rice cultivars grown in different regions vary in their basic composition and physico-chemical attributes owing to the influence of varied geographic, climatic and genetic factors.[1] Therefore, in order to access the effect of such factors on the quality of rice, it becomes imperative to determine the dimensional and physical properties of rice cultivars grown under different climatic conditions. The data base pertaining to such properties will be useful in designing of various post-harvest processing/ handling equipments, storage structures, as well as for the heat and mass transfer applications.[2] In Kashmir valley, rice is cultivated over an area of about 1.43 lakh hectares with an annual production of 38.62 lakh quintals.[3] Thus, the study was undertaken to document the dimensional and physical properties of temperate highland rice varieties which was deemed essential for post-harvest processing and breeding programmes. A correlation analysis was also done to determine the relationship amongst different properties.

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Materials and Methods

Raw Material Selection and Sample Preparation

Eight commonly grown rice varieties (i.e., SR-2, Basmati-1509, Koshikari, China-1007, SKUA-402, Chenab, Jhelum and K-332) were procured from the Mountain Research Centre for Field Crops, Khudwani, Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashmir, (SKUAST-K), India and were subjected to milling in a modern rice mill (ASR RM 209, India) at Division of Food Science and Technology, SKUAST-K. Polished head rice obtained from each variety were dried to moisture content of 11–12% ± 0.12 in a cabinet drier (LSI-EC-STB), Lab Solutions, India at a temperature of 40 ± 5°C and stored separately in air tight containers under ambient conditions for further analysis.

Dimensional Properties

Whole rice grains from each selected variety were transferred to the medium grain rice tray, scanned at 300 dpi and analyzed with a Seed Count (Digital Image Analysis) system. The true kernel length, width and thickness were measured through seed count software using algorithms. The length/width (L/W ratio) was calculated and rice varieties were classified based on size, shape (as per SES/INGER, IRRI 1996) and systematic classification. Different derived dimensional properties like equivalent diameter, geometric diameter, arithmetic diameter, area of transverse surface, surface area, volume, aspect ratio and sphericity were calculated from principal dimensional values (L, W, T) using the standard relationships reported by Hussain & Singh (2014).[5]

Physical Properties

1000 Grain Weight

Randomly selected 250 whole rice grains from each variety were weighed by means of an electronic balance (accuracy of 0.001 g) and thousand grain weight was determined by multiplying the value by 4.

Bulk Density, True Density and Porosity

The bulk density (ρ_b) was determined using the mass/volume relationship and true density (ρt) was determined by toluene displacement method. Porosity was calculated from the bulk and true densities using the following relationship:[6]

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \qquad \ldots (1)$$

ε is the porosity (%), ρ_b is the bulk density (kg/m^3) and ρ_t is the true density (kg/m^3).

Grain Hardness

Grain hardness was measured by Texture Analyzer (TA-HD, Stable Micro Systems Ltd, Surrey, UK) using compression test. A 5 mm diameter stainless steel probe (P/5) was used at a test speed of 0.10 mm/sec. The peak force indicated by the force time curve was taken as the maximum compressive force/ hardness of grains.[6]

Chalkiness

Chalkiness of grains was determined by placing ten randomly selected grains on a light box and grains with ≥ 50% chalky content were visually identified. Percent chalkiness was calculated using the following equation

$$\text{Chalkiness (\%)} = \frac{Weight\ of\ chalky\ grains\ (g)}{Total\ weight\ of\ grains\ (g)} \times 100 \qquad \ldots (2)$$

Instrumental Color

The colour measurement i.e., L*- lightness vs dark (0–50 = dark; 51–100 = light), a*- redness vs greeness (positive value = red; negative value = green), and b*- yellowness vs blueness (positive value = yellow; negative value = blue) of grains were performed using a Hunter Lab Calorimeter (Model CM-508d Minolta co., Japan). Chroma (c*) and hue angle were calculated using the following relationships:

$$\text{Chroma value } (c^*) = \sqrt{{a^*}^2 + {b^*}^2} \qquad \ldots (3)$$

$$\text{Hue angle } (°) = tan^{-1}\ \frac{b^*}{a^*} \qquad \ldots (4)$$

Statistical Analysis

All the experiments were conducted in triplicates and results are expressed as mean ± SD. Analysis of data was done by one-way analysis of variance (ANOVA) and Pearson correlation coefficients were computed using SPSS 20.0 statistical software. Difference between treatment means were calculated at 5% level of significance for ANOVA, and at 5 and 1% level of significance for correlation analysis.

