

# Genetic variability of panicle architecture in traditional finger millets from Koraput valley of Eastern Ghats for crop improvement

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## Research Article

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## Abstract

Panicle phenotyping is most demanding targets in crop breeding programs as panicle is an important plant parts that influences the grain yield. Diversity of panicle traits were analyzed in 20 traditional finger millet genotypes and three hybrid varieties from Koraput valley of Eastern Ghats. Significant difference of panicle characteristics like panicle length, panicle number, panicle weight, flag leaf area, panicle angle and grain yield were observed in experimented finger millet genotypes. In regards to principal component analysis, the first two axis of principal component obtained 52.97% of total variation and reflected huge difference between explored genotypes. Highest positive loading was observed for leaf weight followed by panicle number, panicle weight and panicle length and leaf area and are the major determinant for phenotypic variability. All the studied traits showed maximized phenotypic coefficient of variation (PCV) over genotypic variation (GCV) and lower differences found among them. The genotypes showed maximum broad-sense of heritability value for grain yield (82.27%) and panicle weight (75.96%) compared to other traits. In addition, genetic advance as mean% (GAM) ranged from 11.01–29.26% and high GAM was recorded for panicle angle, leaf area, panicle weight, panicle number and yield. It revealed that these characters can be used as selection criteria in crop improvement program for improving grain yield. Traditional finger millet genotypes such as Bhadi, Murda, Telgu and Chilli recorded superior panicle traits and Limca and Kalia showed better grain yield at par with the hybrids, which can be utilized in future crop improvement program.

## Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn) is most valuable cereals generally grown on arid and semi-arid regions of the globe under rainfed agro-climatic conditions (Chandra et al. 2016). India is the major producer of finger millet which is cultivated on 1.27 million hectares land brings about 1.89 million tons of yearly production (Sood et al. 2019). Special aspects of millets like the capacity to adjust under extremely unfavorable climatic condition, minimal agro-input requirement and remarkable nutritional value label these crops for future food and nutrition security (Gupta et al. 2017). The crop farming related to various eco-geographical climatic conditions worldwide determines higher genetic variations and perhaps fundamental basis for the future breeding programs (Ceasar et al. 2018). However, the genomic assets accessible for finger millet are limited as contrasted to vital cereals such as rice, wheat and maize which hamper the improvement of this valuable crop (Ceasar et al. 2018). Improvement of finger millet productivity remains the first concern research in majority of the breeding programs intending for climate resilient agriculture. Crop yield is the most important multifaceted traits and is the final outcome of combination of different traits like panicle number, panicle length, grain number and weight of grains etc. (Kumari and Singh 2016; Patil et al. 2018). Panicle characteristics in finger millet are regarded as most intuitive part that controls the quality and yield of finger millet (Wu et al. 2016; Lei et al. 2018). Therefore, panicle architecture is an important component and for the most part makes biggest contribution to grain yield (Zhou et al. 2014; Zhao et al. 2016; Patil et al. 2018). Many genes and QTL responsible for panicle traits and yield associated traits has been reported in finger millet (Saha et al. 2016; Ceasar et al. 2018; Sood et al. 2019). However, in compared to other cereals, relatively less information is reported in finger millets in relation to panicle phenotyping and the relationship between panicle characteristics and grain yield is not yet been explored.

Identifying superior germplasm for increasing productivity of finger millet will assist to acquire food and nutritional security (Ceasar et al. 2018). Earlier studies have been attempted to recognize markers linked to important agronomic and nutritional traits (Mutch et al. 2005; Babu et al. 2014; Kumar et al. 2015; Gimode et al. 2016). However, breeding of finger millet with improved qualities is presently restrained by the absence of efficiently characterized germplasms at the agro-morphological levels (Rajendran et al. 2016; Sood et al. 2019). Previously some attempts has been explored to utilize different morphological and agronomic traits for analyzing genetic diversity of finger millet accessions of

Africa and Asia (Dida et al. 2008), global finger millet accessions (Babu et al. 2014; Ramakrishnan et al. 2016; Wakista et al. 2017) and genotypes from India (Babu et al. 2018). The genotypes having superior agronomic traits can be utilized in breeding program. Though India holds good numbers of germplasms of finger millet and the majority of the germplasms are collected from the Andhra Pradesh, Karnataka and Tamil Nadu etc. However, very little information is available on genetic variation of traditional finger millet genotypes of Eastern Ghats, particularly from Koraput.

Koraput valley of Eastern Ghats of India is one of the agro-biodiversity hot spots in India and home to a huge number of traditional finger millets (Pradhan et al. 2019). This region with varied agro-climatic conditions surrounded with thick forest and steep mountainous ranges favorable for millet cultivation by local tribes (Panda et al. 2020b). Nowadays due to modern farming practices, these valuable genetic assets are being continuously eroded. The traditional varieties grown by the farmers are likely to be lost shortly if measures are not taken to protect the valuable genetic resources. Recently, some research highlighted the cultivation practice, nutritional and genetic potentiality of finger millets from Koraput (Pradhan et al. 2019; Panda et al. 2020a, b). However, there is limited phenotypic knowledge in regards to panicle phenotyping and yield related traits. Therefore, the objectives of the current study are to elucidate the genetic variation of panicle traits in underutilized finger millet genotypes from Koraput valley and to elucidate the genetic parameters such as heritability and genetic advance which will be useful for future breeding program.

## **Materials And Methods**

### **Experimental material and growth condition**

Twenty different traditional finger millet genotypes and three hybrid varieties (GPU66, ML365 and Bhairabi) popularly cultivated from Koraput valley of Eastern Ghats were selected for the study. The details of finger millet genotypes with their maturity duration and special characteristics are presented in Table 1.

Table 1

Details of finger millet genotypes with their maturity duration, morphological variation of seed colour and panicle type.

