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Genetic diversity in Indian oat (*Avena sativa* L.) varieties for biomass and seed yield traits

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Abstract
An experiment was conducted during winter seasons of 2014-15 and 2015-16 with 27 released varieties of oats recommended for cultivation in different agro-ecological zones of India. These varieties were evaluated for 14 morphological and phenological traits related to fodder and seed yields at multi-cut conditions. Oat cultivars exhibited wide array of expression for all studied traits and varied significantly. Association analysis showed that biomass yield and seed yield were independent with each other. Principal components (PC 1 to PC 6) cumulatively accounted for 82.17% of the total variation present among the varieties. The dendrogram constructed using average linkage cluster analysis classified the test varieties into three diverse clusters. The results indicated that highest diversity exists for green forage yield, seed yield, plant height, dry matter yield and 1000 seed weight. Based on the study it was concluded that released varieties of oat in the country have ample variability for most of the traits included in the study.

Keywords: Cluster, Correlation, Dual purpose oat, Principal component analysis

Introduction
The cultivated oat (Avena sativa L.), also called as white oat, is a natural allohexaploid (2n=6x=42) with a genomic constitution of AACCDD (Loskutov, 2008). It ranks sixth in the world in cereal production following wheat, maize, rice, barley and sorghum (Hoffman, 2009). It is an important cereal and used as a dual purpose crop of temperate and subtropical areas. Being a highly nutritious cereal, it is useful for human consumption as well as feed and fodder for milching and drought animals. Oat is considered to be a potential source of low cost protein with high nutritional value (Rasane et al., 2015). It contains relatively higher dry matter with 7-10 per cent protein and resistance to diseases and is suited for silage making (Ahmad et al., 2013). The oat grain is high priced commodity due to its positive health benefits. The health benefits associated with consuming oat as a whole grain is associated to beta-glucan, a hemi-cellulose found in endosperm cell walls (Fincher, 2009). This found to have positive effect in respect to blood pressure, diabetes, cholesterol and immune system (Newell et al., 2012). Due to superior forage quality, high productivity and multifarious uses it is expected that oat can bring a winter forage revolution.

In view of the ever increasing human and livestock population together with limited availability of land resources for cultivated fodder (Shinde and Mahanta, 2020), the forage breeders tailored multipurpose varieties that could fit in different cropping systems. Indeed, development of dual purpose forage cum grain type with good grain yield, multi-cut, late flowering and vigorous tillering varieties are required to boost oat cultivation in the country. With increasing demand for oat fodder and food, area under crops is increasing and this has also encouraged researchers involved in the varietal improvement programmes.

To design an effective and result oriented breeding progamme, it is always advocated to assess the extent of diversity exists in cultivars presently grown by the farmers. The information generated will also help to adopt appropriate breeding strategies to fulfill the future requirements. Although oat is recent introduction to India but many improved fodder varieties have been developed by various research institutions and agricultural universities. But the information on extent of diversity is lacking in Indian oat varieties. Thus the present study was carried out with the objectives to gain information on the level of genetic diversity in Indian oat cultivars released for the cultivation and study of relationship amongst released varieties and also for identification of superior cultivars for fodder and seed yield attributes.

Materials and Methods

Location and experimental material: The present investigation was carried out at Agronomy Research Farm (26°29' N latitude, 80°18' E longitude and 125.9 m asl of altitude) of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, India during winter seasons of 2014-15 and 2015-16. The climate of district Kanpur is humid subtropical and it has one of the lowest temperatures in northern plains during the winter season and is one of the warmest during the summer season. Nearly 80% of total rainfall is received during the monsoon (only up to September) with a few showers in the winter. The experimental materials of the study comprised of 27 oat varieties, developed by different research institutes and agricultural universities (Table 1).These varieties were procured from different developing organizations and some from Forage Section, Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, India.