Results and Discussion

Dimensional Properties of Selected Rice Varieties

The data presented in Table 1 indicates that dimensional properties of various rice varieties were significantly ($p \leq 0.05$) different. The grain length was found in the range of 4.47 mm (K-332) to 7.88 mm (Basmati-1509), grain width in the range of 1.73 mm (Basmati-1509) to 2.70 mm (SKUA-402) while thickness was found in the range of 1.55 mm for Basmati-1509 to 2.06 mm for SKUA-402. Rasool *et al*. (2015)[7] also reported mean length and width of different rice varieties almost within the same range. Length to width (L/W) ratio of selected rice varieties ranged from 1.74 to 4.55 (Table 1). Lowest L/W ratio was recorded for SKUA-402 and K-332 (1.74) while, highest value was recorded for Basmati-1509 (4.55). L/W ratio is used to classify grains based on size and shape. On the basis size classification, Basmati-1509 was classified as extra long; SR-2, Chenab and Jhelum as medium, whereas Koshikari, China-1007, SKUA-402 and K-332 were classified as short grain type varieties. Based on the shape, Basmati-1509 was classified as slender variety, SR-2, China-1007, Chenab and Jhelum as medium varieties while as Koshikari, SKUA-402 and K-332 were classified as bold type varieties. However, based on systematic classification, Basmati-1509 was classified as Long slender (LS); China-1007 and Chenab as Medium slender (MS); SR-2 and Jhelum as Long bold (LB) whereas Koshikari, SKUA-402 and K-332 were classified as Short bold (SB) varieties. Such type of classifications will be helpful to plant breeders as they rely much on size and shape of grains while developing improved varieties for commercial purposes. The equivalent (De), geometric diameter (Dg) and arithmetic diameter (Da) of different rice cultivars varied from 2.75 mm (China-1007) to 3.01 mm (SR-2), 2.74 mm (China-1007) to 2.99 mm (SR-2)

Table 1 — Dimensional and physical properties of commonly grown rice varieties of temperate regions of Kashmir