Sl No.	Variety name	Origin of Finger millet	Maturity (days)	Seed colour	Panicle type
1	Bada	Local landrace of Koraput	90–110	Reddish brown	Semi-compact finger
2	Bhadi	Local landrace of Koraput	110–115	Dark brown	Open finger
3	Biri	Local landrace of Koraput	90–100	Reddish brown	Droopy finger
4	Chilli	Local landrace of Koraput	110–120	Reddish brown	Droopy finger
5	Chillikangra	Local landrace of Koraput	90–110	Orange red	Semi-compact finger
6	Dasara	Local landrace of Koraput	80–90	Brown	Fist type finger
7	Jama	Local landrace of Koraput	100–105	Light brown	Compact finger
8	Jhana	Local landrace of Koraput	110–125	Brown	Semi-compact finger
9	Kalia	Local landrace of Koraput	105–115	Light brown	Semi-compact finger
10	Kurkuti	Local landrace of Koraput	115–125	Reddish brown	Semi-compact finger
11	Ladu	Local landrace of Koraput	110–120	Reddish brown	Semi-compact finger
12	Lala	Local landrace of Koraput	100–110	Brown	Open finger
13	Limca	Local landrace of Koraput	110–120	Reddish brown	Semi-compact
14	Kalua	Local landrace of Koraput	105–110	Brown	Compact finger
15	Mami	Local landrace of Koraput	110–120	Brown	Semi-compact type finger
16	Murda	Local landrace of Koraput	100–110	Reddish brown	Open type finger
17	Muskuri	Local landrace of Koraput	110–120	Dark brown	Open finger
18	Sillijanha	Local landrace of Koraput	100–110	Brown	Semi-compact finger
19	Taya	Local landrace of Koraput	115–120	Dark brown	Semi-compact finger
20	Telugu	Local landrace of Koraput	100–110	Orange red	Open type finger

SI No.	Variety name	Origin of Finger millet	Maturity (days)	Seed colour	Panicle type
21	GPU 66	Hybrid variety (PR 202 x GPU 28) from PC Unit, Bangalore, Karnataka	112–115	Brown	Medium compact ears with tip incurved fingers
22	ML 365	Developed and released by University of Agricultural Science, Bangalore	110–115	Brown	Semi compact ears with tip incurved fingers
23	Bhairabi	Mutant of Budha Mandia from OUAT, Bhubaneswar, Odisha	105–110	Orange red	Compact type finger

The finger millet genotypes are grown in the experiment garden of Regional Center of Swaminathan Research Foundation, Koraput during Kharif season in three replications with randomized block design. Healthy seeds of all the genotypes were selected shown in the nursery bed. Experiment field was prepared by adding organic fertilizer in the form of farmyard manure. After 25 days of growth 3 seedlings per hill was transplanted in the area of one  $m^{-2}$  with 20 cm x 15 cm spacing between the hill. The plants are regularly irrigated with running water. The maximum light intensity, air temperature and humidity were recorded daily basis and were  $1310 \pm 60 \mu mol m^{-2} s^{-1}$ ,  $33.5 \pm 3^{\circ}C$  and 60–70%, respectively.

### Phenotypic Characterization

Three different panicles were collected from healthy seedlings during the maturity stage (20th to 30th December 2019). The panicles were cut down through a sharp scissor about 1 cm below from first leaf during collection. The panicle samples were photographed by using a DSLR camera and brought to the laboratory for measurement of panicle traits.

Panicle numbers of each plant were counting by total branch number emerged per hill. Angle between leaf and panicles of individual sample was determined by using a protractor during collection time. Leaf area was determined by measuring length and width of leaf through a measuring scale and further calculated following Yoshida et al. (1976) formula [Leaf Area = length×width×0.67  $cm^2$ ]. Scientific ruler was used to determine panicle length from 1 cm down of flag leaf to the tip. Dry weight of leaf and panicle were obtained by oven dried ( $72^{\circ}C$ ) of individual sample around 48 h and subsequent weighing using digital electronic balance. After harvesting of total plot, the grain weight was noted and grain yield of each genotype was expressed in t per  $ha^{-1}$ .

### Measurement Of Genetic Parameters

Genetic variability parameters such as variance at genetic level ( $\sigma^2_G$ ) and variance at phenotyping level ( $\sigma^2_P$ ) were calculated following the formula of Steel et al. (1997). Then phenotypic coefficient of variance (PCV), genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV) were determined according to Burton and Devane (1953). By taking the PCV and GCV value, heritability ( $h^2_{bs}$ ) was calculated following Falconer and Mackay (1996). Further, as per Johnson et al. (1955) genetic advance (GA) and genetic advance as mean% (GAM) were calculated.

### Statistical analysis

Different parameters were recorded triplicate and one-way ANOVA was performed by applying CropStat-7.2 software. Multiple correlation and multivariate analysis (Principal component analysis and Cluster analysis) were carried out by

PAST-3 software. Based on the panicle phenotyping parameters, dendrogram exhibiting Bray-Curtis similarity index among studied finger millets were constructed using UPGMA cluster analysis.

## Results

### Diversity of panicle traits

Morphological diversity of panicles in studied finger millets were depicted in Fig. 1. Variation of different morphological characteristics like panicle number, panicle length, panicle weight, leaf area, leaf weight, panicle weight and grain yield were shown in Table 2. The summary statistics of various panicles attributes in finger millet genotypes were shown in Table 3. The coefficient of variation (CV) of different panicle traits were ranged from 4.501–25.450% among the finger millet genotypes. The maximal CV % was noticed in panicle angle (25.45%) followed by leaf area (23.60%), panicle number (19.81%), panicle weight (17.21%), grain yield (13.59%), panicle length (10.10%) and lowest CV was observed in leaf weight (4.501%). The ANOVA analysis also clearly showed that remarkable variation between genotypes for studied panicle traits (Table 3). The value of variance was highest in panicle angle (31.2%) followed by leaf area (8.51%), panicle length (9.0%) and lowest variance was observed in leaf weight (0.003%).

Table 2

Variation of panicle traits in studied finger millet genotypes of Koraput. Data are mean of three replications  $\pm$  SD. Same alphabet in a column are not significantly different at  $P < 0.05$ .

