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Research Article

Genotypic studies for value addition traits in pearl millet

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Abstract
In the present study, attempt was made to identify pearl millet (*Pennisetum glaucum* L. R. Br.) genotypes having good processing potential as well as to estimate variability, heritability and genetic advance among eight genotypes, including five composites *viz.* PCB 164, PC 334, PC 443, PC 612, Dhanshakti and three hybrids *viz.* PHB 2168, PHB 2884, PHB 3053. The ancillary data was recorded on different morphological traits and extruded snacks were prepared form these genotypes. Phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) showed higher values of PCV than GCV for all the traits studied. Ear length showed high estimates of heritability with high genetic advance as percent of mean. The processing studies showed that genotypes PCB 164 and PC 443 had highest appearance and texture and were at par in the flavor. Also, these two genotypes had higher overall acceptability based on sensory evaluation.

Key words
Pearl millet, variability studies, extruded snacks

Introduction

Pearl millet (*Pennisetum glaucum* L. R. Br.) is an important coarse grain cereal grown on 26 m ha for food, feed and fodder in different parts of the semi arid tropical environments of Asia and Africa. India is the largest producer of pearl millet both in terms of area (7.12 m ha) and production (8.06 mt) with an average productivity of 1132 kg/ha (Directorate of Millets Development, 2017). It is cultivated mainly in sandy, infertile soils and droughty environments where no other cereal crops can survive. The increasing urbanization and industrialization is putting heavy pressure on water resources for agricultural use. Further, the climate change may also lead to variable water scarcity. Pearl millet is not only the most water use efficient but also most heat tolerant cereal under water limiting environments. Pearl millet grain is highly nutritious enriched with high dietary fiber, protein and fat, balanced amino acid profile and high levels of micronutrients especially Fe and Zn, polyphenols and antioxidants, thus, making it a promising crop to address both energy and micronutrient malnutrition issues. Thus, there is need to promote pearl millet as a nutri-cereal and health food rather than coarse grain cereal, not only in the areas where it is traditionally produced and consumed but also in non-traditional areas within India and elsewhere. Genetic variability for agronomic traits is the key component of pearl millet breeding programmes for broadening the gene pool. The overall performance of a genotype may vary due to changes in the environment and if the heritability of the traits is higher, the selection process will be simpler and response to selection will be greater (Soomro *et al*., 2008). The information on variability and heritability of characters is essential for identifying characters amenable to genetic improvement through selection (Vidya *et al*., 2002). The present investigation was carried out to identify various pearl millet genotypes having good processing potential as well as to estimate variability, heritability and genetic advancement in pearl millet hybrids and cultivars.

Materials and Methods

This experiment was conducted during *kharif* 2016 at Forage and Millet Research Farm, Department of Plant Breeding and Genetics, Punjab Agricultural University (PAU), Ludhiana. Eight genotypes includes five composites *viz.* PCB 164 (PAU, Ludhiana), PC 334, PC 443, PC 612 (IARI, New Delhi) and Dhanshakti (ICRISAT, Hyderabad) and three hybrids *viz.* PHB 2168, PHB 2884 and PHB 3053 (PAU) were evaluated for processing quality and agronomic performance.

The ancillary data was recorded on randomly selected plants on traits *viz*., days to 50% flowering, plant height (cm), ear length (cm), ear girth (cm), number of productive tillers and grain yield (q/ha) and was analyzed to study the variation observed in all the genotypes. Further, mean separation of genotypes was accomplished by Tukey’s Honest Significant Difference test. Genotypic and phenotypic coefficient of variance was estimated (Burton *et al*., 1953). Heritability, genetic advance (GA) and GA (% of mean) were

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calculated (Lush, 1949). All data analyzed was carried out using SAS software version 9.4.
To study the processing quality of genotypes, first genotypes were grounded into powder using cemotac flour mill.

For the preparation of extruded snacks a co-rotating intermeshing twin screw extruder (Clextral, Firminy, France) having barrel diameter and length to diameter (L/D) of 2.5 mm and 16:1, respectively was used. The extruder barrel was divided into 4 zones and temperature maintained was 40, 70 and 100 ^{o}C in first, second and third zone, respectively. Raw material was fed into the extruder with a single screw volumetric feeder. The moisture content of feed was adjusted by injecting water into the extruder through pump. A variable speed die face cutter with four blade knives was used to cut the extrudates.