Experimental design: The experiment was sown in second week of November during both the years i.e. 2014-15 and 2015-16. Each variety was sown in 03 replications in randomized complete block design in a plot of 5.0 m × 2.5 m long broad consisting 10 rows per plot with a row to distance of 25 cm. Four rows per plot were used for recording observations pertaining to green forage yield and four rows for the observations related to seed yield excluding border rows in each plot. First cut of green herbage was taken after 50 days of sowing and second cut after 35 days of first cut. The characters i.e. days to 50% flowering and days to maturity were recorded on plot basis, while traits viz. plant height, number of tillers plant-1, spike length, number of leaves plant-1, leaf length, leaf width, Leaf: stem ratio, total chlorophyll, seed yield plant-1 and test weight were observed on randomly selected five plants in each replication for each variety. Green fodder yield and dry matter yield were observed on one square meter of competitive row. All the recommended cultural practices were followed for raising a good crop.

Table 1. Details of oat varieties used for diversity analysis

Variety	Year of release	Developing institute	Area of adaptation
JHO 822	1989	IGFRI, Jhansi	Entire country
Kent	1978	PAU, Ludhiana	NW and CZ
OS 7	1981	CCSHAU, Hisar	Entire country
UPO 94	1981	GBPUA.&T, Pantnagar	Entire country
JHO 851	1998	IGFRI, Jhansi	Entire country
OS 6	1981	CCSHAU, Hisar	Entire country
UPO 212	1990	GBPUA&T, Pantnagar	Entire country
OL 125	1995	PAU, Ludhiana	NW and CZ
Sabzar	1997	SKUA&T, Srinagar	Jammu & Kashmir
JHO 99-2	2004	IGFRI, Jhansi	NW and NE
RO 19	2006	MPKV, Rahuri	NW and CZ
PLP 1	1980	HPKV, Palampur	Himachal Pradesh
JO 1	2004	JNKVV, Jabalpur	Central zone
NDO 1	2009	NDUA&T, Faizabad	Entire country
JHO 2004	2006	IGFRI, Jhansi	South, NW, Hill zones
JO 03-93	2010	JNKVV, Jabalpur	Central zone
SKO 96	2011	SKUA&T, Srinagar	Hill zone
NDO 2	2010	NDUA&T, Faizabad	Uttar Pradesh
HFO 114	1974	CCS HAU, Hisar	Haryana
JHO-2001-3	2005	IGFRI, Jhansi	NW and Southern zone
HJ 8	1997	CCSHAU, Hisar	Haryana
OS 346	2009	CCSHAU, Hisar	Central zone
SKO 20	2009	SKUA&T, Srinagar	Jammu & Kashmir
JHO-99-1	2007	IGFRI, Jhansi	Entire country
JO 03-91	2009	JNKVV, Jabalpur	Central zone
SKO-90	2010	SKUA& T, Srinagar	Hill zone
OL-9	1986	PAU, Ludhiana	NW and Punjab

NW: North western zone; CZ: Central zone; NE: North east zone

Table 2. Descriptive statistics of biomass contributing traits in Indian oat varieties evaluated over two years in central India

Traits	Year I						Year II					
	I Cut			II Cut			I Cut			II Cut		
	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV
PHT	76.83	53.20-90.40	8.33	51.20	31.87-67.12	18.65	76.91	51.00-90.50	8.81	50.53	31.12-66.37	19.71
LL	56.09	45.23-65.56	7.74	46.29	28.15-63.65	20.46	56.08	43.83-65.83	8.10	45.93	28.25-61.45	19.57
LW	1.62	1.45-1.88	6.94	1.54	1.35-1.77	7.58	1.58	1.36-1.88	10.56	1.57	1.32-1.80	9.02
NL	22.75	14.16-28.26	13.76	14.99	11.06-19.23	10.96	22.64	13.50-28.00	14.85	14.60	11.06-19.24	12.92
TPP	4.60	3.16-9.16	28.42	5.01	3.50-10.36	29.59	4.68	3.16-10.16	31.29	4.87	3.33-10.00	30.21
LSR	0.28	0.22-0.40	14.22	0.27	0.20-0.35	12.15	0.27	0.20-0.40	18.45	0.25	0.17-0.48	24.40
GFY	208.89	137.00-307.33	23.17	242.56	135.33-298.33	14.71	206.93	104.67-305.67	24.30	241.67	128.33-298.33	15.20
DMY	77.27	43.00-129.00	29.23	79.67	51.66-106.33	16.75	76.95	42.33-128.66	29.30	79.89	44.33-110.66	18.89
CHL	35.15	31.36-41.20	7.22	31.65	24.38-36.58	8.40	35.10	30.41-40.03	7.62	31.51	24.06-36.57	8.79