Variety	Panicle No	Panicle length (cm)	Panicle angle (degree)	Leaf area ( $\text{cm}^{-2}$ )	Leaf weight ( $\text{g leaf}^{-1}$ )	Panicle weight ( $\text{g Panicle}^{-1}$ )	Yield ( $\text{t ha}^{-1}$ )
Bada	6.50 $\pm$ 0.71 <sup>a</sup>	33.50 $\pm$ 0.99 <sup>a</sup>	25.00 $\pm$ 7.07 <sup>a</sup>	11.27 $\pm$ 2.96 <sup>b</sup>	1.17 $\pm$ 0.07 <sup>b</sup>	11.20 $\pm$ 1.24 <sup>a</sup>	2.14 $\pm$ 0.03 <sup>d</sup>
Bhadi	7.00 $\pm$ 1.41 <sup>a</sup>	31.75 $\pm$ 1.06 <sup>a</sup>	25.00 $\pm$ 7.07 <sup>a</sup>	6.95 $\pm$ 2.67 <sup>c</sup>	1.08 $\pm$ 0.03 <sup>c</sup>	8.78 $\pm$ 1.09 <sup>c</sup>	1.89 $\pm$ 0.01 <sup>e</sup>
Biri	4.00 $\pm$ 0.00 <sup>b</sup>	34.45 $\pm$ 3.46 <sup>a</sup>	27.50 $\pm$ 3.54 <sup>a</sup>	13.47 $\pm$ 1.31 <sup>b</sup>	1.25 $\pm$ 0.12 <sup>a</sup>	11.57 $\pm$ 0.36 <sup>a</sup>	1.45 $\pm$ 0.07 <sup>e</sup>
Chilli	4.50 $\pm$ 0.71 <sup>b</sup>	31.60 $\pm$ 3.11 <sup>a</sup>	20.00 $\pm$ 0.00 <sup>b</sup>	14.55 $\pm$ 0.79 <sup>a</sup>	1.22 $\pm$ 0.02 <sup>a</sup>	13.06 $\pm$ 0.03 <sup>a</sup>	1.92 $\pm$ 0.06
Chillikangra	5.00 $\pm$ 1.41 <sup>b</sup>	34.35 $\pm$ 1.06 <sup>a</sup>	15.00 $\pm$ 0.00 <sup>b</sup>	12.62 $\pm$ 1.08 <sup>b</sup>	1.19 $\pm$ 0.00 <sup>b</sup>	7.64 $\pm$ 0.61 <sup>c</sup>	1.92 $\pm$ 0.03 <sup>e</sup>
Dasara	3.50 $\pm$ 0.71 <sup>b</sup>	25.25 $\pm$ 4.74 <sup>b</sup>	30.00 $\pm$ 7.07 <sup>a</sup>	9.45 $\pm$ 2.27 <sup>c</sup>	1.14 $\pm$ 0.05 <sup>c</sup>	9.26 $\pm$ 1.09 <sup>b</sup>	1.85 $\pm$ 0.07 <sup>e</sup>
Jama	4.00 $\pm$ 0.00 <sup>b</sup>	29.35 $\pm$ 0.64 <sup>b</sup>	10.00 $\pm$ 0.00 <sup>c</sup>	11.26 $\pm$ 2.11 <sup>b</sup>	1.23 $\pm$ 0.06 <sup>a</sup>	9.36 $\pm$ 1.42 <sup>b</sup>	2.05 $\pm$ 0.07 <sup>d</sup>
Jhana	5.50 $\pm$ 0.71 <sup>b</sup>	30.90 $\pm$ 1.27 <sup>a</sup>	15.00 $\pm$ 7.07 <sup>b</sup>	14.18 $\pm$ 6.86 <sup>a</sup>	1.23 $\pm$ 0.04 <sup>a</sup>	12.08 $\pm$ 0.14 <sup>a</sup>	1.82 $\pm$ 0.05 <sup>e</sup>
Kalia	5.00 $\pm$ 1.41 <sup>b</sup>	28.15 $\pm$ 0.92 <sup>b</sup>	17.50 $\pm$ 3.54 <sup>b</sup>	9.33 $\pm$ 0.57 <sup>c</sup>	1.18 $\pm$ 0.12 <sup>b</sup>	11.93 $\pm$ 2.41 <sup>a</sup>	2.20 $\pm$ 0.05 <sup>d</sup>
Kurkuti	5.50 $\pm$ 0.71 <sup>b</sup>	33.65 $\pm$ 4.74 <sup>a</sup>	22.50 $\pm$ 3.54 <sup>a</sup>	14.38 $\pm$ 1.75 <sup>a</sup>	1.18 $\pm$ 0.04 <sup>b</sup>	11.66 $\pm$ 2.17 <sup>a</sup>	1.92 $\pm$ 0.06 <sup>e</sup>
Ladu	6.00 $\pm$ 0.00 <sup>a</sup>	28.05 $\pm$ 2.62 <sup>b</sup>	27.50 $\pm$ 3.54 <sup>a</sup>	13.75 $\pm$ 1.71 <sup>a</sup>	1.16 $\pm$ 0.00 <sup>b</sup>	10.56 $\pm$ 0.97 <sup>b</sup>	2.13 $\pm$ 0.05 <sup>d</sup>
Lala	4.00 $\pm$ 0.00 <sup>b</sup>	30.45 $\pm$ 4.60 <sup>a</sup>	22.50 $\pm$ 3.54 <sup>a</sup>	17.06 $\pm$ 4.06 <sup>a</sup>	1.18 $\pm$ 0.01 <sup>a</sup>	10.01 $\pm$ 1.19 <sup>b</sup>	1.61 $\pm$ 0.04 <sup>e</sup>
Limca	5.50 $\pm$ 0.71 <sup>b</sup>	28.15 $\pm$ 2.33 <sup>b</sup>	22.50 $\pm$ 3.54 <sup>a</sup>	14.17 $\pm$ 0.03 <sup>a</sup>	1.19 $\pm$ 0.01 <sup>a</sup>	10.25 $\pm$ 0.55 <sup>b</sup>	2.33 $\pm$ 0.04 <sup>c</sup>
Kalua	4.50 $\pm$ 0.71 <sup>b</sup>	26.60 $\pm$ 2.55 <sup>b</sup>	30.00 $\pm$ 14.14 <sup>a</sup>	14.24 $\pm$ 3.48 <sup>a</sup>	1.14 $\pm$ 0.02 <sup>b</sup>	8.74 $\pm$ 0.76 <sup>c</sup>	1.93 $\pm$ 0.11 <sup>e</sup>
Mami	5.00 $\pm$ 1.41 <sup>b</sup>	23.95 $\pm$ 1.06 <sup>c</sup>	22.50 $\pm$ 3.54 <sup>a</sup>	7.22 $\pm$ 0.36 <sup>c</sup>	1.12 $\pm$ 0.00 <sup>b</sup>	9.61 $\pm$ 0.63 <sup>b</sup>	1.81 $\pm$ 0.04 <sup>e</sup>
Murda	7.00 $\pm$ 1.41 <sup>a</sup>	27.50 $\pm$ 3.25 <sup>b</sup>	22.50 $\pm$ 3.54 <sup>a</sup>	12.31 $\pm$ 2.26 <sup>b</sup>	1.13 $\pm$ 0.01 <sup>b</sup>	10.90 $\pm$ 2.32 <sup>b</sup>	2.04 $\pm$ 0.04 <sup>e</sup>
Muskuri	6.00 $\pm$ 0.00 <sup>a</sup>	25.95 $\pm$ 0.49 <sup>b</sup>	27.50 $\pm$ 3.54 <sup>a</sup>	12.48 $\pm$ 0.45 <sup>b</sup>	1.14 $\pm$ 0.03 <sup>b</sup>	8.30 $\pm$ 0.36 <sup>c</sup>	1.74 $\pm$ 0.04 <sup>e</sup>

