Morphological characterization using nonmetric variables in exotic oat (Avena SP.) accessions

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Morphological characterization using nonmetric variables in exotic oat (*Avena SP.*) accessions

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ABSTRACT

Oat (*Avena sativa* L.) ranked 6th in the world cereal production which is an important annual crop of rabi season. The genus *Avena* is very large and diverse and includes diploid, tetraploidand hexaploid species (Kaur and Kapoor, 2017). Genus *Avena* includes 70 species, most of the oat's production in worldwide belongs to the hexaploid species: *Avena sativa* L. (widely cultivated white oat) (2n=6x=42. AACCDD) and *Avena byzantina* C. Koch (red oats) (2n=6x=42. AACCDD). Other minor cultivated species includes *Avena abyssinica* (Ethiopian Oats) (2n=4x=28, AABB) and *Avena strigosa* (Known by Black Oats) (2n=2x=14, AsAs) (Gorash *et.al.*, 2017). There is tremendous variability available in oat germplasm studied to characterize and evaluate the exotic genotypes excluding checks using DUS guidelines of different nonmetric traits. Two ninety-four oat genotypes belonging to ten different *Avena species* procured from NBPGR were characterized on the basis of observations recorded for eight morphological non-metric charactersas per the guidelines for the conduct of test for Distinctiveness, Uniformity and Stability. The observations were recorded on five randomly selected plants in each genotype for the following thirteen non-metric traits *viz.*, Early plant vigour, growth habit, leaf colour, leaf sheath pubescence, flag leaf attitude, Panicle attitude, awn per spikelet, seed colour, stem solidness, primary floret pubescence, spikelet shattering, hullness and biotic stress susceptibility at Research cum Instructional Farm, IGKV, Department of Genetics & Plant Breeding, Raipur during *Rabi* 2019-20. Coefficient of variation and principal component analysis revealed variability among the genotypes for the non-metric traits evaluated. Highly Significant positive correlation showed among traits *viz.*, seed colour (black) and biotic stress susceptibility (very low). PCA analysis showed that genotypes namely EC0004456, EC0099165, EC0178761, EC0104007, EC0537811 were very different from each other. Cluster analysis separated genotypes into four sub cluster: genotype EC0022023 with erect flag leaf attitude and brown seed colour (*Avena sativa*) present in different cluster and 23 genotypes with brown seed present in one cluster, all belongs to *Avena sativa* only one genotype IC0282934 belongs to *Avena byzantina*. Genotype namely EC0108477, EC0039402, EC0039915 (*Avena sterilis)* showed black seed. The genotype EC0178761 having compact panicle attitude. stem solidness, primary floret pubescence, spikelet shattering, hullness shows only one class.

Keywords oat. Augmented design. Non-metric traits. Cluster analysis. Principal component analysis. Variability. Dendrogram. Shannon-Weaver index

INTRODUCTION

Oats ranks around sixth in the world cereal production statistics with global production of 33.6 lac ton annually on an area of about 1.0 lac hectares (Anonymous, 2018). Unfortunately, there is acute shortage of green as well as dry fodder by 35.6 and 11.0 per cent, respectively (IGFRI Vision 2050) due to less acreage of green fodder crops (4.9 per cent) and more emphasis on food grain production (Kumar *et al.,* 2018) that drastically affects the productivity of animals in comparison with other countries. In hulled varieties, the spikelets usually contain three florets, one of which is rudimentary and nonfunctional. In naked (hullness) oats, 3 to 7 florets may be produced per spikelet. The florets consist of a lemma and palea, which enclose the reproductive organs – stamens and ovary. Oat (*Avena spp*.) has a taxonomic pattern similar to that of wheat, consisting of a polyploid series of species with seven basic (x = 7) chromosomes, *i.e.,* diploid, tetraploid and hexaploid. Besides the wild species, there are cultivated forms at each ploidy level: the diploid (2n = 2x = 14) grey oat A. strigosa, the tetraploid (2n = 4x = 28) Ethiopian oat A. abyssinica, and the hexaploid (2n = 6x = 42) red oat A. byzantina, and common oat or white or yellow oat *A. Sativa*. The total area covered under oat cultivation in world is 27 mha and production is 40 mt (FAOSTAT, 2019). The total area covered under oat cultivation in the country is about 5,00,000 ha. (Anonymous 2012). Average yield varies from 45 to 55 tons of green fodder and 200-400 kg grain per hectare. Study of variation present in the characters of agronomic importance within large collection ofmaterials is required to use the valuable genotypes for crop improvement program (Jaipal and Shekhawat, 2016). Assessment of the genetic variability can be achieved using morphological measurements and phenotypic characterization. Very good information on sources of germplasm, various descriptors, data on various morphological traits and characterization of oat germplasm on the basis of morphological traits has been well documented (Choubey *et al.* 2005). Characterization of genotypes is the recording of distinctlyidentifiable characteristics which are highly heritable whereas evaluation refers to the agronomic description of the genotypes, for the traits, that are generally important to breedersand researchers in crop improvement. Both are needed to understand the genetic relationship among the genotypes so that they may be deployed effectively in oat breeding program. So, these are crucial for varietal development, identification and release. Morphological descriptors can provide a unique identification of cultivated varieties.