PHT: Plant height (cm); TPP: Number of tillers plant^{-1}; NL: Number of leaves plant^{-1}; LL: Leaf length (cm); LW: Leaf width (cm); LSR: Leaf :stem ratio; CHL: Total chlorophyll; GFY: Green fodder yield (q/ha); DMY: Dry matter yield (q/ha)

The data of both the years related to green forage yield, seed yield and their component traits were pooled for computation of correlations amongst traits. The average values over the years for all 14 traits were used for principal component analysis (PCA) by using the computer software SAS Ver.9.3 (SAS Institute, 2011) based on the procedure suggested by Sokal and Michner (1958). The cluster analysis for grouping of varieties was carried by using average linkage method following the described standard procedures (Lance and Williams, 1967).

Results and Discussion

Mean performance for fodder and seed yield traits: Mean performance of varieties for different forage and seed yields during both the years showed wide range and coefficient of variation (CV) indicating that Indian oat cultivars were bred with broad genetic base (Table 2). While mean performance for most of the traits were higher at first cut stage except for number of tillers plant-1, green fodder yield and dry matter yield which was observed at second cut stage indicating that cutting induced tillers in turn which enhanced biomass production. Highest variation amongst all the traits was observed including for number of tillers plant-1 during both the years at both green fodder harvesting stages. Other biomass contributing traits *viz.*, number of leaves plant-1, green fodder yield, dry matter yield and leaf stem ratio also exhibited broad range of expression under both cutting regimes in different oat cultivars. Similarly seed yield related traits also showed presence of ample diversity amongst cultivars (Table 3). All five traits *viz.*, days to 50% flowering, days to maturity, spike length, seed yield plant-1 and 1000 seed weight also showed wide variation for range of expression of traits. Although all the varieties of oat in India were bred and released for fodder production but the high seed yield potential also showed possibilities for their evaluation for grain production and utilization in future breeding progammes targeted for the development dual purpose cultivars. Wide genetic diversity were also demonstrated earlier in global collections of oat varieties/genotypes by Achleitner et al. (2008), Iannucci et al. (2011) and Montilla-Baseon et al. (2013), in Indian collections by Shekhawat et al. (2006), Ahmed et al. (2011), Ruwali et al. (2013), Kaur and Kapur (2017), Rana et al. (2019) and Sood et al. (2016), and mutant lines by Gupta and Mehta (2020).

Table 3. Descriptive statistics of seed yield contributing traits in Indian oat varieties evaluated over two years in central India

Traits	Year I			Year II		
	Mean	Range	CV	Mean	Range	CV
DTF	93.02	78.00-16.00	9.70	93.17	75.00-113.66	9.85
DTM	132.08	120.00-147.00	4.18	132.02	120.00-147.00	4.25
SL	29.50	27.33-31.83	4.38	28.63	23.16-32.33	7.96
SY	7.17	5.10-11.10	21.67	7.01	4.20-10.80	24.30
TW	33.21	18.63-48.72	21.41	33.39	18.21-48.09	20.95

DTF: Days to 50% flowering; DTM: Days to maturity; SL: Spike length (cm); SY: Seed yield/plant (g); TW: Test weight (g)