Extruded products prepared from different genotypes were evaluated for various physical and functional properties like

Expansion Ratio
The ratio of diameter of extrudate and the diameter of die (6 mm) was used to express the expansion of extrudate (Fan *et al*., 1996). The diameter of extrudate was determined as the mean of 10 random measurements made with a vernier caliper. The extrudate expansion ratio was calculated by following formula:

$$\text{Expansion ratio} = \frac{\text{Extrudate diameter (mm)}}{\text{Die diameter (mm)}}$$

Bulk Density
The bulk density (g/ml) of extruded products was measured by rapeseed displacement method using 100 ml graduate cylinder. The volume of 20 g randomize sample was measured for each test. The ratio of sample weight and the replaced volume in cylinder was calculated as density (Patil *et al*., 2007).

$$\text{Bulk Density} = \frac{\text{Weight of extrudates (g)}}{\text{Volume extrudates (ml)}}$$

Water absorption index (WAI)
Water absorption index of the extruded snacks was determined using the method outlined by Anderson *et al* (1969). It measures the volume occupied by the granule or starch polymer after swelling in excess of water. The ground extrudates were suspended in distilled water at room temperature (34 °C) for 30 minutes, gently stirred during this period, and then centrifuged at 3000g for 15 minutes. The supernatant liquid was poured carefully into tared evaporating dish. The remaining gel was weighed and water absorption index was calculated as the grams of gel obtained per gram of solid.

$$\text{Water absorption index} = \frac{\text{Weight of sediment (g)}}{\text{Weight of dry solids (g)}}$$

Water solubility index (WSI)
The WSI was the weight of dry solids in the supernatant from the water absorption index test described above (Anderson *et al*., 1969) and expressed as a percentage of the original weight of the sample.

$$\text{Water solubility index (\%)} = \frac{\text{Weight of dissolved solid in supernatant (g)}}{\text{Weight of dry solids (g)}} \times 100$$

Textural quality of the extruded snacks was examined by using a TA-XT2i Texture Analyzer (Stable Microsystems ™, Surrey, UK). The compression probe (75 mm diameter, aluminium cylinder) was applied to measure the compression force required for samples breakage which indicates hardness expressed in Newton. Other properties like springiness, cohesiveness, chewiness and resilience were also measured. Springiness is how well a product physically springs back after it has been deformed during the first compression and has been allowed to wait for the target time between strokes. The spring back is measured at the down-stroke of the second compression. Cohesiveness is the capability of the product to withstand a second deformation relative to its resistance under the first deformation. Cohesiveness takes an account of the strength of internal linkages in the sample. Chewiness is the amount of force required to masticate product at constant rate in order to reduce its particle size such that it is suitable enough for swallowing.

Extruded products were evaluated for sensory attributes (appearance, texture, flavor and over all acceptability) through a panel of semi-trained judges using 9- point hedonic scale (Larmond, 1970). The scale ranges from like extremely to dislike extremely, where 1 stands for liked extremely and 9 for disliked extremely.

Results and Discussion
The eight genotypes of pearl millet differ significantly for all the traits studied *viz*., days to 50% flowering, plant height (cm), ear length (cm), ear girth (cm), number of productive tillers and grain yield (q/ha). The plant height varied between 181-238 cm, ear length: 17.63 -29.0 cm, ear girth: 8.33-11.89 cm, number of productive tillers: 1.45-2.89, days to 50% flowering: 42-51 and grain yield: 15.20-26.66 q/ha (Table 1 and Fig. 1). Results of this study showed that the genotype PHB 2884, PC 443 and PHB 2168 took maximum days to 50% flowering and were grouped in a single group. The earliest flowering genotype was PC 334 and was at par with PCB 164. Maximum ear length was noticed in PC 334 followed by PHB 2884 but

maximum ear girth was recorded in PHB 2884 and minimum was recorded in PC 612. Maximum number of productive tillers were recorded in PC 334. The maximum grain yield was recorded in hybrid PHB 2884. In a study, Bhardwaj *et al* (2014) also reported higher seed yield of hybrid PHB 2884 which may be due to more ear length and ear girth.