MATERIALS AND METHOD

Genetic evaluation of oat germplasm on the basis of agro-morphological traits was performed at Research cum instructional farm, Department of Genetics and Plant Breeding, IGKV, Raipur Chhattisgarh. The experiment was conducted in augmented design with plot size of 20 × 21.6 m^2 during *Rabi* 2019-20. Plot is divided into 6 blocks and each block occupied 2.5 m length with spacing of 40 cm (R-R). Each block distance is 1m. Standard recommended agronomical package of practices was followed with (20N:50P:20K kg/ha). The climate of Raipur is subtropical and receives 1200-1400 mm rainfall annually out of which about 8 percent is received during *Rabi* season. The experimental material comprised of 294 oat genotypes including check (table-1), belonging to ten different Avena species obtained from NBPGR, Delhi (Table-1). These genotypes included released varieties. Oat germplasm lines were characterized and grouped into different classes on the basis of observations recorded as per the guidelines for the conduct of test for distinctiveness, uniformity and stability on oat by International Union for the Protection of New Varieties, (UPOV, 1994) for morphological characters at different stages of plant growth. According to descriptor Indian grassland and Fodder Research Institute, Jhansi, India (Roy et al., 2017) eight non-metric traits *viz.,* Early plant vigour (recorded at 20-25 days after sowing) was based on a rating scale of 1-3, where 1=poor, 2= good, 3 = very good. Growth habit (recorded at start of spike emergence on the basis of visual scoring and classified into erect (score = 1, semi-prostrate (score = 2), prostrate (score = 3) and others (score = 9). leaf colour (Colour of the leaf on themain tiller was recorded at 50% flowering and classified into green (1), dark green (score = 2) and other (specify) (score = 9). Flag leaf attitude (recorded at spike emergence on the basis of visual scoring classified into erect (score = 1), drooping (score = 2) and semi-drooping (score = 9). Panicle attitude (recorded near maturity stage and classified into compact, semi-compact, lateral, equilateral and others). awn per spikelet (presence or absence of awn and classified as absent (score = 0), one awn (score = 1) or two awn (score = 2). seed colour (recorded after harvesting and classified into white (score = 1), yellow (score = 2), grey (score = 3), black (score = 4) and others (score = 9). Biotic stress susceptibility (at 50% flowering and classified into low (score = 1, very low (score = 3), intermediate (score = 5), high (score = 7) and very high (score = 9) (Table – 2).

Pearson correlation coefficient was worked out for thirteen non-metric traits and correlation matrix was prepared for comparing different traits. Principal component analyses (PCA) based on 13 non-metric traits was performed to find out the relative importance of different traits in capturing the genetic variation in oat. The factors of these traits were used to determine the contribution of each factor towards variation. The standardized values were used to perform PCA using XLSTAT. A scree plot was drawn from the eigenvalues associated with a component and factor in descending order versus the number of the component or factor. Scree plot used for visually assess which component or factors explain most of the variability in the data. Shannon-Weaver diversity index (H′) (Shannon and Weaver 1949) was used as a measure of phenotypic diversity and worked out for each trait. A low H′ indicates extremely unbalance frequency classes for an individual trait and a lack of genetic diversity. The index was estimated based on eight non-metric traits using XLSTAT.

Table 1 List of genotypes of oat used in the study

S.NO.	Botanical name	Accession	Var_OI	Country Name	S.NO.	Botanical name	Accession	Var_OI	Country Name