Varieties	SR-2	Basmati- 1509	Koshikari	China-1007	SKUA-402	Chenab	Jhelum	K-332	CD ($p<0.05$)
Dimensional properties									
Length (L) (mm)	$6.33^{b} \pm 0.38$	$7.88^{a} \pm 0.26$	$5.01^{e} \pm 0.28$	$5.49^{d} \pm 0.18$	$4.70^{ef} \pm 0.13$	$5.66^{cd} \pm 0.04$	$6.04^{bc} \pm 0.27$	$4.47^{f} \pm 0.08$	0.398
Width (W) (mm)	$2.40^{cd} \pm 0.04$	$1.73^{f} \pm 0.03$	$2.65^{ab} \pm 0.52$	$2.16^{e} \pm 0.17$	$2.70^{a} \pm 0.06$	$2.23^{e} \pm 0.07$	$2.42^{d} \pm 0.03$	$2.56^{bc} \pm 0.03$	0.128
Thickness (mm)	$1.77^{bc} \pm 0.03$	$1.55^{d} \pm 0.04$	$1.90^{ab} \pm 0.15$	$1.74^{bcd} \pm 0.03$	$2.06^{a} \pm 0.3$	$1.8^{bc} \pm 0.03$	$1.67^{cd} \pm 0.05$	$1.85^{bc} \pm 0.06$	0.199
L/W	$2.63^{b} \pm 0.12$	$4.55^{a} \pm 0.03$	$1.89^{c} \pm 0.03$	$2.54^{b} \pm 0.16$	$1.74^{c} \pm 0.03$	$2.53^{b} \pm 0.12$	$2.49^{b} \pm 0.05$	$1.74^{c} \pm 0.04$	0.151
Equivalent diameter, De (mm)	$3.01^{a} \pm 0.09$	$2.76^{b} \pm 0.05$	$2.95^{ac} \pm 0.05$	$2.75^{b} \pm 0.19$	$2.98^{ad} \pm 0.06$	$2.84^{bcd} \pm 0.12$	$2.93^{adc} \pm 0.06$	$2.79^{bc} \pm 0.03$	0.163
Geometric diameter, Dg (mm)	$2.99^{a} \pm 0.04$	$2.76^{c} \pm 0.04$	$2.93^{ab} \pm 0.04$	$2.74^{c} \pm 0.15$	$2.96^{ab} \pm 0.04$	$2.83^{bc} \pm 0.13$	$2.9^{ab} \pm 0.02$	$2.76^{c} \pm 0.05$	0.135
Arithmetic diameter, Da (mm)	$3.5^{b} \pm 0.04$	$3.72^{a} \pm 0.07$	$3.18^{d} \pm 0.04$	$3.13^{d} \pm 0.05$	$3.15^{d} \pm 0.03$	$3.23^{d} \pm 0.06$	$3.37^{c} \pm 0.04$	$2.96^{e} \pm 0.06$	0.108
Area of transverse surface, At (mm^2)	$3.33^{d} \pm 0.03$	$2.10^{f} \pm 0.03$	$3.95^{b} \pm 0.09$	$2.95^{e} \pm 0.31$	$4.36^{a} \pm 005$	$3.15^{de} \pm 0.06$	$3.17^{d} \pm 0.03$	$3.71^{c} \pm 0.07$	0.210
Surface area, S (mm^2)	$24.45^{a} \pm 0.34$	$22.59^{c} \pm 0.05$	$22.73^{bc} \pm 0.07$	$20.27^{e} \pm 0.22$	$23.20^{b} \pm 0.77$	$21.62^{d} \pm 0.09$	$22.86^{bc} \pm 0.01$	$20.16^{e} \pm 0.01$	0.538
Volume, V (mm^3)	$14.39^{a} \pm 0.4$	$11.08^{fg} \pm 0.09$	$13.56^{c} \pm 0.07$	$10.85^{g} \pm 0.19$	$13.92^{b} \pm 0.03$	$12.01^{e} \pm 0.04$	$13.21^{d} \pm 0.06$	$11.36^{f} \pm 0.06$	0.288
Aspect ratio, Ra	$0.37^{b} \pm 0.07$	$0.22^{c} \pm 0.04$	$0.52^{a} \pm 0.05$	$0.39^{b} \pm 0.04$	$0.57^{a} \pm 0.05$	$0.39^{b} \pm 0.03$	$0.4^{b} \pm 0.04$	$0.57^{a} \pm 0.06$	0.086
Sphericity (%)	$47^{c} \pm 3.05$	$35^{d} \pm 4.04$	$58^{ab} \pm 6$	$49^{c} \pm 4.04$	$62^{a} \pm 4.04$	$50^{bc} \pm 4.04$	$48^{c} \pm 5.50$	$61^{a} \pm 5.50$	8.01
Physical properties									
1000 grain weight (gm)	$23.72^{a} \pm 0.07$	$21.6^{c} \pm 0.2$	$22.16^{b} \pm 0.04$	$19.84^{g} \pm 0.04$	$20.4^{f} \pm 0.04$	$21.28^{d} \pm 0.07$	$20.68^{e} \pm 0.04$	$18.8^{h} \pm 0.31$	0.239
Bulk density (kg/m^3)	$626^{cd} \pm 3$	$600^{e} \pm 4.04$	$675^{a} \pm 4$	$617.33^{d} \pm 5.50$	$682^{a} \pm 9.01$	$642.66^{b} \pm 6.02$	$630.96^{c} \pm 6$	$604^{e} \pm 5$	9.681
True density (kg/m^3)	$1405^{d} \pm 4$	$1370.21^{f} \pm 16$	$1482.2^{b} \pm 5.01$	$1385.34^{e} \pm 6.05$	$1503.46^{a} \pm 3.5$	$1438.83^{c} \pm 4.10$	$1415.62^{d} \pm 5.6$	$1370.23^{f} \pm 9.25$	13.404
Porosity (%)	$55.44^{ab} \pm 0.15$	$56.21^{a} \pm 0.70$	$54.45^{c} \pm 0.16$	$55.43^{ab} \pm 0.14$	$54.63^{bc} \pm 1.18$	$55.33^{abc} \pm 0.21$	$55.42^{ab} \pm 0.1$	$55.91^{a} \pm 0.39$	0.902
Grain hardness (N)	$65.41^{d} \pm 0.90$	$129.54^{a} \pm 6.50$	$126.99^{ab} \pm 1.40$	$68.65^{d} \pm 5.05$	$120.64^{b} \pm 5.35$	$63.05^{de} \pm 2.65$	$58.64^{e} \pm 0.35$	$93.44^{c} \pm 1.95$	6.42
Chalkiness (%)	$30^{b} \pm 10$	$60^{a} \pm 10$	$20^{bc} \pm 10$	$10^{c} \pm 5.50$	$10^{c} \pm 4.50$	$20^{bc} \pm 10$	$20^{bc} \pm 10$	$20^{bc} \pm 10$	15.610
Instrumental color L*	$85.87^{abc} \pm 0.48$	$84.89^{bc} \pm 0.44$	$84.04^{c} \pm 0.67$	$86.85^{ab} \pm 1.36$	$85.04^{c} \pm 1.58$	$87.80^{a} \pm 0.44$	$86.07^{ab} \pm 1.76$	$86.54^{ab} \pm 1.57$	2.03
a*	$-0.74^{a} \pm 0.07$	$-0.59^{a} \pm 0.15$	$-0.50^{a} \pm 0.06$	$-0.49^{a} \pm 0.18$	$-0.71^{a} \pm 0.14$	$-0.55^{a} \pm 0.10$	$-0.65^{a} \pm 0.16$	$-0.23^{b} \pm 0.20$	0.251
b*	12.97	12.72	13.85	11.99	12.19	12.20	12.13	12.52	NS
c*	$12.99^{b} \pm 0.43$	$12.73^{bc} \pm 0.70$	$13.85^{a} \pm 0.21$	$12.00^{d} \pm 0.1$	$12.21^{cd} \pm 0.17$	$12.21^{cd} \pm 0.28$	$12.14^{cd} \pm 0.45$	$12.52^{bcd} \pm 0.08$	0.630
Hue angle	$86.73^{e} \pm 0.58$	$87.34^{cd} \pm 0.20$	$87.93^{b} \pm 0.07$	$87.65^{bc} \pm 0.11$	$86.66^{e} \pm 0.33$	$87.41^{c} \pm 0.20$	$86.93^{de} \pm 0.06$	$88.94^{a} \pm 0.05$	0.453