The estimates of genetic parameters like mean, genotypic and phenotypic coefficient of variation, heritability, genetic advance and genetic advance (%) are presented in Table 2 and Fig. 2.

The trends of phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) showed higher values of PCV than GCV for all the traits studied (Fig. 2 and Table 2). The narrow range of difference between PCV and GCV in all the traits except number of productive tillers and grain yield suggested the less influence of environment in the expression of these traits. Sumathi *et al* (2010) also reported similar results for number of productive tillers. The perusal of results indicated that PCV was higher for grain yield and number of productive tillers. Similar results were reported by Govindaraj *et al* (2010) for these two traits. The traits ear girth, plant height and days to 50% flowering showed low PCV and GCV values. Similar results were reported by Sumathi *et al* (2010) for these three traits. Vetriventhan and Nirmalakumari (2007) also reported low PCV and GCV for days to 50% flowering and ear head breadth. Although the PCV and GCV values were medium for ear length (17.98 and 17.92) but the trait showed very high heritability (99.28%) along with high estimates of mean, genetic advance as percentage of mean (36.78%). Similarly, grain yield with high PCV and GCV values showed high heritability (75.44%) and high GA% (35.03). Similar findings for grain yield and panicle girth have been reported (Govindaraj *et al.,* 2010 and Sumathi *et al.,* 2010). The characters which exhibited high heritability and GA% of mean indicated additive gene action in its inheritance and such characters could be improved by simple selection methods (Panse, 1957). The high heritability recorded for all the traits studied showed that genotype rather than environment plays an important role in determining the phenotype suggesting the preponderance of additive gene effects in the inheritance of the traits. Concomitant results were also reported (Lakshmana and Guggari, 2001, Govindaraj *et al.,* 2011). The traits with high heritability coupled with low genetic advance were controlled by non-additive gene action.

Millets are unique among cereals and have received attention from health point of view due to their high dietary fibre content, polyphenols, proteins and richness in calcium (Devi *et al.,* 2011). To diversify the food use of pearl millet extruded snacks were prepared from different genotypes to identify the most suitable genotype on the basis of the functional properties and sensory evaluation for preparation of ready to eat extruded snacks.

Expansion ratio measures the degree of puffing undergone by the product as it exits the extruder. Expansion ratio is one of the important physical properties of the extrudates and it varies greatly with variations in extrusion processing variables. A porous, expanded, sponge-like structure is formed inside extrudates due to many tiny steam bubbles produced by rapid release of pressure after exiting the die (Suknark *et al.,* 1997). The perusal results of Expansion ratio of extrudates prepared from different pearl millet genotypes ranged from 2.47 to 3.27 indicating a good expansion ratio as per data given in Table 3. Among all pearl millet genotypes, extrudates prepared from PHB 2884 show lowest expansion ratio while PCB 164 shows highest expansion ratio followed by Dhanshakti and PC 443 genotypes. It was observed that pearl millet genotype has a significant effect on the expansion ratio of the exturdates and it varied among different genotypes. Higher expansion ratio indicates good puffed snack.

Bulk density of extrudates also describes the degree of expansion undergone by the melt as it exits the extruder. The sectional expansion ratio only considers expansion in the direction perpendicular to extrudate flow, while bulk density considers expansion in all directions (Altan *et al.,* 2008). The bulk density of extrudates from different pearl millet genotypes ranged from 0.068 to 0.107g/ml (Table 3). Among all the genotypes lowest bulk density was observed in the extrudates prepared from PCB 164, followed by PHB 2168 while highest bulk density was found in extrudates prepared from PHB 2884 genotype. As bulk density is also related to the expansion ratio of the extrudates, it was also observed that genotype with higher expansion ratio has lower bulk density. A high bulk density is associated with a low expansion index (Raysas-Duarte *et al.,* 1998 and Suknark *et al.,* 1997).