1.	Avena sativa	EC0108120	Bonaere Nso - 201	ARGENTINA	43.	Avena sativa	EC0841794	JO 0980	SWEDEN
2.	Avena sativa	EC0108122	Buck Epecuen	ARGENTINA	44.	Avena sativa	EC0841793	Kalott	SWEDEN
3.	Avena sativa	EC0108124	Stanton Se. MASSAUX	ARGENTINA	45.	Avena sativa	EC0841791	ODIN	SWEDEN
4.	Avena sativa	EC0108125	Suregrain	ARGENTINA	46.	Avena sativa	EC0841790	JO Tul	SWEDEN
5.	Avena sativa	EC0108126	No. 1 - No. 69 & No. 70 - No. 71	ARGENTINA	47.	Avena sativa	EC0841789	Hird	SWEDEN
6.	Avena sativa	EC0246122	UPF-11	BRAZIL	48.	Avena sativa	EC0841788	HEIN II	SWEDEN
7.	Avena sativa	EC0246131	UFRGS-10	BRAZIL	49.	Avena sativa	EC0841787	grenader	SWEDEN
8.	Avena sativa	EC0246132	UFRGS-11	BRAZIL	50.	Avena sativa	EC0841785	HJA 71801	SWEDEN
9.	Avena sativa	EC0246134	CTC-82B 307	BRAZIL	51.	Avena sativa	EC0006715	BAMBII	SWEDEN
10.	Avena sativa	EC0246144	UPF 78 227	BRAZIL	52.	Avena sativa	EC0013354	LAME	SWEDEN
11.	Avena sativa	EC0246145	UPF 78 237 Lb	BRAZIL	53.	Avena sativa	EC0013351	GREAT MOGUL	SWEDEN
12.	Avena sterilis	EC0062320	Pol	NORWAY	54.	Avena sativa	EC0004721		FRANCE
13.	Avena sativa	EC0057332	Pendek	FINLAND	55.	Avena sativa	EC0003230	WHITE ALGERIAN	CYPRUS
14.	Avena sativa	EC0057333	Jo 0793	FINLAND	56.	Avena sativa	EC0007815	URUSEVOC 6	YUGOSLAVIA
15.	Avena sativa	EC0099174	28160	PORTUGAL	57.	Avena byzantina	IC0282934		Uttarakhand
16.	Avena byzantina	EC0099164	30185	PORTUGAL	58.	Avena sativa	EC0246149	UPF 79B 388-1	BRAZIL
17	Avena byzantina	EC0099163	17232	PORTUGAL	59.	Avena sativa	EC0246148	UPF 79 339-2	BRAZIL
18.	Avena sativa	EC0099178	28091	PORTUGAL	60.	Avena sativa	EC0246150	UPF 79 239-1	BRAZIL
19.	Avena sativa	EC0099175	2783	PORTUGAL	61.	Avena sterilis	EC0013183	REPETER	CANADA
20.	Avena sativa	EC0099170	23025	PORTUGAL	62.	Avena sativa	EC0109261	Hinoat	CANADA
21.	Avena byzantina	EC0099161	30351	PORTUGAL	63.	Avena sativa	EC0113921	var. Cassia	AUSTRALIA
22.	Avena sativa	EC0007814	NOVISOD 4120	YUGOSLAVIA	64.	Avena byzantina	EC0015550	A. Ave 120/57	GERMANY
23.	Avena sativa	EC0054834	MULGA	ISRAEL	65.	Avena byzantina	EC0108724	Metualit	ISRAEL
24.	Avena sativa	EC0095143	Condor	CHILE	66.	Avena byzantina	EC0099165	30191	PORTUGAL
25.	Avena sativa	EC0096459	Mapua-70	NEW ZEALAND	67.	Avena sativa	EC0054937	CLINTLAND -60	NEW ZEALAND
26.	Avena sativa	EC0112078	Santa catalina	ECUADOR	68.	Avena sterilis	EC0013594		AUSTRALIA
27.	Avena sativa	EC0112079	INIAP-67	ECUADOR	69.	Avena sativa	EC0004438	HORNING AMARILLA	AUSTRALIA
28.	Avena sativa	EC0157669	Moiwa	JAPAN	70.	Avena sativa	EC0008367	FULGUM	AUSTRALIA
29.	Avena sativa	EC0030247	Camas	RUSSIA	71.	Avena sativa	EC0008369	AVEIA 5106	AUSTRALIA
30.	Avena sativa	EC0030244	Monarch	RUSSIA	72.	Avena sativa	EC0086444	Bundy	AUSTRALIA
31.	Avena sativa	EC0159072	Nasta	FINLAND	73.	Avena sativa	EC0056175	Dwarf Palestine	AUSTRALIA
32.	Avena sativa	EC0159073	Punti	FINLAND	74.	Avena sativa	EC0057341	Dwarf Palestine	AUSTRALIA
33.	Avena sativa	EC0159069	Hankkijas 20ata	FINLAND	75.	Avena sativa	EC0055197	SWAN	AUSTRALIA
34.	Avena sativa	EC0067153	TITUS	SWEDEN	76.	Avena sativa	EC0107533	Avon X (Garry X Avon) X Curt. 34-1	AUSTRALIA
35.	Avena sativa	EC0028808	CPI 22806	SWEDEN	77.	Avena sativa	EC0103929		AUSTRALIA
36.	Avena sativa	EC0028814	CPI 22405	SWEDEN	78.	Avena sativa	EC0102649	Swan	AUSTRALIA
37.	Avena sativa	EC0028817	CPI 27890	SWEDEN	79.	Avena sativa	EC0114385	West	AUSTRALIA
38.	Avena sativa	EC0025140	Same	SWEDEN	80.	Avena sativa	EC0108660	XB. V.T. 164	AUSTRALIA
39.	Avena sativa	EC0028815	CPI 27888	SWEDEN	81.	Avena sativa	EC0108659	XB. V.T. 72	AUSTRALIA
40.	Avena sativa	EC0028804	CPI 27892	SWEDEN	82.	Avena sativa	EC0108656		AUSTRALIA
41.	Avena sativa	EC0841796	HJA 76037 N	SWEDEN	83.	Avena sativa	EC0108652	Irwin	AUSTRALIA
42.	Avena sativa	EC0841795	HJA 76416	SWEDEN	84.	Avena sativa	EC0108651	Fulghum	AUSTRALIA