Mean values in the rows with different superscripts are significantly different at $p \leq 0.05$. NS =Non-Significant; CD= Critical Difference

and 2.96 mm (K-332) to 3.72 mm (Basmati-1509) respectively. Area of transverse surface (At) of different rice grains ranged from 2.10 mm^2 (Basmati-1509) to 4.36 mm^2 (SKUA-402) and surface area (S) from 20.16 mm^2 for K-332 to 24.45 mm^2 for SR-2. Lowest volume (V) (10.85 mm^3) was occupied by China-1007 and highest (14.39 mm^3) by SR-2. Aspect ratio demonstrates the tendency to slide or roll on flat surfaces. Aspect ratio (Ra) of different rice varieties ranged from 0.22 for Basmati-1509 to 0.57 for SKUA-402 and K-332. Thus, SKUA-402 and K-332 varieties tend to slide easily on flat surfaces than other varieties. Sphericity of different rice varieties varied from 35% for Basmati-1509 to 62% for SKUA-402 (Table 1) which indicates that, SKUA-402 grains are more spherical than rice grains of other varieties. Bhat and Riar (2016) reported sphericity range of 49 to 63% for different traditional brown rice cultivars. Sphericity has an inverse relationship with length, thus round grains have higher sphericity than cylindrical ones.[2] In our study also, highest sphericity as well as lowest L/W ratio were exhibited by the same variety i.e., SKUA-402 (Table 1).