Similar to the bulk density, apparent density of extrudates prepared from different genotypes of pearl millet ranged from 0.287 to 0.590 g/ml. The highest apparent density was observed in extrudates prepared from PHB 2884 genotype and lowest in PHB 2168 (Table 3).

Water absorption index of extrudates measures the amount of water held by the starch after dispersion of starch in excess water and may be related to the degree of starch damage due to gelatinization and fragmentation of starch during high temperature and shear extrusion cooking (Anderson and Ng, 2003). WAI of extrudates prepared from different pearl millet genotypes ranged from 2.50 to 4.08 g/g. Highest WAI was observed in PCB 164 extrudates followed by PHB 2168, while extrudate from PC 443 genotypes has lowest WAI (Table 3).

Water solubility index, WSI, often used as an indicator of degradation of molecular components, measures the degree of starch conversion during extrusion, which is the amount of soluble polysaccharides released from the starch component after extrusion (Ding *et al.,* 2005). The water solubility index of extrudates measures the amount of soluble components released from starch upon extrusion and is considered an indicator of degradation of molecular components (Kirby *et al.,* 1998). The higher mean value of WSI was observed in extrudates prepared from PC 612 and PC 443 genotypes, while extrudates prepared from pearl millet genotype PCB 164 shown relatively lower values of WSI (Table 3).

The hardness is the peak force required for a probe to penetrate the extrudates. The higher the value of maximum peak force required, the higher the hardness of sample (Altan, 2008). The hardness of different extrudates ranged from 18.649 to 28.24 N (Table 4). The highest mean value of hardness was observed in extrudates from genotype PHB 2884, followed by PHB 3053 while lowest mean hardness was noticed in the extrudates prepared from genotype PC 612. It was observed that genotypes pearl millet have significantly affected the hardness of the extrudates. Similarly springiness, cohesiveness, chewiness and resilience were also influenced by the pearl millet genotypes (Table 4).

Overall acceptability of the products takes in account all the sensory parameters such as appearance, flavor and texture. Overall acceptability is considered as ultimate indicator of the quality of product at consumer end. The mean score for appearance, flavor, texture and overall acceptability of extruded snacks prepared from different pearl millet genotypes is given in Fig 3. The appearance, flavor and texture score of snacks ranged from 6 to 8 and extruded snacks prepared from genotype PCB 164 and PC 443 has highest (8) appearance and texture (Fig 4) and were at par in the flavor. The overall acceptability of snacks ranged from 6 to 8, on 9-point hedonic scale. It is noticeable from the Table 4 that pearl millet genotypes have effect on the overall acceptability of extruded snacks.

Thus, it is observed that pearl millet genotypes used in the present study have shown ample variability for agronomic traits and scope for preparation of extruded snacks. The genotype PCB 164 and PC 443 have shown good potential for extruded snacks preparation and can be used at commercial level preparation of these snacks.

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Table 1. Mean of ancillary characters for different genotypes under study

Genotype	Plant height (cm)	Ear length (cm)	Ear girth (cm)	No. of productive tillers	Days to 50% flowering	Grain yield (q/ha)
PCB 164	181[e]	19.52[f]	9.33[cd]	2.22[ab]	46[c]	16.93[bc]
PC 334	196[cd]	29.00[a]	10.00[bc]	2.89[a]	42[c]	15.20[c]
PC 443	203[bc]	23.81[d]	10.66[b]	2.22[ab]	51[a]	15.46[c]
PHB 2168	226[a]	26.07[c]	9.67[bc]	2.67[a]	51[a]	22.80[ab]
PHB 2884	238[a]	27.78[b]	11.89[a]	2.45[ab]	51[a]	26.66[a]
PHB 3053	210[b]	17.63[g]	10.67[b]	1.89[ab]	48[ab]	20.80[ab]
Dhanshakti	183[de]	20.93[e]	8.89[cd]	2.11[ab]	45[bc]	20.40[abc]
PC 612	191[cde]	20.41[ef]	8.33[d]	1.45[b]	49[ab]	17.80[bc]
HSD (5%)	7.59	0.61	0.70	0.59	3.18	5.29