Source: Procured from NBPGR (National Bureau of Plant Genetic Resources)

S.NO.	Botanical name	Accession	Var_OI	Country Name	S.NO.	Botanical name	Accession	Var_OI	Country Name
85.	Avena sativa	EC0108648	Bundy	AUSTRALIA	126.	Avena sterilis	EC0062355	Mostyn	UK
86.	Avena sterilis	EC0130450	CAV4882	CANADA	127.	Avena sativa	EC0108600	Condor	UK
87.	Avena sativa	EC0178760	Dumont	CANADA	128.	Avena sativa	EC0108599	Selma	UK
88.	Avena sativa	EC0176071	PGR 16145	CANADA	129.	Avena sativa	EC0108593	Fulghum	UK
89.	Avena sativa	EC0109263	Rodney	CANADA	130.	Avena sativa	EC0108587	Burt	UK
90.	Avena sativa	EC0109243	Victory	CANADA	131.	Avena sativa	EC0108586	Albyn bard	UK
91.	Avena sativa	EC0109104	Hinoar	CANADA	132.	Avena sativa	EC0108603	Nauarro	UK
92.	Avena sativa	EC0092887	Yamaska	CANADA	133.	Avena sativa	EC0024900	85 Resistance	UK
93.	Avena sativa	EC0043840	DORVEL 41 GRAMEL	CANADA	134.	Avena brevis	EC0032557		UK
94.	Avena sativa	EC0112034	Hudson	CANADA	135.	Avena sativa	EC0055196	BENTLAND OATS	AUSTRALIA
95.	Avena sativa	EC0109262	Kelsey	CANADA	136.	Avena sativa	EC0029051	Avon	AUSTRALIA
96.	Avena sativa	EC0178759	Caseade	CANADA	137.	Avena sativa	EC0143511	West	AUSTRALIA
97	Avena sativa	EC0178761	Calibre	CANADA	138.	Avena sativa	EC0029055	Cooba	AUSTRALIA
98.	Avena sativa	EC0140899	NYI-VR(PIR-8682)	CANADA	139.	Avena sativa	EC0029053	Fulmark	AUSTRALIA
99.	Avena sativa	EC0117407	Irwin	AUSTRALIA	140.	Avena sativa	EC0117406	Coolabah	AUSTRALIA
100.	Avena sativa	EC0117404	Avon	AUSTRALIA	141.	Avena sativa	EC0107532	Avon X (Garry X Avon) X Curt S-13	AUSTRALIA
101.	Avena sativa	EC0114246	Black butt	AUSTRALIA	142.	Avena sativa	EC0029058	Burke	AUSTRALIA
102.	Avena sativa	EC0108657		AUSTRALIA	143.	Avena sativa	EC0096533	Green Russian CI 1891 (USAMO)	USA
103.	Avena sativa	EC0055192	LANDHAFER Q.3390	AUSTRALIA	144.	Avena sativa	EC0096577	Autotetraploid Sais CI 8089(USAID)	USA
104.	Avena sativa	EC0004453	RUBIA LIPINGUE	AUSTRALIA	145.	Avena sativa	EC0029057	Klein 69B	AUSTRALIA
105.	Avena sativa	EC0004456	HAWKEY CI-2464	AUSTRALIA	146.	Avena sativa	EC0107531	Avon X (Garry X Avon) X Curt S-60-2	AUSTRALIA
106.	Avena sativa	EC0007662	BOVAH	AUSTRALIA	147.	Avena sativa	EC0107530	Avon X (Garry X Avon) X Curt. S-35	AUSTRALIA
107.	Avena sativa	EC0008370	F	AUSTRALIA	148.	Avena sativa	EC0096537	CI 2185 (USAMI)	USA
108.	Avena sativa	EC0061704	MOSTYN S242	UK	149.	Avena sativa	EC0096540	Boer CI-2531(353)	USA
109.	Avena sativa	EC0108588	Bond	UK	150.	Avena sativa	EC0096536	Black CI 2165(FRANCE)	USA
110.	Avena sativa	EC0108601	Tam finlay	UK	151.	Avena sativa	EC0096583	COMPACT.CI.8280 (917)	USA
111.	Avena sativa	EC0108604	A (67) F5	UK	152.	Avena longiglumis	EC0537819	CW 53	USA
112.	Avena sativa	EC0108602	Blenda	UK	153.	Avena sativa	EC0179872	Nora	USA
113.	Avena sativa	EC0107538	Fulmark	AUSTRALIA	154.	Avena sativa	EC0005681	ANDREW CI-4170	USA
114.	Avena sativa	EC0107536	Coolabah	AUSTRALIA	155.	Avena sativa	EC0035137	Garfield Elnok	HUNGARY
115.	Avena sativa	EC0107534	Clintford	AUSTRALIA	156.	Avena sativa	EC0035131	Gem	HUNGARY
116.	Avena sativa	EC0160165	CV- Carbeen	AUSTRALIA	157.	Avena sativa	EC0035114	Hatvami 117	HUNGARY
117.	Avena sativa	EC0029050	Kent	AUSTRALIA	158.	Avena sativa	EC0035144	Stupicke skelenikose	HUNGARY
118.	Avena sativa	EC0102653	OxB 164 {(Mulga x Belar) x Fulghum) x Bollia) x orient} x Avon	AUSTRALIA	159.	Avena sativa	EC0104475	Jaycee CI_7971	USA
119.	Avena sativa	EC0102652	OxB 161 (Sib line to Oxb 164)	AUSTRALIA	160.	Avena sativa	EC0005853	VICTORIAN 48-93	USA
120.	Avena sativa	EC0019711	Australian	AUSTRALIA	161.	Avena sativa	EC0107022	Seminole	USA
121.	Avena sativa	EC0108654	Mugga	AUSTRALIA	162.	Avena abyssinica	EC0108432	CI-9126	USA
122.	Avena sativa	EC0108650	Coolabah	AUSTRALIA	163.	Avena sativa	EC0102008	cober. 72-34	USA
123.	Avena sativa	EC0004451	SUNRISE	AUSTRALIA	164.	Avena sativa	EC0179874	Cimarron	USA
124.	Avena sativa	EC0030248	Black diamond		165.	Avena sativa	EC0159548	Portor (CI-9412)	USA
125.	Avena sativa	EC0029049	Var. Belar PI 61/20	AUSTRALIA	166.	Avena sterilis	EC0131306	PI-266831	USA

Source: Procured from NBPGR (National Bureau of Plant Genetic Resources)