Physical Properties of Selected Rice Varieties

The data depicted in Table 1 indicates that physical properties of different rice varieties differed significantly ($p \leq 0.05$). The thousand grain weight varieties varied from 18.8 g for K-332 to 23.72 g for SR-2. Rasool *et al*. (2015)[7] also reported more or less similar range of 1000 grain weight for different rice varieties. 1000 grain weight is an important physical parameter to predict the milling recovery and flour yield. The 1000 grain weight of above 20 g indicates the presence of sound, intact and mature grains.[2] Highest 1000 grain weight of SR-2 variety (Table 1) could be attributed to its highest De (3.01mm) (Table 1). Bulk density (BD) of different rice varieties varied from 600 kg/m^3 for Basmati-1509 to 682 kg/m^3 for SKUA-402 and true density (TD) from 1370.21 kg/m^3 (Basmati-1509) to1503.46 kg/m^3 (SKUA-402) (Table 1). Granule structure compaction governs the density of grains. Therefore, the presence of internal voids and air spaces in grain endosperm tends to decrease the density of grains.[2] Hussain and Singh (2014)[5] reported that grains having higher L/B ratio tend to have lower density. During the present study also, variety (i.e., Basmati-1509) having lowest BD (600 kg/m^3) and TD (1370.21 kg/m^3) was having highest L/B ratio (4.55) (Table 1). Grain porosity varied from 54.45% for Koshikari to 56.21% for Basmati-1509. Since porosity is a function of BD and TD. Therefore, highest porosity value (56.21%) of Basmati-1509 might be due to its lowest TD value. Grain hardness is an important textural attribute which maximizes the milling yield depending upon the moisture content and starch granular structure. Hardness of selected rice varieties ranged from 58.64

N for Jhelum to 129.54 N for Basmati-1509 (Table 1). Chalkiness which is characterized by the presence of opaque portions (white core) in milled rice grains is an important parameter to predict the milling recovery in rice. Therefore, higher chalk content downgrades the market value of grains.[8] Chalkiness of different rice varieties ranged from 10 to 60% (Table 1). Lowest chalkiness percentage was recorded in China-1007 and SKUA-402 and highest in Basmati-1509. Chalkiness formation in grains depends on numerous factors including climatic conditions, fertilizer dosage, planting density and variety type. Feng *et al*. (2017)[9] reported that higher chalkiness degree was observed in Indica varieties as compared to Japonica types.

Colour Values

Grain colour is one of the most important quality attributes to govern the consumer acceptability. Brightness (L*- value) of various rice varieties ranged from 84.04 to 87.80 (Table 1). L* values of different rice varieties showed non-significant difference except Chenab and Koshikari. Highest L* value (87.80) was recorded for Chenab and lowest for Koshikari (84.04) while a*-value (greeness) was highest for SR-2 (−0.74) and lowest (−0.23) for K-332. However, there was non-significant difference in b* values amongst the tested varieties. Chroma (c* value) calculated for different rice varieties varied from 12.00 (China-1007) to 13.85 (Koshikari) while the hue angle varied from 86.66 (SKUA-402) to 88.94 (K-332). These colour variations in different rice varieties can be attributed to inherent factors like grain composition, genetic variability, and presence of pigments.[2] In addition, degree of milling is also known to affect the grain colour.[10] Kraithong *et al*. (2018)[11] also reported that lower b* value of white rice can be attributed to lower carotenoid content of white rice compared to brown rice while, Morales-Martínez *et al*. (2014)[10] reported that redness and yellowness of grains is inversely related to degree of milling.

Correlations among Various Dimensional and Physical Properties of Selected Rice Varieties

Pearson correlation coefficients among various dimensional and physical parameters of rice varieties have been presented in Table 2. Length exhibited highly significant ($p \leq 0.01$) positive correlations with L/W, Da, chalkiness and negative correlations with width, thickness, At, Ra and sphericity. Width showed highly significant ($p \leq 0.01$) positive correlation with thickness, De, Dg, At, V, Ra, sphericity and negative correlation with L/W, Da and chalkiness. L/W ratio showed highly significant ($p \leq 0.01$) positive correlations with Da, chalkiness and negative correlations with thickness, De, At, V, Ra and sphericity. Thickness showed highly significant ($p \leq 0.01$) positive correlations with De, At, Ra, sphericity, true density and negative correlations with Da. De showed highly significant ($p \leq 0.01$) positive correlations with Dg, At, S, V, bulk density and true density. Dg showed highly significant ($p \leq 0.01$) positive correlations with At, S, V, 1000 grain weight, bulk density and true density. Da showed highly