Variety	Panicle No	Panicle length (cm)	Panicle angle (degree)	Leaf area (cm <sup>-2</sup> )	Leaf weight (g leaf <sup>-1</sup> )	Panicle weight (g Panicle <sup>-1</sup> )	Yield (t ha <sup>-1</sup> )
Sillijanha	6.00 ± 1.41 <sup>a</sup>	29.75 ± 1.48 <sup>b</sup>	15.00 ± 7.07 <sup>b</sup>	12.06 ± 4.31 <sup>b</sup>	1.19 ± 0.09 <sup>a</sup>	10.43 ± 0.92 <sup>b</sup>	1.86 ± 0.02 <sup>e</sup>
Taya	4.50 ± 0.71 <sup>b</sup>	28.05 ± 2.76 <sup>b</sup>	17.50 ± 3.54 <sup>b</sup>	12.37 ± 5.05 <sup>b</sup>	1.17 ± 0.06 <sup>b</sup>	9.00 ± 0.79 <sup>c</sup>	2.02 ± 0.02 <sup>d</sup>
Telugu	4.00 ± 0.00 <sup>b</sup>	30.60 ± 3.82 <sup>a</sup>	17.50 ± 3.54 <sup>b</sup>	9.10 ± 0.59 <sup>c</sup>	1.20 ± 0.01 <sup>a</sup>	13.08 ± 0.41 <sup>a</sup>	2.09 ± 0.05 <sup>d</sup>
Gpu 66	5.00 ± 1.41 <sup>b</sup>	26.70 ± 5.23 <sup>b</sup>	30.00 ± 0.00 <sup>a</sup>	10.62 ± 0.70 <sup>c</sup>	1.12 ± 0.02 <sup>c</sup>	10.30 ± 2.28 <sup>b</sup>	2.23 ± 0.04 <sup>c</sup>
MI365	4.00 ± 1.41 <sup>b</sup>	32.45 ± 2.47 <sup>a</sup>	25.00 ± 7.07 <sup>a</sup>	19.64 ± 1.40 <sup>a</sup>	1.34 ± 0.07 <sup>a</sup>	14.88 ± 0.37 <sup>a</sup>	2.44 ± 0.02 <sup>b</sup>
Bhairabi	4.50 ± 0.71 <sup>b</sup>	31.90 ± 1.84 <sup>a</sup>	17.50 ± 3.54 <sup>b</sup>	11.78 ± 0.34 <sup>b</sup>	1.19 ± 0.01 <sup>b</sup>	8.06 ± 0.17 <sup>c</sup>	2.72 ± 0.03 <sup>a</sup>
Mean	5.06	29.69	21.95	12.35	1.18	10.46	2.00
LSD ( <i>P</i> < 0.05)	1.91	5.02	10.8	5.6	0.106	2.53	0.104

Table 3

Summary statistics of different panicle traits in studied finger millet genotypes of Koraput. \*\* significance at 0.01 level of probability.

Statistical parameters	Panicle number	Panicle length (cm)	Panicle angle	Leaf area (cm <sup>-2</sup> )	Leaf weight	Panicle weight (g Panicle <sup>-1</sup> )	Yield (t ha <sup>-1</sup> )
Number	23	23	23	23	23	23	23
Minimum	3.500	23.95	10.00	6.955	1.085	7.637	1.450
Maximum	7.000	34.45	30.00	19.644	1.338	14.879	2.720
Sum	116.500	683.05	505.00	284.268	27.138	240.670	46.055
Mean	5.065	29.698	21.957	12.359	1.180	10.464	2.002
Standard error	0.209	0.626	1.165	0.608	0.011	0.376	0.057
Variance	1.007	9.000	31.225	8.511	0.003	3.243	0.074
Standard deviation	1.003	3.000	5.588	2.917	0.053	1.801	0.272
CV (%)	19.811	10.102	25.450	23.604	4.501	17.211	13.590
F value	2.39**	2.14**	2.27**	2.23**	2.13**	4.14**	55.56**

Panicle number remarkably ( $P < 0.05$ ) changed from 3.5 in Dasara to 7.0 in Murda and Bhadi having average value of 5.06 across the studied finger millet genotypes (Table 2). Panicle length notably ( $P < 0.05$ ) ranged from 23.95 cm (Mami) to 34.45 cm (Biri) having mean estimation of 29.69 cm across the genotypes. Panicle angle varied from 10° to 30° across the genotypes and maximum panicle angle was noted in 'Dasara' and 'Kalua' landraces (Table 2). Leaf area was significantly ( $P < 0.05$ ) ranged from 6.955 cm<sup>2</sup> in 'Bhadi' to 19.64 cm<sup>2</sup> in 'ML 365' with a mean value of 12.35 cm<sup>2</sup>. Similarly, significant ( $P < 0.05$ ) difference of leaf weight were found among genotypes and varied from 1.08 g leaf<sup>-1</sup> in 'Bhadi' landrace to 1.34 g leaf<sup>-1</sup> in 'ML 365'. Panicle weight was remarkably ( $P < 0.05$ ) varied among examined genotypes and hybrid variety 'ML 365' showed highest panicle weight of 14.88 g panicle<sup>-1</sup> whereas 'Chillikangra' showed lowest panicle weight of 7.64 g panicle<sup>-1</sup> (Table 2). Significant ( $P < 0.05$ ) difference of grain yield were recorded among the studied finger millet genotypes. The hybrid variety 'Bhairabi' showed highest yield 2.72 t ha<sup>-1</sup>, whereas 'Limca' genotype showed the lowest yield of 1.45 t ha<sup>-1</sup> with a mean value of 2.00 t ha<sup>-1</sup> across the genotypes (Table 2).