S.NO.	Botanical name	Accession	Var_OI	Country Name	S.NO.	Botanical name	Accession	Var_OI	Country Name
167	Avena sterilis	EC0130643	PI-4726	USA	209	Avena sativa	EC0182974	Florida 502	USA
168	Avena sterilis	EC0130641	PI-267989	USA	210	Avena sativa	EC0100750	Gopher 432	USA
169	Avena sterilis	EC0130639	PI-317963	USA	211	Avena sativa	EC0099357	Ventura	USA
170	Avena sativa	EC0159067	Sonora/ 8cc CI-14/22	USA	212	Avena sativa	EC0099353	Rapida	USA
171	Avena sativa	EC0130648	India CI. 7292	USA	213	Avena sativa	EC0022034	MO O. 205	USA
172	Avena sativa	EC0130646	Early grain CI. 7708	USA	214	Avena sativa	EC0022031	Indio	USA
173	Avena byzantina	EC0131300	PI-266827	USA	215	Avena sativa	EC0095144	Soleil ii	CHILE
174	Avena sativa	EC0310504	TAM 312	USA	216	Avena sativa	EC0095707	Multiline E70	USA
175	Avena sterilis	EC0039403	Muncy chielf cover crop	USA	217	Avena sativa	EC0095708	Multiline E69	USA
176	Avena sativa	EC0043583	ALAMO	USA	218	Avena sativa	EC0095832	California CCII	USA
177	Avena sativa	EC0043556		USA	219	Avena sativa	EC0096530	Richland. CI 1412 (USAMN)	USA
178	Avena sativa	OL-1896		Punjab	220	Avena sativa	EC0096531	Storm King CI 1507 (USAMY)	USA
179	Avena fatua	EC0537815	AF 540	USA	221	Avena sativa	EC0096534	Daubeney CI 1928 (USACo)	USA
180	Avena sativa	HFO-718		Haryana	222	Avena sativa	EC0110313	Variety	USA
181	Avena brevis	EC0537806	25-68	USA	223	Avena sterilis	EC0108477	PI-282731	USA
182	Avena brevis	EC0537805	-	USA	224	Avena sativa	EC0140867	GP-11	USA
183	Avena abyssinica	EC0537798	CAV 3096	USA	225	Avena sativa	EC0107021	Florida 501	USA
184	Avena sativa	EC0022041	Seminole	USA	226	Avena sativa	EC0104492	Elan CI-8443	USA
185	Avena sativa	EC0022025	Delta Red No. 88	USA	227	Avena sativa	EC0104483	O Brein CI-8174	USA
186	Avena sativa	EC0022023	Curt	USA	228	Avena sativa	EC0103202		USA
187	Avena sativa	EC0022019	(Cherokee x Ark 674) x Newton	USA	229	Avena sativa	EC0102353	Bingham CI Number 7588 spring	USA
188	Avena sativa	EC0022017	Brunker	USA	230	Avena sativa	EC0102347	Wyndmere CI Number 7552 spring	USA
189	Avena sativa	EC0022012	Algerian	USA	231	Avena sativa	EC0102345	O` Brien CI Number 8174 Spring	USA
190	Avena sativa	EC0022009	AB 177	USA	232	Avena sativa	EC0102333	Otter CI Number 8304 Spring	USA
191	Avena sativa	EC0104486	Kota CI-8178	USA	233	Avena sativa	EC0100753	Portal 412	USA
192	Avena sativa	EC0104485	Orbit CI-7811	USA	234	Avena strigosa	EC0108483	PI-258733	USA
193	Avena sativa	EC0104012	Coronado	USA	235	Avena sativa	EC0114256	Wright	USA
194	Avena sativa	EC0104007	Cortez	USA	236	Avena sativa	OS-6	HFO-10 x HFO-55 – P2-2	Haryana
195	Avena sativa	EC0104006	71C 3090	USA	237	Avena sativa	EC0528864	Starter	USA
196	Avena sativa	EC0104004	FLA 501	USA	238	Avena eriantha	EC0537811	KM 13397	USA
197	Avena sativa	EC0104003	71C 3098	USA	239	Avena brevis	EC0537809	WIR 5229	USA
198	Avena sativa	EC0102354	Mesa CI Number 8277 spring	USA	240	Avena brevis	EC0537808	TURGIDA	USA
199	Avena sativa	EC0102348	Coach man CI Number 7684 spring	USA	241	Avena abyssinica	EC0537800	CAV 3076	USA
200	Avena sativa	EC0102342	Holden CI Number 7978 spring	USA	242	Avena strigosa	EC0108485	PI-291990	USA
201	Avena sativa	EC0102337	Pettis CI Number 7805 spring	USA	243	Avena magna	EC0108466	CI-8332	USA
202	Avena sativa	EC0102331	Nodaway.70 CI Number 8442 spring	USA	244	Avena byzantina	EC0108451	PI-266827	USA
203	Avena sativa	EC0310508	COKER 234	USA	245	Avena abyssinica	EC0108436	PI-304555	USA
204	Avena sativa	EC0310510	BOB	USA	246	Avena byzantina	EC0108448	PI-9023	USA
205	Avena sativa	EC0310507	H - 833	USA	247	Avena sterilis	EC0039402	Russell	USA
206	Avena sativa	EC0310506	H - 422	USA	248	Avena sativa	EC0057662	Multiline M 68 CI-8346	USA
207	Avena sativa	EC0310505	TAM 386	USA	249	Avena sativa	EC0043555		USA
208	Avena sativa	EC0179873	Okay	USA	250	Avena sativa	EC0022026	Fayette	USA

Source: Procured from NBPGR (National Bureau of Plant Genetic Resources)

S.NO.	Botanical name	Accession	Var_OI	Country Name	S.NO.	Botanical name	Accession	Var_OI	Country Name
251.	Avena sativa	EC0130635	Black Algerian CI. 3215	USA	273.	Avena abyssinica	EC0108434	PI-196835	USA
252.	Avena sativa	EC0130633	Red Algerian CI. 840	USA	274.	Avena sativa	EC0005677	SOUTHLAND CI-5207	USA
253.	Avena sativa	EC0114547	Spear	USA	275.	Avena sativa	EC0005680	ARKWIN 5850	USA
254.	Avena sativa	EC0096580	CI 8195(USAKY)	USA	276.	Avena sativa	EC0005854	FULGRAIN	USA
255.	Avena sativa	EC0096578	CI 8183(USA.OK)	USA	277.	Avena sativa	EC0005906	L-281 C LINES	USA
256.	Avena sativa	EC0096539	Copperfield.CI.2338(902)	USA	278.	Avena sterilis	EC0008287	CIMARRON	USA
257.	Avena sativa	EC0096529	Bumper crop CI 1386(USA OH)	USA	279.	Avena sativa	EC0057661	Multiline E 68 CI-8345	USA
258.	Avena sativa	EC0093069	Froker CI-8444	USA	280.	Avena sativa	EC0093065	Pennfield CI-7561	USA
259.	Avena sativa	EC0093066	Holden CI-7978	USA	281.	Avena sativa	EC0209260	PI-497905	USA
260.	Avena sativa	EC0067316	Century CI-8351	USA	282.	Avena sativa	EC0043665	WYNDMERE	USA
261.	Avena sativa	EC0102011	Cober. 72-28	USA	283.	Avena sativa	EC0043586	BLOUNT	USA
262.	Avena sativa	EC0528874	Horicon	USA	284.	Avena sterilis	EC0039915	P.I 296261	USA
263.	Avena sativa	EC0528871	Valley	USA	285.	Avena sativa	EC0209213	PI-497762	USA
264.	Avena sativa	EC0106148	Peltis	USA	286.	Avena sterilis	EC0131305	PI-228337	USA
265.	Avena sativa	EC0100754	Illi 66-2287 a405	USA	287.	Avena sativa	EC0093068	Yancey CI-8420	USA
266.	Avena sativa	EC0100752	Orbit 410	USA	288.	Avena sativa	EC0209198	PI-497726	USA
267.	Avena sativa	EC0099358	Kanota	USA	289	Avena sativa	RO-19	Selection from KENT	MH
268.	Avena sativa	EC0096846	Nodaway-70 CI-8442	USA	290	Avena sativa	JHO-822	IGO-4268 x Indio	U. P
269.	Avena sativa	EC0096589	BEIAR.PI-197835 (SWEDEN)	USA	291	Avena sativa	OS-405	HJ-8 × KENT	Haryana
270.	Avena sativa	EC0096588	ENDREB.WEIB.PI-197703(GERMANY)	USA	292	Avena sativa	J0-1	Kent x UPO-50	M.P
271.	Avena sativa	EC0096586	PI-193027(SCOTLAND)	USA	293	Avena sativa	JHO-851	Japanese oat genetic material "HIUGAKAIRYOKURO"	JAPAN
272.	Avena abyssinica	EC0108435	PI-258540	USA	294	Avena sativa	UPO-12-1		Uttarakhand