Same alphabet indicates no significant difference among genotypes (P≤ 0.05)

Table 2. Estimates of various genetic parameters

Character	GM	Heritability (%)	% GA	PCV	GCV	CV
Plant Ht.	203.36	95.4	19.78	10.06	9.83	2.16
Ear Length	23.14	99.28	36.7	17.98	17.92	1.52
Ear girth	9.93	88.34	21.6	11.87	11.16	4.05
No. of Productive tillers	2.24	58.82	28.64	23.63	18.13	15.17
Days to 50% flowering	47.67	79.31	13.84	8.47	7.55	3.85
Grain yield (q/ha)	19.73	75.44	35.03	22.54	19.58	11.17

Table 3. Various quality parameters of extruded snacks prepared from different pearl millet genotypes

Genotype	Expansion ratio	Bulk Density (g/ml)	Apparent Density (g/ml)	WAI (g/g)	WSI (%)
PHB 2884	2.47	0.107±0.007	0.590±0.001	2.81±0.31	52.37±0.61
PHB 3053	2.93	0.076±0.005	0.304±0.001	3.42±1.11	52.10± 2.53
PHB 2168	2.99	0.068±0.008	0.287±0.001	3.93±0.90	42.04±3.17
PCB 164	3.27	0.068±0.009	0.323±0.001	4.08±0.46	38.90±0.94
Dhanshakti	3.14	0.069±0.001	0.323±0.001	2.70± 0.55	56.39±2.52
PC 612	2.91	0.072±0.002	0.334±0.001	2.52±0.19	58.83±0.36
PC 334	2.98	0.070±0.007	0.309±0.007	3.05±0.01	53.24±2.83
PC 443	3.12	0.071±0.004	0.334±0.001	2.50±0.03	58.61±3.75

Table 4. Texture analysis of extruded snacks prepared from different pearl millet genotypes

Genotype	Hardness (N)	Springiness	Cohesiveness	Chewiness	Resilience
PHB 2884	28.84± 2.391	0.413±0.229	0.151±0.092	305.762±53.529	0.066±0.017
PHB 3053	27.73± 2.681	0.369±0.169	0.149±0.001	166.129±38.836	0.061±0.011
PHB 2168	22.74± 1.392	0.479±0.201	0.237±0.116	132.922±8.770	0.081±0.042
PCB 164	24.76±5.325	0.380±0.061	0.216±0.057	339.661±35.218	0.087±0.024
Dhanshakti	20.42±1.718	0.523±0.155	0.257±0.065	297.694±67.620	0.078±0.019
PC 612	18.65±0.925	0.432±0.109	0.207±0.121	179.149±62.883	0.068±0.034
PC 334	24.68±0.355	0.517±0.133	0.208±0.043	329.058±58.318	0.067±0.018
PC 443	26.68±0.397	0.384±0.138	0.181±0.003	137.712±8.568	0.065±0.007