### **Genetic Variability Parameters**

Genetic variability of studied morphological traits was shown in Table 4. All the studied traits showed higher phenotypic variation ( $\sigma^2_p$ ) than that of genotypic variation ( $\sigma^2_g$ ). In addition, PCV was > GCV and ECV in studied panicle traits and lower differences found among them (Table 4). The trait showed the largest PCV data for panicle angle (25.34%) next to leaf area (23.15%) and lowest PCV data was obtained for panicle length (9.957%). Similarly, GCV value varied from 7.29–18.97% and panicle angle showed highest GCV (%) accounts for 18.97% (Table 4). The broad sense of heritability ( $h^2_{bs}$ ) varied from 50–82.270% and the highest  $h^2_{bs}$  value was observed for grain yield (82.270%) followed by panicle weight (75.968%) among the finger millets. The highest genetic advance (GA) was recorded for panicle angle (6.424%). The GAM value varied from 11.007–29.269% and maximum GAM was recorded for panicle angle (29.269%) followed by leaf area (26.419%), panicle weight (26.342%), panicle number (23.733%) and yield (22.477%) (Table 4).

Table 4

Genetic variability parameters such as range, mean, standard error (SE), genotypic variation ( $\sigma^2_G$ ), phenotypic variation ( $\sigma^2_P$ ), environmental coefficient of variation (ECV), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense ( $h^2_{bs}$ ), genetic advance (GA) and genetic advance as percentage of the mean (GAM) for different traits in finger millet genotypes of Koraput.

Parameters	Range	Mean ± SE	$\sigma^2_G$	$\sigma^2_P$	ECV (%)	GCV (%)	PCV (%)	$h^2_{bs}$ (%)	GA	GAM
Panicle number	3.50–7.00	5.065 ± 0.209	0.585	1.005	18.095	15.101	19.793	58.209	1.202	23.733
Panicle length	23.95–34.45	29.690 ± 0.626	4.690	8.740	9.586	7.294	9.957	53.661	3.268	11.007
Panicle angle	10.0–30.0	21.950 ± 1.165	17.350	30.950	23.760	18.976	25.345	56.058	6.424	29.269
Leaf area	6.95–19.60	12.350 ± 0.608	4.530	8.180	21.877	17.234	23.158	55.379	3.263	26.419
Leaf weight	1.08–1.34	1.179 ± 0.011	0.013	0.026	13.676	9.671	13.676	50.000	0.166	14.087
Panicle weight	7.64–14.87	10.460 ± 0.376	2.355	3.100	11.670	14.671	16.833	75.968	2.755	26.342
Yield	1.45–2.72	2.002 ± 0.057	0.058	0.071	7.898	12.030	13.263	82.270	0.450	22.477

### Principal Component Analysis

Variations of panicle traits among finger millet genotypes were evaluated by multivariate analysis including PCA (Table 5; Fig. 2). All the studied parameters were separated into seven principal components (PC), among which, three PC having Eigen value > 1 (Table 4). In PC 1 the highest positive loading was found for leaf weight (0.588) succeeded by leaf area (0.442), panicle weight (0.424) and panicle length (0.390) with a variance of 38.06%, whereas in PC 2 maximal variability was marked in panicle angle (0.726) and leaf area (0.331). In PC 3, highest positive loading was noted for panicle number (0.792) followed by panicle length (0.432) and panicle angle (0.256) with a variance of 14.28% (Table 4). The initial 2 axis of principal components (PC1 and PC2) captures 52.97% of total variation. The scatter plot was drawn between two principal components represented a clear pattern of grouping of finger millet cultivars into four quarters (Fig. 2). Based on biplot analysis, four traditional finger millet viz., 'Lala', 'Biri', 'Kurkuti' and 'Chili' were present in one quarter along with hybrid variety 'ML 365' and differentiated from other on the basis of leaf area and panicle weight. In another quarter five local genotypes such as 'Chillikangra', 'Jama', 'Jhana', 'Limca' and 'Telugu' along with hybrid variety 'Bhairabi' and usefully separated from other based upon panicle length and yield parameters. Similarly, based on panicle angle five local finger millet genotypes such as 'Dasara', 'Kalua', 'Muskuri', 'Mami' and 'Ladu' along with 'GPU 66' were separated. In quarter fourth, six traditional finger millet cultivars viz., 'Bada', 'Bhadi', 'Kalia', 'Murda', 'Sillijanha' and 'Taya' were successfully separated from other for the panicle number.

Table 5  
Principal component analysis (PCA) of different morphological traits in studied finger millet genotypes of Koraput.

Parameters	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7
Panicle number	-0.277	-0.278	0.792	0.118	-0.032	-0.344	0.292
Panicle length	0.390	-0.274	0.432	-0.319	0.260	0.622	-0.174
Panicle angle	-0.190	0.726	0.256	0.339	0.127	0.442	0.213
Leaf area	0.442	0.331	0.173	0.090	0.531	-0.519	-0.325
Leaf weight	0.588	0.005	-0.112	-0.010	-0.025	-0.060	0.798
Panicle weight	0.424	0.159	0.245	0.215	-0.772	-0.018	-0.303
Yield	0.114	-0.431	-0.132	0.845	0.191	0.165	-0.071
% variance	38.069	16.908	14.285	13.830	9.010	6.497	1.400
Eigen value	2.665	1.184	1.000	0.968	0.631	0.455	0.098

### Relationship Among Studied Panicle Traits

Relationship among different panicle traits in studied finger millet were carried out by multiple correlation analysis (Fig. 3). Based on the results, panicle length was positively associated with leaf area, leaf weight, panicle weight and yield and negatively related with panicle number and panicle angle (Fig. 3). In addition, on the basis of Pearson's correlation coefficient, panicle number was positively correlated with panicle length ( $r = 0.997$ ), panicle angle ( $r = 0.725$ ), leaf area ( $r = 0.298$ ) and panicle weight ( $r = 0.532$ ) (Table 6). Grain yield in finger millet was positively related with panicle length ( $r = 0.933$ ), panicle angle ( $r = 0.531$ ), leaf area ( $r = 0.843$ ), leaf weight ( $r = 0.439$ ) and panicle weight ( $r = 0.654$ ) (Table 6).