Source: Procured from NBPGR (National Bureau of Plant Genetic Resources)

Table 2 Non-biometric agro-morphological characters for different germplasm accessions.

S. N.	Descriptor	Class	Score	No. of genotypes	Frequency (%)
		Poor	1	100	34.01
1.	Early plant Vigour	Good	2	137	46.6
		Very Good	3	56	19.05
		Erect	1	237	80.61
		Semi-prostate	2	49	16.66
2.	Growth Habit	Prostate	3	8	2.72
		Other (specify)	9	0	0
		Green	1	203	68.04
3.	Leaf Colour	Dark Green	2	91	30.95
		Other (specify)	9	0	0
		Erect	1	17	5.78
4.	Flag leaf attitude	Drooping	2	7	2.4
		Semi-drooping	9	270	91.83
		Compact	1	1	0.3
5.	Panicle Attitude	Semi-compact	2	0	0
		Lateral	3	18	5.8
		Equilateral	4	275	93.5
		Other (specify)	9	0	0
		Absent	0	13	4.42
6.	Awn per spikelet	One	1	270	91.84
		Two	2	11	3.74
		White	1	7	2.4
7.		Yellow	2	285	96.94
	Seed colour	Grey	3	0	0
		Black	4	3	1.02
		Other (Brown)	9	27	9.18
		Very Low	1	141	47.96
8.	Biotic Stress susceptibility	Low	3	148	50.34
		Intermediate	5	5	1.70
		High	7	0	0
		Very High	9	0	0

Results

Evaluation of genotypes based on non-metric traits

Observation on eight Non-metric traits were recorded for all the 294 genotypes and the score were analysed (Table 2). Maximum number of genotypes (275) was observed with equilateral panicle attitude, while (18) genotypes were lateral and one is EC0178761 is compact. Three group erect, drooping and semi-drooping were observed. Semi-drooping was found in 270 genotypes, 17 were erect and seven (EC0246132, EC0003230, EC0108724, EC0057341, EC0107531, EC0108435, EC0209198) is drooping. Among the genotypes, 237 were found to be erect, 49 were semi-prostate and eight genotypes (JHO-851, EC0159073, EC0841790, EC0841789, EC0537821, EC0310508, EC0310507, EC0209260) is prostate. Three categories of plant vigour namely poor, good, very good were observed. Good vigour types found to be higher (137) followed by poor vigour (100) and very good (56). Among the genotypes, five categories namely very low, low, intermediate, high, very high were observed for biotic stress susceptibility. Low incident was found in 148 genotypes, very low for 141 genotypes and 5 genotypes were (EC0246148, EC0099165, EC0004456, EC0104007, EC0096531) intermediates. Three group namely one, two, zero was observed. One awn was found in 270 genotypes, two awns were in 11 genotypes and 13 genotypes have no awns. Two classes of leaf colour namely green colour and dark green colour were observed. Green leaves were found to be higher (203) when compared to dark green leaves (91). In case of seed colour, most of the genotypes possessed yellow colour group (285), however 27 genotypes were brown, seven genotypes (EC0246134, EC0099178, EC0054834, EC0841790, EC0029055, EC0310506, EC0537800) were white colour and only 3 genotypes, belonged to EC0039402, EC0108477, EC0039915 black group.

Correlation among non-metric traits

Pearson (1901) correlation coefficient was employed among the non-metric traits. Among the 28 inter correlation coefficients, five were significant. The highest significant positive correlation was observed between early plant vigour and biotic stress susceptibility (0.24**). Significant correlation was observed between growth habit and leaf Colour (0.14*), Seed colour and biotic stress susceptibility (0.12*), growth habit and biotic stress susceptibility (0.12*). Significant negative correlation was observed between biotic stress susceptibility and Flag leaf attitude (-0.12*). All other inter correlations were found to be non-significant (Table 3)

Principal component analysis (PCA)

Five significant principal components were identified and accounted for a cumulative variation of 71.09 %. The first principal component accounted for 18.5%. second for 15.24 %, third for 13.23 %, fourth for 12.69 % and fifth for 11.44 % of total variation (Table 4).

Contribution of character towards principal component factors

The scores of non-metric traits were taken into account and subjected to PCA using XLSTAT. Eigenvectors and principal components based on non-rotated loadings were estimated for all the non-metric traits (Table 5). First principal component (PC 1) was correlated with biotic stress susceptibility (0.70), early plant vigour (0.65), seed colour (0.34). The PC 2 was associated with leaf colour (0.76), awns per plant (0.34), growth habit (0.28) and seed colour (0.24) (manivannan *et.al.,* 2016). The PC 3 was correlated with seed colour (0.62), flag leaf attitude (0.59) and awns per plant (0.49). The PC 4 was associated with awns per plant (0.68), panicle attitude (0.59) and biotic stress susceptibility (0.18). The PC 5 was correlated with growth habit (0.73), early plant vigour (0.37), panicle attitude (0.31) and seed colour (0.24). Based on the four PCs, scatter and scree plots depicted the variability.