Correlation studies: Correlation amongst 05 seed yield contributing traits and 09 biomass yield contributing traits at first and second cut showed total 23 significant associations (Table 4). Green fodder yield was associated positively (P<0.05) with dry matter yield and leaf number. Both green fodder yield and dry matter yields were associated positively with plant height, leaf length, leaf width, and number of leaf plant-1. Dry matter yield was negatively associated with leaf stem ratio. The strong positive association were observed in first cut and second cut for all biomass contributing traits except leaf length and plant height. Plant height and leaf length were positively associated in first cut, however, in second cut the association was non-significant. Dry matter yield showed positive (P<0.05) association with plant height and leaf length in first cut and second cut. Tillers plant-1 and plant height were associated negatively. Correlation analysis showed that seed yield and biomass yield were independent from each other; and could be improved simultaneously. Thus there is a scope to improve both seed and fodder yields potential of oats. Days to 50% flowering showed negative significant correlation (P<0.01) with plant height and leaf length, and positive significant correlation (P<0.01) with tillers plant-1. Days to maturity showed positive significant association (P<0.05) with tillers plant-1 and leaf: stem ratio. Thousand seed weight was associated positively (P<0.05) with leaf length and chlorophyll content. Seed yield showed positively weak associations with plant height, leaf length, leaf width, number of leaf and chlorophyll content, and negative weak association with leaf: stem ratio, fodder yield and seed yield. Traits like plant height, leafiness and chlorophyll content were associated positively with both seed yield and biomass yield. Therefore, these traits could be used in selection during development of dual purpose variety of oats. Similar pattern of associations among biomass and seed yield contributing traits were also reported earlier in different studies (Ahmad et al., 2013; Iannucci et al., 2011).

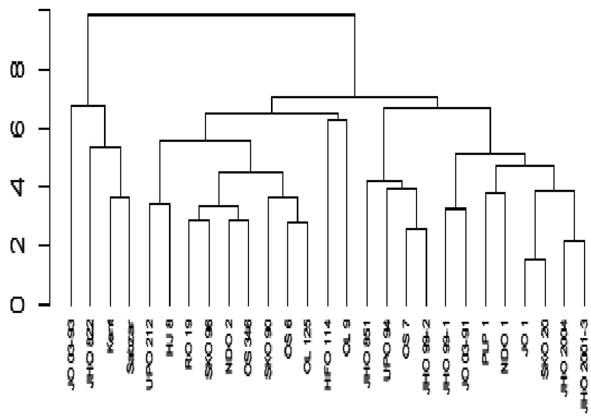

Fig 1. Grouping 27 oat varieties using 14 morphological traits

Principal component analysis: The principal component analysis (PCA) computed using 14 traits revealed that the first six principal components (PC 1 to PC 6) gave eigen values >0.89 and cumulatively accounted for 82.17% of the total variation (Table 5). The first principal component which explained maximum variability (29.99%) was of mainly due to leaf length and plant height, whereas contributions of all other traits were negative or negligible. While succeeding principal components accounted for remaining possible variability as PC 2 explained about 14.99%, mainly contributed by variable performance for spike length, number of leaves plant^{-1}, leaf width and leaf stem ratio. Green fodder yield, dry matter yield and number of tillers contributed positively for the third PC, accounting for 13.95% of the total variation. Spike length and plant height with positive weights were important delineating traits associated with the fourth PC that explained 9.61% variation. PC 5 explained only 7.95 % of total variation and important traits contributing to the variation with positive weight were seed yield plant-1and leaf width. PC 6 explained only 5.69% of total variation and important traits contributing to the variation with positive weight were leaf width and total chlorophyll. PCA pattern and contribution of different

Table 4. Correlation analysis of seed yield and biomass contributing traits in oat varieties evaluated in central India for two years

Traits	Seed yield contributing traits					Biomass contributing traits								
	DTF	**DTM**	**SL**	**SY**	**TW**	**PHT**	**LL**	**LW**	**NL**	**TPP**	**LSR**	**GFY**	**DMY**	**CHL**
PHT	-0.63**	-0.34	0.13	0.16	0.38	**0.38**	0.27	0.06	0.24	-0.39*	-0.19	0.20	0.40*	0.13
LL	-0.64**	-0.38	0.13	0.21	0.41*	0.94**	**0.29**	0.08	0.32	-0.31	-0.25	0.26	0.43*	0.11
LW	0.19	0.21	0.28	0.19	-0.07	0.07	0.05	**0.57****	0.19	0.15	0.19	0.11	0.14	0.05
NL	-0.09	-0.04	0.18	0.29	0.22	0.32	0.48*	0.16	**0.39***	0.12	-0.04	0.17	0.01	0.15
TPP	0.51**	0.40*	-0.10	0.07	-0.23	-0.47*	-0.33	0.26	0.23	**0.63****	0.26	-0.20	-0.31	-0.27
LSR	0.32	0.44**	0.24	-0.12	-0.19	-0.08	-0.12	0.08	0.11	0.27	**0.40***	-0.10	-0.29	-0.04
GFY	-0.25	-0.35	-0.10	-0.08	0.08	0.13	0.24	0.10	0.44*	0.09	-0.06	**0.39***	0.34	-0.03
DMY	-0.30	-0.41*	-0.34	-0.06	-0.01	0.24	0.32	0.08	0.25	-0.14	-0.38	0.74**	**0.57****	-0.05
CHL	-0.30	-0.27	-0.08	0.14	0.49**	0.18	0.17	-0.08	0.29	-0.32	0.02	-0.01	-0.07	**0.70****