Table 6

Relationship between different morphological traits in studied finger millet genotypes of Koraput. \*: significance at  $P < 0.05$ , \*\*: significance at  $P < 0.01$ . ns: non-significant.

Parameters	Panicle number	Panicle length	Panicle angle	Leaf area	Leaf weight	Panicle weight	Yield
Panicle number	1.000	0.997**	0.725**	0.298*	0.017 <sup>ns</sup>	0.532*	0.935**
Panicle length		1.000	0.188 <sup>ns</sup>	0.107 <sup>ns</sup>	0.009 <sup>ns</sup>	0.161 <sup>ns</sup>	0.933**
Panicle angle			1.000	0.766 <sup>ns</sup>	0.132 <sup>ns</sup>	0.938**	0.531*
Leaf area				1.000	0.001 <sup>ns</sup>	0.074 <sup>ns</sup>	0.843**
Leaf weight					1.000	0.001 <sup>ns</sup>	0.439*
Panicle weight						1.000	0.654**
Yield							1.000

### Cluster analysis based on panicle traits in finger millet genotypes

The genotypic relationship among 20 indigenous finger millet genotypes and three hybrid cultivars was evaluated through Bray-Curtis similarity index (Fig. 4). Based on studied morphological traits, finger millet genotypes clustered into 2 large clusters and different sub-clusters. The largest cluster consists of 15 finger millet genotypes with more than 88% similarity which consisting of 13 indigenous genotypes (Dasara, Kalua, Ladu, Muskuri, Biri, Bada, Chilli, Kurkuti, Lala, Limca, Murda, Mami and Bhadi) and 2 hybrid variety (GPU 66 and ML 365). The hybrid variety 'GPU 66' showed more than 95% similarity with 'Kalua' and 'Dasara' and present in a small sub group. Similarly, in another major cluster, seven indigenous finger millet genotypes along with hybrid variety 'Bhairabi' showed more than 90% similarity (Fig. 4).

## Discussion

Genetic variability study of germplasm provides fundamental information concerning genetic characteristics of the population based upon which breeding techniques are developed (Umar and Kwon-Ndung 2014). This is the first report on genotypic variability of panicle traits in traditional finger millet genotypes from Koraput valley of Eastern Ghats. The present investigation analyzed panicle phenotyping in 20 traditional finger millet genotypes and compared with 3 hybrid cultivars (GPU66, ML365 and Bhairabi) popularly cultivated in the locality. The analysis of variance clearly indicated that high significant difference of panicle traits viz., panicle length, panicle number, panicle weight, panicle angle and grain yield were recorded across the examined finger millet genotypes. Current findings also exhibited higher CV% of different panicle traits were observed among the studied finger millet genotypes. Thus, it is indicated that there was sufficient variation of panicle characteristics in the studied genotypes, which provide ample scope for selecting superior genotypes and could be utilized in future breeding programs. Similarly, physiological variability in different underutilized finger millets from various parts of India also reported earlier by Panda et al. (2020b), Pradhan et al. (2019) and, Kumari and Singh (2015).

The panicle architecture is a key component which enhances grain productivity and basically controlled by panicle number, panicle length, accompanying branching pattern and grains (Huang et al. 2018; Patil et al. 2018). Certain traditional finger millet genotypes like Bhadi, Mudra, Telgu and Chilli exhibited significantly higher panicle number and panicle weight in comparison to rest genotypes that determined superiority of panicle traits. Panicle length was highest in 'Chillikangra' and highest panicle angle was found in 'Dasara' and 'Kalua' genotypes in comparison to rest genotypes. Wang et al. (2008) reported the shape, size and angle of panicle is crucial for arrangement of grains in the panicle and also helpful for grain filling in cereal crops. There were significant variability of leaf area and leaf weight observed among finger millet genotypes and maximum leaf area and leaf weight was observed in hybrid variety ML 365. It is generally advocated that larger leaf area increases the photosynthesis capacity and improve the dry matter and ultimately helpful for better panicle growth (Yoshinaga et al. 2013). Yield is most significant complex traits in finger millet that is affected by numerous genetic and environmental elements (Ulaganathan and Nirmalakumari 2013). In the current experiment significant variability of grain yield was recorded among the finger millet genotypes. Though the hybrid varieties Bhairabi and ML 365 showed highest yield but some of the traditional genotypes such as 'Limca' and 'Kalia' showed better yield at par with the hybrids. Similar results of morphological variations in finger millets are also reported in indifferent germplasm collections (Shet et al. 2009; Ulaganathan and Nirmalakumari 2013; Patil et al. 2018). To know the relationship of grain yield with other panicle traits, data are subjected to multiple correlation analysis. Results indicated that grain yield in studied finger millet genotypes were positively associated with panicle number, panicle length, leaf weight, leaf area, and panicle angle and panicle weight. These findings are reliable with the previous literature of Reddy et al. (2013); Ulaganathan and Nirmalakumari (2013) and Wolie et al. (2013) that grain weight and harvest index depend on the shape, size and number of panicles. Kumari and Singh (2016) reported that yield of finger millet relies upon different growth and yield characteristics like filled grain number, panicle number and grain weight. In contrast, it was also reported that variation of grain yield was not necessarily associated with leaf area in cereals like finger millet (Panda et al. 2020b) and rice (Subrahmanium 2000; Panda et al. 2020c).

In the present study, panicle angle, leaf area and panicle weight showed the higher PCV and GCV value indicating these traits are more variable in the germplasm. The PCV value was greater than GCV and ECV for panicle traits and also interesting to note that the variation among GCV and PCV were minimum in all traits. This implies about following traits were least affected by environment and additive gene effects indicating genotypes can be improved based on genotypic values (Reddy et al. 2013). Similar results were also published by Wolie et al. (2013) and Kumari and Singh (2015) in different finger millet accessions. High level of heritability and genetic advance will be helpful for selection in crop improvement (Sahu et al. 2017; Panda et al. 2020c). The genotypes under study showed high broad-sense of heritability value for grain yield (82.27%) and panicle weight (75.96%) compared to other traits. It indicates that following traits are less impacted by environment and effective for selection on the basis of phenotypic performance. The following results are consistent with previous report of Reddy et al. (2013) and, Kumari and Singh (2015) that higher value of heritability can be used for selection criteria for finger millet improvement program. In the present study GAM value changed from 11.01–29.26% and high GAM was recorded for panicle angle, leaf area, panicle weight, panicle number and yield. It is suggested that these traits can be used as selection criteria in improving grain yield in crop improvement program.