Grouping genotypes based on PCA biplot

A scatter plot (Fig. 2) drawn using PCI and PC2 factor scores (Table 5) and clear pattern of grouping between the genotypes was observed in the factor plane. The occupied genotypes namely EC0004456, EC0099165, EC0178761, EC0104007 and these genotypes showed the highest point among the factors having diversity. The genotype EC0131300 placed in proximity to EC0107531, similarly the genotype EC0022009 placed in proximity to EC0113921. The genotypes namely EC0310507, EC0209260 and placed in a single point, similarly the genotypes namely EC0028814,0S-405, EC0110313, EC0246145 also grouped together in a single position. Fourteen genotypes namely EC0093068, EC0108451, EC0179873, EC0104486, EC0086444, JHO-822, RO-19, EC0030244, UPO-12-1, EC0019711, EC0159067, EC0117406, EC0095144, ECOO96577 congregated in a single position.

Shannon-Weaver diversity index (H′)

The H′ of eight non-metric traits was used for estimating the frequency distribution of diversity index (Table 6) The H′ of the trait panicle attitude was observed to be higher among (5.68) other traits. An average index (H′) of 5.60 was observed among all the traits.

Cluster analysis

The factors corresponding to five PCs were subjected to cluster analysis based on Euclidean distances and grouped by unweighted paired group method using arithmetic average (UPGMA) using XLSTAT. The depicted four distinct clusters. The cluster I consist of one sub cluster having one genotype, cluster II considered of four sub clusters, sub cluster 1 having 8 genotypes, sub cluster 2 having 2 genotypes, sub cluster 3 having 1 genotype, sub cluster 4 having 12 genotypes.

cluster III considered of four sub clusters, sub cluster 1 having 2 genotypes, sub cluster 2 having 124 genotypes, sub cluster 3 having 2 genotype, sub cluster 4 having 117 genotypes while cluster IV considered of three sub clusters, sub cluster 1 having 1 genotype, sub cluster 2 having 1 genotype and sub cluster 1 having 23 genotypes.

Table 3 Correlation among traits

	EPV	**GH**	**LC**	**FLA**	**PA**	**A/S**	**SC**	**BSS**
EPV	1	-0.11	-0.06	-0.10	-0.05	-0.06	0.08	0.24**
GH		1	0.14*	0.04	0.04	0.01	-0.06	-0.12*
LC			1	-0.10	-0.11	0.09	0.03	-0.10
FLA				1	0.05	-0.01	0.03	-0.12*
PA					1	0.03	-0.09	-0.08
A/S						1	0.05	0.02
SC							1	0.12*
BSS								1

** Significant at 5%, * Significant at 1 %

EPV = Early plant vigour GH = Growth habit LC = Leaf colour FLA = Flag leaf length

PA = Panicle attitude A/S = Awn per spikelet SC = Seed colour BSS = Biotic stress susceptibility

Table 4 Principal component analysis of different traits

Principal component	Eigen value	Variability (%)	Cumulative %
PC1	1.48	18.49	18.50
PC2	1.22	15.24	33.73
PC3	1.06	13.23	46.96
PC4	1.02	12.69	59.65
PC5	0.91	11.44	71.09
PC6	0.83	10.36	81.45
PC7	0.78	9.80	91.25
PC8	0.70	8.75	100.00

Table 5 Principal component of various traits

	PC1	PC2	PC3	PC4	PC5
Early plant vigour	0.65	-0.03	-0.15	0.04	0.37
Growth habit	-0.48	0.28	-0.12	-0.04	0.73
Leaf colour	-0.23	0.76	-0.08	-0.03	0.01
Flag leaf attitude	-0.30	-0.38	0.59	-0.35	0.13
Panicle attitude	-0.27	-0.48	0.02	0.59	0.31
Awn per plant	-0.08	0.34	0.49	0.68	-0.17
Seed colour	0.34	0.24	0.65	-0.22	0.22
Biotic stress susceptibility	0.70	0.03	0.03	0.18	0.22

Table 6 Shannon-Weaver diversity indices (H′) of traits

Characters	EPV	GH	LC	FLA	PA	A/S	SC	BSS	Average
H′	5.61	5.62	5.63	5.63	5.68	5.62	5.49	5.55	5.60

EPV = Early plant vigour GH = Growth habit LC = Leaf colour FLA = Flag leaf length

PA = Panicle attitude A/S = Awn per spikelet SC = Seed colour BSS = Biotic stress susceptibility

DISCUSSION

Non-metric trait evaluation

Among the evaluation traits, the trait seed colour showed much variation (four group), while other showed only three groups. Most accession possessed yellow seed colour, awn per spikelet, equilateral panicle attitude, semi-drooping flag leaf attitude, erect growth habit, good plant vigour with green leaf colour. Growth habit and plant vigour are easily remarked (JHO-851, EC0159073, EC0841790, EC0841789, EC0537821, EC0310508, EC0310507, EC0209260) all belongs to *Avena sativa* and these genotypes is prostate growth habit having poor plant vigour. Prostate genotypes have one awn and equilateral panicle attitude. Erect growth habit genotype EC0095144, EC0099165 having very good plant vigour as they bear a greater number of tillers and leaves.

Two hundred three genotypes namely (OS-6, JHO-851) were identified as green leaf colour. Kumari *et.al.,* (2018) also identified two genotypes namely OS-6 (light green), JHO-851. The genotype EC0039402, EC0108477, EC0039915 showed black colour seed (*Avena sterilis*) which was differed from EC0537800 belongs to *Avena abyssinica* which is white colour seed, such seed traits useful in removing the admixture during processing state.