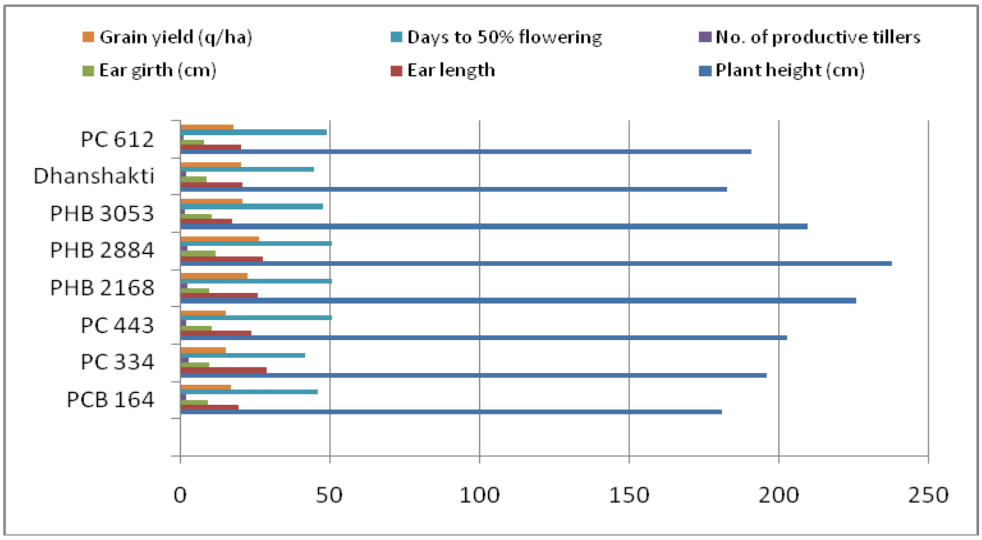

Fig. 1. Mean of ancillary characters for different genotypes under study

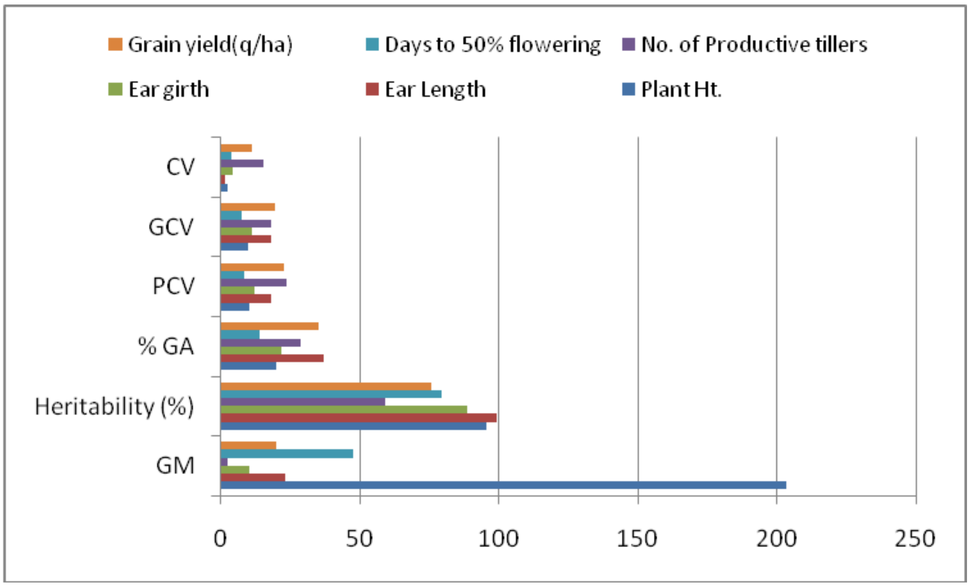

Fig. 2 Variability parameters for different traits in pearl millet

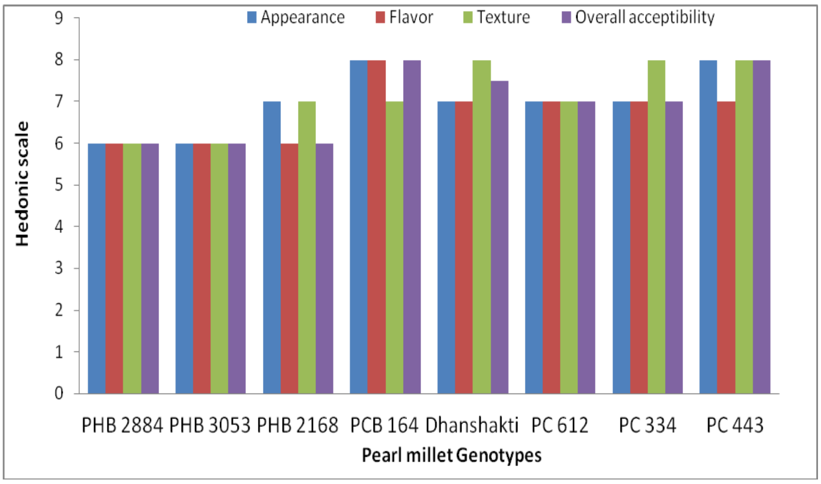

Fig. 3. Sensory scores of pearl millet based extruded snacks from different genotypes

Fig. 4. Comparative photographic representation of extruded snacks