Table 2 — Pearson correlation between various dimensional and physical properties of selected rice cultivars

	L	W	L/W	Thickness	De	Dg	Da	At	S	V	Ra	Sphericity	1000 Grain weight	BD	TD	Porosity	Hardness	Chalkiness
L																		
W	−0.927**																	
L/W	0.959**	−0.971**																
Thickness	−0.702**	0.759**	−0.683**															
De	−0.350*	0.546**	−0.475**	0.502**														
Dg	−0.292	0.527**	−0.444*	0.317	0.713**													
Da	0.805**	−0.691**	0.780**	−0.498**	−0.211	−0.183												
At	−0.931**	0.960**	−0.944**	0.786**	0.525**	0.486**	−0.710**											
S	0.408*	−0.115	0.255	−0.078	0.570**	0.638**	0.488**	−0.123										
V	−0.375*	0.646**	−0.551**	0.423*	0.841**	0.893**	−0.159	0.606**	0.662**									
Ra	−0.883**	0.876**	−0.897**	0.754**	0.255	0.316	−0.821**	0.891**	−0.358*	0.369*								
Sphericity	−0.901**	0.823**	−0.828**	0.787**	0.455*	0.137	−0.658**	0.864**	−0.353*	0.306	0.729**							
1000 Grain weight	0.395*	−0.170	0.270	−0.145	0.420*	0.481**	0.436*	−0.169	0.805**	0.486**	−0.335	−0.369*						
BD	−0.082	0.260	−0.149	0.264	0.502**	0.545**	0.000	0.351*	0.574**	0.600**	0.167	0.126	0.445*					
TD	−0.234	0.388*	−0.256	0.530**	0.539**	0.552**	−0.088	0.512**	0.526**	0.615**	0.318	0.324	0.261	0.875**				
Porosity	−0.280	0.197	−0.207	0.367*	−0.049	0.044	−0.297	0.279	−0.192	−0.049	0.304	0.301	−0.431*	−0.314	0.140			
Hardness	0.058	−0.136	0.219	0.227	−0.227	−0.244	0.064	0.047	−0.056	−0.262	0.067	0.096	0.005	0.433*	0.501**	0.057		
Chalkiness	0.709**	−0.771**	0.801**	−0.438*	−0.323	−0.285	0.480**	−0.698**	0.149	−0.506**	−0.682**	−0.569**	0.284	−0.115	−0.173	−0.032	0.352*	

*Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level
L/W length/width ratio; De Equivalent diameter; Dg Geometric diameter; Da Arithmetic diameter; S Surface Area; V Volume; Ra Aspect ratio; BD bulk density; TD true density.

significant ($p \leq 0.01$) positive correlations with S, chalkiness and negative correlations with At, Ra and sphericity. At showed highly significant ($p \leq 0.01$) positive correlations with V, Ra, sphericity and true density. Surface area exhibited highly significant ($p \leq 0.01$) positive correlations with V, 1000 grain weight, bulk density, true density. Volume exhibited highly significant ($p \leq 0.01$) positive correlations with 1000 grain weight, bulk density and true density. Sphericity was positively correlated with Ra. Chalkiness showed highly significant ($p \leq 0.01$) negative correlation to Ra, sphericity, At and V. Bulk density exhibited highly significant ($p \leq 0.01$) positive correlation with 1000 grain weight, true density. True density showed highly significant ($p \leq 0.01$) positive correlation with hardness. Many researchers in past have reported more or less similar correlations for different dimensional and physical properties of rice.[2,7]

Conclusions

The findings of the present study confirmed the varietal influence upon dimensional and physical attributes of rice. The perusal of results showed that the dimensional and physical properties of rice vary from short to long grain varieties. It can be suggested that Basmati-1509 is a perfect nomination to be used as parent in development of long slender type variety for temperate highland regions. Further, the information generated on dimensional and physical properties during the present investigation will help food engineers to promote technological intervention in post-harvest handling of rice. The character association devised through correlation analysis may be useful for generating correlated response from selection of more heritable traits for improving traits with low heritability. However, path analysis with even larger number of genotypes of temperate Himalayan regions will help to hasten the breeding programmes of quality rice for such regions.

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