Morphological variability was observed in oat cultivars *i.e.,* pubescence of the leaf sheath, hullness, spikelet shattering, primary floret pubescence, stem solidness and these traits were widely employed for characterization of oat germplasm

Correlation among non-metric traits

Pearson (1901) correlation coefficient, among the eight non-metric traits revealed that five inter correlation showed significant interaction. The positive correlation was observed between early plant vigour and biotic stress susceptibility, EC0108477 genotypes (*Avena sterilis*) is very good plant growth and low biotic attack. Significant correlation was observed between growth habit and leaf Colour as most of the genotypes grow erect having green colour leaf. The trait Seed colour and biotic stress susceptibility since all genotypes namely EC0039402, EC0108477, EC0039915 have very low biotic stress susceptibility.

Principal component analysis (PCA) and clustering

PCA is a powerful and the most preferred multivariate statistical technique that carries out a data reduction routine among several independent variables while retaining those characteristics of the dataset that contribute most to its variance. The morphological non-metric data were used in multivariate analysis with the major goal to measure the observed diversity, to confirm the result of the taxonomical identification and to determine the main characters that allow differentiate between the varieties. PCA were used for analysis of morphological traits.

Non-metric morphological traits are widely preferred for characterization of the germplasm because they are relatively less influenced by the environment unlike that of quantitative traits. This is the reason why a large number of DUS (distinctiveness, uniformity and stability) characters for plant cultivar registration are defined using non-metric traits. The PCA of the non-metric data derived from 294 phenotypes revealed five independent variables accounting to 70.96% of total variation (Eigen value more than 1). The PCA is highly effective as a data reduction tool, when variables are inter-correlated (Pearson 1901). These independent components therefore would be used for effective classification of the genotypes.

Since the biological explanation of PCA is tricky, the best way to make sense of the PC is to find the degree of influence of each variable on each of the components. Primary variability was governed by the trait's biotic stress susceptibility, early plant vigour, growth habit, leaf colour, flag leaf attitude, panicle attitude, awn per plant and seed colour as explained by the first five PCs.

The genotypes namely EC0004456, EC0099165, EC0178761, EC0104007, EC0537811 were much diverse as observed in the biplot (Fig. 2). These diverse genotypes can be employed as distinct parents for future breeding programs especially hybridization. There was clear that EC0178761 genotype having compact panicle attitude with brown seed colour. Genotype namely, EC0004456 belongs to very good vigour with brown seed colour. EC0537811 were genetically found huge variability existed different species of oat (*Avena eriantha*). These diverse genotypes are useful to broaden the gene pool of oat.

Further grouping based on standardized Euclidean distance and un-weighted paired group method using arithmetic average (UPGMA) clustering method showed four distinct clusters (Fig. 3). The cluster I consist of one sub cluster having one genotype (EC0022023) with erect flag leaf attitude and brown seed colour (*Avena sativa*), cluster II considered of four sub clusters, sub cluster 1 having 8 genotypes, sub cluster 2 having 2 genotypes (EC0246148, EC0099165) belongs to different species with erect flag leaf attitude and yellow seed colour, sub cluster 3 having 1 genotype (EC0108477) black seed colour, sub cluster 4 having 12 genotypes. cluster III considered of four sub clusters, sub cluster 1 having 2 genotypes (EC0039402, EC0039915) both having black seed colour belongs to *Avena sterilis*, sub cluster 2 having 124 genotypes, sub cluster 3 having 2 genotype (EC0104007, EC0096531), sub cluster 4 having 117 genotypes while cluster IV considered of three sub clusters, sub cluster 1 having 1 genotype (EC0178761) having compact panicle attitude, sub cluster 2 having 1 genotype (EC0004456) with erect growth habit and sub cluster 1 having 23 genotypes with brown seed colour, all belongs to *Avena sativa* only one genotype IC0282934 belongs to *Avena byzantina*. These distinct morphological traits can be useful for maintaining the varietal purity and also to remove the off-types and further selection program especially pedigree breeding.

Diversity analysis

The highest diversity was observed in the trait panicle attitude based on the Shannon-Weaver diversity indices (H') followed by flag leaf attitude and leaf colour, growth habit and awn per spikelet, early plant vigour, biotic stress susceptibility. The set of genotypes occupied the convex of the hull in PCA Biplot. Improvement in seed yield along with gum content can be attained by exploiting these two diverse groups.

Conclusion

This study is conducted for comparing the morphological characteristics of oat accessions. The data obtained showed that germplasm resources present a wide range of diversity for morphological traits. The investigations were also very useful in choosing the most precious accessions for further breeding programs. Among the traits early plant vigour and biotic stress susceptibility, EC0108477 genotypes (*Avena sterilis*) is very good plant growth and low biotic attack with growth habit and leaf Colour as most of the genotypes grow erect having green colour leaf. PCA analysis showed that genotypes namely EC0004456, EC0099165, EC0178761, EC0104007, EC0537811 were much diverse, so it can be employed as a distinct parent for future breeding program. Cluster analysis revealed that cluster I consist having one genotype (EC0022023) with erect flag leaf attitude and brown seed colour (*Avena sativa*), sub cluster 2 of cluster I having 2 genotypes (EC0246148, EC0099165) belongs to different species with erect flag leaf attitude and yellow seed colour, sub cluster 3 of cluster III having 1 genotype (EC0108477) black seed colour. cluster III considered sub cluster 1 having 2 genotypes (EC0039402, EC0039915) both having black seed colour belongs to *Avena sterilis*. while cluster IV considered of three sub clusters, sub cluster 1 having 1 genotype (EC0178761) having compact panicle attitude, sub cluster 2 having 1 genotype (EC0004456) with erect growth habit and sub cluster 1 having 23 genotypes with brown seed colour, all belongs to *Avena sativa* only one genotype IC0282934 belongs to *Avena byzantina*. In the era of Intellectual Property Rights, these morphological traits can be used as DUS (distinctiveness, uniformity and stability) characters for plant variety registration and protection. The present study clearly emphasis the power of morphological markers in characterization and utilization of plant genetic resource.

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