Principal component analysis reveals the pattern of genotypic variation and useful for identifying the major contributing traits for phenotypic variability (Mishra et al. 2019). In the light of the outcomes, first two principal components capture 52.97% of total variation and highest positive loading was observed for leaf weight followed by panicle number, panicle weight and panicle length and leaf area. It suggested that these parameters are the major determinant for phenotypic diversity in studied genotypes compared to other traits. Similar results of phenotypic diversity of morpho-physiological traits are also proclaimed in traditional rice landraces (Panda et al. 2020c) and in

underutilized millets (Panda et al. 2020b) from Koraput. Based on panicle attributes, genotypic relationship among the studied finger millet genotypes were evaluated by cluster analysis (Fig. 4). Bray-Curtis similarity index classified the genotypes in two major clusters and different sub-clusters. The largest cluster consists of 15 genotypes with more than 88% similarity which consisting of 13 indigenous genotypes and two hybrid variety. Higher similarity among the genotypes may be because of their similar origin, ecotype and cultivated only in a particular region. Results also recorded that no duplicate genotypes existed and indicated the considerable genetic difference between the genotypes for panicle traits. Three indigenous finger millet genotypes such as Taya, Kalua and Dasara were having maximal similarity index along with hybrid cultivars GPU 66 and Bhairabi. The genetic variability results in indigenous finger millet genotypes may provide baseline information for conservation and could be used for varietal improvement of future breeding programmes.

## Conclusion

The present study revealed existence of huge variability of panicle traits in studied finger millet genotypes, which provide ample scope for selecting superior genotypes for future breeding programs. Principal component analysis revealed that panicle number, panicle length, panicle weight and leaf area are the major contributing traits for phenotypic variability between the examined genotypes. Some traditional finger millet genotypes like Bhadi, Murda, Telgu and Chilli revealed superiority of panicle traits and Limca and Kalia showed better grain yield at par with the hybrids, which can be utilized in the future crop improvement program. Higher level of heritability and genetic advance were observed for panicle angle, leaf area, panicle weight, panicle number and yield, which suggested that these characters may be helpful for selection in finger millet improvement programs. Further research on population structure, QTL mapping and allele diversity in these genotypes are required for use in future breeding program.

## Declarations

**Conflict of interest:** The authors declare that they have no conflict of interest

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**Ethics approval:** NA

**Consent to participate:** NA

**Consent for publication:** NA

**Availability of data and material:** NA

**Code availability:** NA

**Author contributions:** DP and AT designed the experiments; KL cultivated the plants and maintained the experimental field. AT, AP and PKB performed the measurement of panicle traits. DP analyzed the data and wrote the paper. All authors read and provided helpful discussions for the manuscript.

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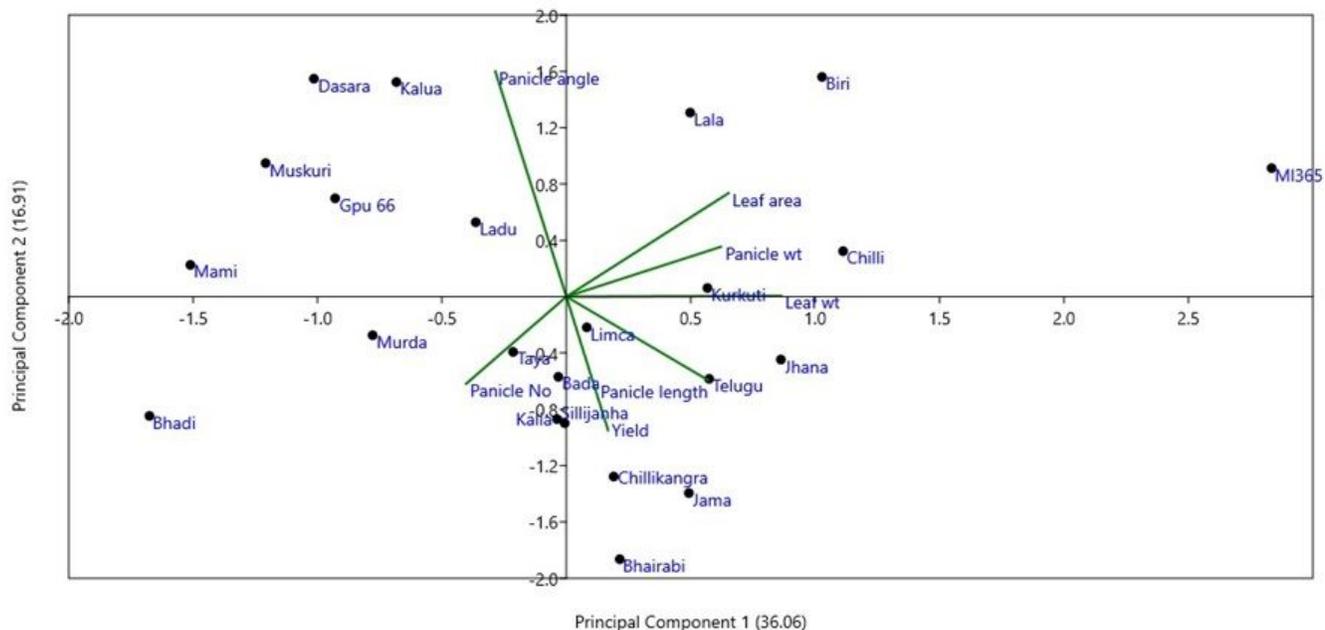
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## Figures