DTF: Days to 50% flowering; DTM: Days to maturity; PHT: Plant height ; TPP: Number of tillers plant^{-1}; SL: Spike length ; SY: Seed yield plant^{-1} ; TW: Test weight; NL: Number of leaves plant^{-1}; LL: Leaf length ; LW: Leaf width ; LSR: Leaf: stem ratio; CHL: Total chlorophyll; GFY: Green fodder yield; DMY: Dry matter yield In biomass contributing traits lower diagonal values are correlation (r) between biomass contributing traits, upper diagonal values are r between first cut and second cut, diagonal values are r between first cut and second cut of same traits; *(P<0.05); **(P<0.01)

traits to the total variation indicated that Indian oat varieties possess high variability for some of the traits *viz.*, green forage yield, seed yield, dry matter yield and 1000 seed weight, leaf length, leaf width, number of tillers plant^{-1} and number of leaves plant^{-1}. Similar pattern of variability in different oat collections, were also reported in different studies earlier (Iannucci et al., 2011; Rezai and Frey, 1990; Peterson et el., 2005; Rebiei et al., 2012; Kujur et al., 2017). Presence of wide variability for all important traits also exhibited potential of available oat cultivars for utilization in future improvement progammes of fodder and seed yields as these genotypes could be considered as potential sources of green fodder yield, dry matter yield, plant height and 1000 seed weight.

Cluster analysis: The grouping of varieties was difficult only on the basis of PCA, thus cluster analysis was performed using average linkage cluster on the basis of combined phenotypic data of both years to study connections amongst these varieties. The dendrogram obtained consists of three groups and a number of subgroups that resulted from different biomass and seed yield contributing traits (Fig 1).The results indicated that cluster I comprised of 4 varieties, cluster II contained 11 varieties and group III involved 12 varieties. Varieties falling in different clusters were most diverged than others *viz.*, JO 03-93, JHO 2001-3, UPO-212, HFO-114 and JHO 851. This indicated that these varieties are most suitable for utilization in future breeding progamme involving hybridization. In some cases grouping of varieties into different group even though developed and released for the same geographical region also indicated that oat improvement progamme at these institutes were highly diverse and could fulfill future requirements. The reason for grouping of genotypes of same geographic origin into different clusters might be due to the different genetic architecture resulted wide divergence in morphological features. Grouping of varieties showed that cluster II and cluster III pooled with maximum number of varieties which indicated similarities for phenotypic traits and genetic linkage including their breeding from same organization. The different genetic architecture resulted perhaps due to free exchange of materials among different regions of country, either for direct introduction for breeding purposes or for general cultivation. Genetic drift and selection in different environments could be the other important factors contributing towards the divergence. The results were in agreement with the previous findings of Sood et al. (2016) and Zaheri et al. (2013), who also suggested similar reasons for diversity in oats.