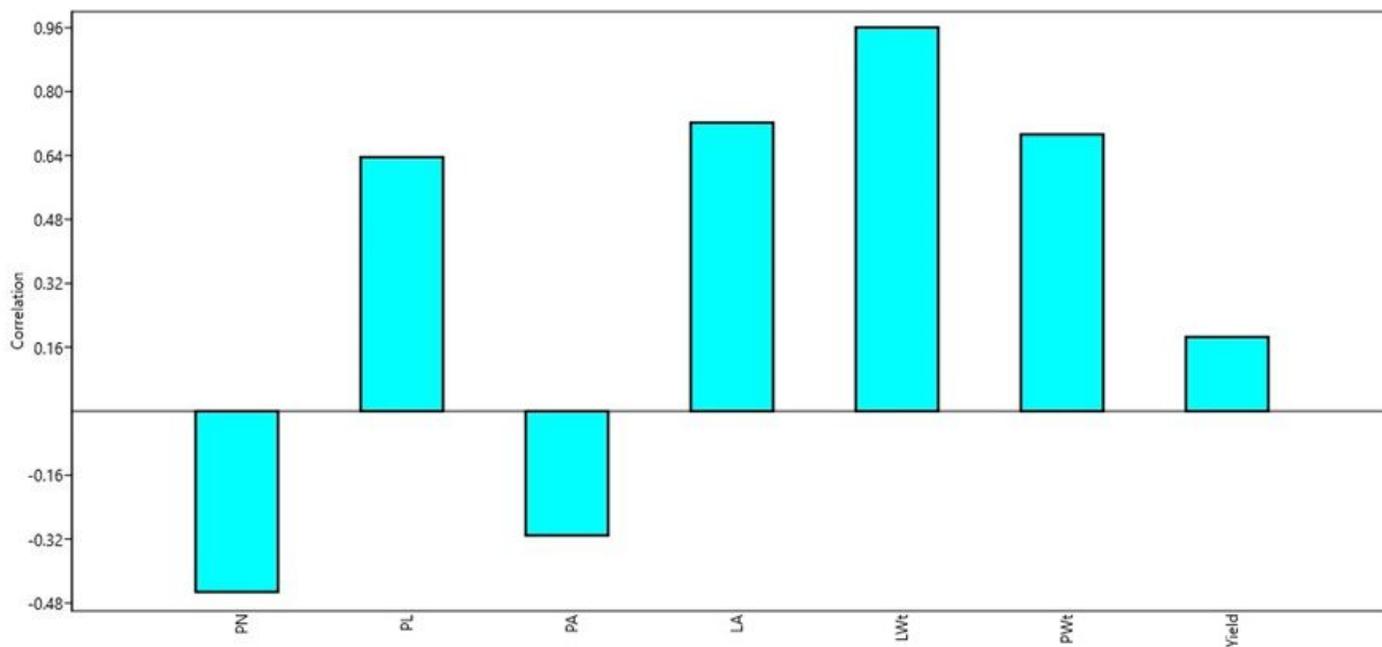
**Figure 1**

Morphological diversity of panicles in studied finger millet genotypes of Koraput.



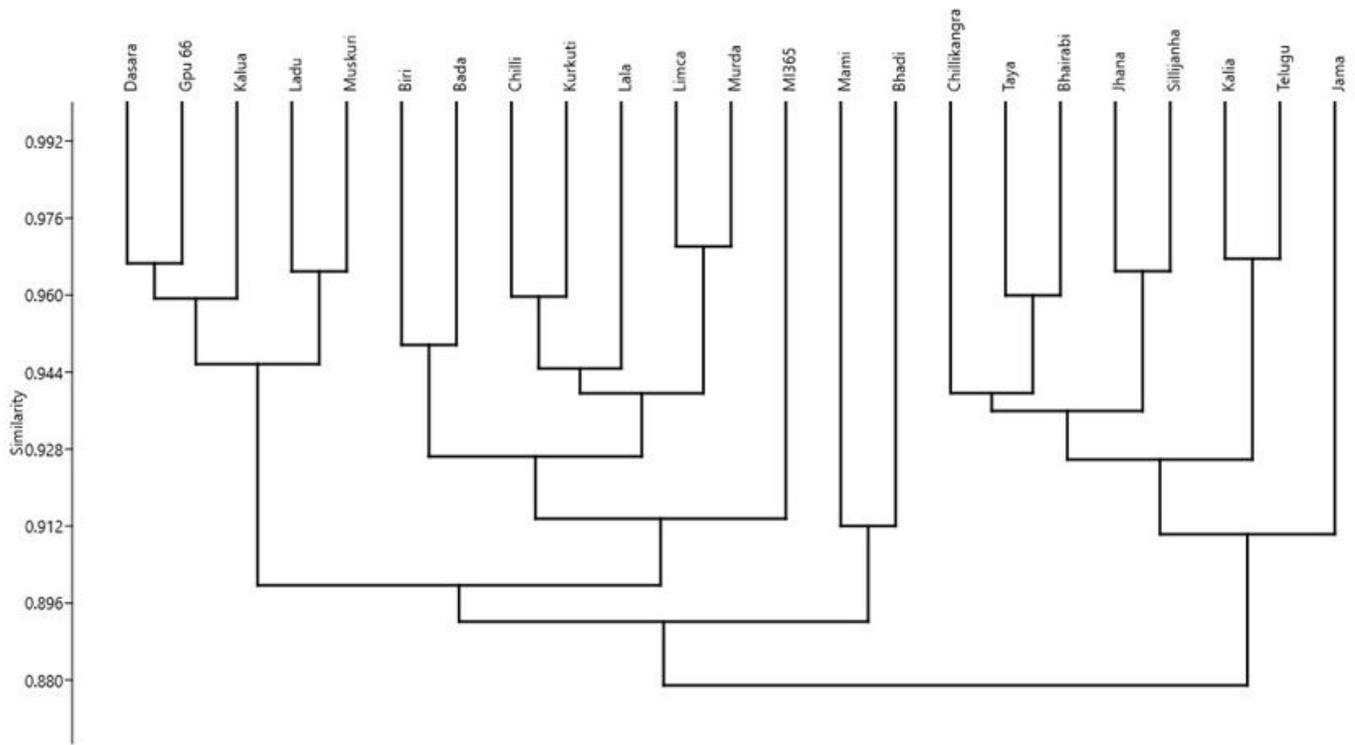
**Figure 2**

Scatter plot showing the genotypic relationship in studied finger millet genotypes of Koraput on the basis of different panicle traits.



**Figure 3**

Relationship of different panicle traits in studied finger millet genotypes of Koraput.



**Figure 4**

Dendrogram showing the genotypic relationship for different finger millet genotypes of Koraput based on panicle traits.