Table 5. Eigen values and Eigenvectors of the important principal components (PC) for variation among the Indian oat varieties

Characters	PC1	PC2	PC3	PC4	PC5	PC6
Plant height	0.372	0.244	-0.123	0.318	0.002	-0.202
Leaf length	0.391	0.278	-0.023	0.233	0.000	-0.261
Leaf width	-0.049	0.373	0.207	0.022	0.411	0.509
Number of leaves plant^{-1}	0.179	0.447	0.251	-0.246	-0.209	-0.099
Number of tillers plant^{-1}	-0.257	0.182	0.343	-0.354	0.072	-0.342
Leaf stem ratio	-0.196	0.326	-0.068	-0.006	-0.494	-0.280
Green fodder yield	0.203	0.031	0.555	0.003	-0.251	0.146
Dry matter yield	0.250	-0.146	0.525	0.139	-0.009	0.155
Total chlorophyll	0.201	0.069	-0.265	-0.435	-0.367	0.432
Days to 50% flowering	-0.416	0.090	0.111	-0.101	-0.053	0.127
Days to maturity	-0.384	0.292	-0.027	0.166	-0.085	0.056
Spike length	-0.075	0.454	-0.186	0.343	0.048	0.297
Seed yield plant^{-1}	0.130	0.233	-0.081	-0.402	0.568	-0.242
1000 Seed weight	0.288	0.067	-0.219	-0.364	-0.067	0.172
Eigen value	2.04	1.44	1.39	1.16	1.06	0.89
Proportion of variance explained	29.99	14.99	13.95	9.61	7.95	5.69
Cumulative variance explained	29.99	44.98	58.93	68.55	76.50	82.19

Table 6. Identified superior performing varieties for forage and seed yield contributing traits

Traits	Criteria	Promising varieties
Plant height (first cut)	>80 cm	OL 9, JHO 2001-3, JO 03-91, OS 7, SKO 96
Leaf length	>55 cm	JHO 851, HFO 114, NDO 2, JHO 2001-3, OS 7
Leaf width	>1.65 cm	JHO 2001-3, NDO 1, OL 9, OS 6, UPO 94
Number of leaves plant^{-1}	>25	HFO 114, OS 6, JHO 2001-3
Number of tillers plant^{-1}	>5.5	JO 3-91, HJ 8, UPO 212, NDO 2
Early flowering	<90 days	JO 3-91, JHO 851, JHO 2001-3, JO 1, OL 125
Early maturity	<130 days	JO 3-91, JO 3-93, JHO 851, JHO 99-2, RO 19
Late flowering	>100 days	JHO 822, OS 346, OL 9, Kent, PLP 1
Late maturity	>140 days	JHO 822, Kent, HJ 8, OS 346
Spike length	>30 cm	NDO1, HFO 114, JHO 2001-3, JHO 822, UPO 212
Green fodder yield (m^2)	>285 g	JHO 2001-3, JHO 2004, PLP 1, SKO 20
Seed yield plant^{-1}	>8.5 g	HFO 114, HJ 8, UPO 212, OS 6, OS 346
Dual purpose use	High fodder and high seed yield	OL 9, RO 19, JHO 851, JHO 822
1000 seed weight	>35 g	NDO 1, JHO 99-2, NDO 2, OS 7, JO3-93

Identification of superior varieties: In order to achieve optimal and sustainable productivity, it is of utmost important to improve the genetic yield potential. Identification of trait specific superior genotypes helps the researchers in exploitation of genetic potential of selected genotypes by utilization in the breeding programmes (Singh et al., 2014). In present study on the basis of mean performance for both the years, no single variety was found to superior for all the traits but few varieties were found performing better for more than one trait. Varieties like OL 9, JHO 851, JHO 2001-3, UPO 212, JHO 99-2 and RO 19 were observed to be performing better than one trait and showed superior performance in general. Some varieties *viz*., JHO 2001-3, JHO 2004, PLP 1 and SKO 20 showed high green forage yield, while varieties HFO 114, HJ 8, UPO 212 and OS 6 were better seed yielder based on mean data of both years when compared to other varieties. Based on the performance of both years, superior performing varieties for different traits were identified (Table 6). The superior varieties could be used in the selective breeding progamme where objective is to improve a particular trait.

Conclusion

Based on the above study it was concluded that oat varieties viz. OL 9, JHO 851, JHO 2001-3, UPO 212, JHO 99-2 and RO 19 were better performing for green forage and seed related traits. Wide diversity and grouping of varieties into distinct groups clearly indicated that varieties developed and released in the country have good diversity and there is no point of concerned at present for narrow genetic base of released varieties. The release varieties are important for future breeding programmes too where they could be utilized as parent for development of fodder or dual type varieties of oat.

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