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Characterization of Oats (*Avena sativa* L.) Cultivars Using Machine Vision

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Abstract: Machine vision or image analysis is an important tool in the study of morphology of any materials. This technique has been used successfully to differentiate the eleven oats cultivars based on morphological characters. The geometry of seeds was measured through image analyzer and the variation was observed and recorded. From the recorded data, the cluster analysis was carried out and it revealed that the cultivars could be grouped into two main clusters based on similarity in the measured parameters. Cultivar Sabzar, UPO 212, OL 9 and OL 88 formed one main cluster. The another main cluster includes cv. Kent, OS 6, UPO 94, HFO 114, OS 7, HJ 8 and JHO 822 with many sub clusters. Among the cultivars HJ 8 and JHO 822 has more similarity in all measured parameters than other cultivars. Thus morphological characterization through seed image analysis was found useful to discriminate the cultivars.

Key words: Oats, morphological characters, image analysis, cultivar identification

INTRODUCTION

Oats is an important cereal cum forage crop. It has rich medicinal value and being used as food by the diabetic patients, since the grains are filled with cholesterol fighting soluble fibre (Singh *et al*., 2003). Among the cereals *Avena sativa* ranks fifth position after wheat, rice, maize and barley. The leading oats producing countries are Russian Federation, Canada, USA, Poland, Finland, Australia, Germany, France and China. In India presently it is cultivated on large scale in Punjab, Haryana, Uttar Pradesh and to a limited extent in certain parts of Himachal Pradesh, Maharastra, Gujarat, Madhya Pradesh, Orissa, Bihar and West Bengal. At present large number of oats cultivars are available for commercial cultivation. Among the varieties the identification or characterization of cultivars based on morphological features is essential for quality seed production through the successful operation of seed certification programme and granting the plant breeders' right under the PVP and FR act.

Machine vision is a computerised tool for cultivar identification, its functions are similar to the human observations. Simply machine vision refers to the acquisition of data (shape, size etc.,) via., video camera or similar system and subsequent computer analysis of these data following suitable processing. The measurement of geometry of single seed is possible with image analysis technique (Geetha *et al*., 2011). Generally, cultivar identification is done manually on the basis of distinctive traits such as shape, size, colour of the testa and ornamentations. Machine vision systems provide an alternative to manual inspection of samples for characteristic properties, where the information could be visually obtained repeatedly, monotonously and nondestructive inspection with much faster (Grillo *et al*., 2011). In this method the researchers will be able to study seed surface features more closely than manual method. It is an attractive system and easily employed in many environments and gives a real time analysis and inexpensive (Myers and Edsall, 1989).

Uchigasaki *et al.* (1998) developed automated machine vision system to classify seeds based on their colour features. Aquila *et al.* (2000) used the image analysis system to measure area, perimeter, width and length of white cabbage seeds in order to monitor changes in seed physical parameters during imbibitions and suggested that image analysis techniques has high potential in seed biological studies. Anouar *et al.* (2001) grouped the four types of carrot seeds based on seed size using image analysis system. The use of machine vision system to discriminate the varieties by their seed morphological characters was reported by Kumar (2003) in lucerne and Suma (2005) in sesamum. Zapotoczny *et al.* (2008) in barley and Medina *et al.* (2010) in Quinoa seeds successfully employed the image analysis technique for preliminary identification of seeds based on morphological features. From the above facts the present study was formulated to characterize the oats cultivars by using machine vision system.

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MATERIALS AND METHODS

The genetically pure eleven oats cultivars viz., Sabzar, Kent, HFO 114, OS 6, UPO 212, OS 7, HJ 8, UPO 94, OL 9, JHO 822 and OL 88 obtained from Pant University of Agriculture and Technology, Uttar Pradesh were subjected to image analysis technique. The methodology and the parameters studied are described below.

Image analysis system: Image analysis was carried out using Delta-T (Delta-instrument device-Cambridge, UK©) Image analysis system by running custom written software 'winDIAS' (Webb and Jekins, 2000).

For every replication fifteen seeds were placed on lighting hood in such a way that embryo axis of seed facing image analysis system and longitudinal axis of the seed running parallel to the surface of the camera lens. Seeds were viewed with video camera (DSP surveillance color CCD camera CVS 200/3300) using transmitted light, so that a binary image of the silhouette of the seed was recorded by the 'winDIAS'. The image of the support was removed by software after image grabbing in the computer which thus leaving an image of the objects consists five columns for geometric data measurements.

Data recording: Before going for actual measurement, calibration was done by placing transparent plastic ruler on the lighting hood illuminated from below. Ruler was aligned diagonally across the field of view and adjusting focus sharpened image. Again aperture adjustment was done until optimum colour and contrast was achieved. Input measurement was given in centimeter. To measure descriptors like area, perimeter etc. from the menu, object meter was selected. After the image was grabbed using image grabber and colour thresholding was done until the entire area was highlighted. By logging the data, clicks in the measurement bottom, the entire data were extracted by every time clicking entire objects. Data were viewed from the review and mean data for the each parameter were summed up for average value in the 'win DIAS' itself. The entire images and their data were saved in the document file and interpreted data results and images were reported. The parameters studied are as follows:

- **Area:** Multiplication of length and breadth
- **Perimeter:** Multiplication of length, breadth and height of the object
- **Length:** Distance between two points marked on screen using the mouse (or) Diameter of the smallest circumscribed circle that will fit around an object
- **Width:** Length is measured in horizontal X-axis
- **Elongation:** Elongation is the ratio of the length and width
- **Centriod:** The centriod of an object is the most central point or centre of gravity of the object (measured from the top left-hand corner of the screen):

$$X = \frac{1/6 \times \Sigma(x_i^2 + 1 + {}^{*}X_i + X_i^2)(Y_{i+1} - Y_i)}{1/2\,(Y_{i+1} + Y)(X_i - X_{i+1})}$$

$$Y = \frac{1/6 \times \Sigma(Y_{i+1}^2 + Y_{i+1}^2 \times Y_i + Y_i^2)(X_{i+1} - X_i)(X_{i+1} - X_i)}{1/2\,(X_{i+1} + X)(Y_i - Y_{i+1})}$$

- **Circularity:** Circularity is the square root of the ratio of the actual area of the object to the area of a circle with the same circumscribed shell:

$$C = \sqrt[3]{\frac{A}{A_p}}$$

where, A is the actual of the object, A_p is the area of a circle with a diameter equal to the circumscribed diameter or length of the object

- **Average radial:** It is an average of all the distance measured from the centriod to each perimeter point:

$$R = \frac{\Sigma R_j}{n}$$

- **Radial variance:** Radial variance is square of the standard deviation of all distances measured from the centriod to each perimeter point:

$$RV = \frac{\Sigma(R_j - R)^2}{n - 1}$$

where, R_j is the jth radius measured form the centriod to the jth perimeter point and n is the total number of perimeter points

- **CMRV:** It is the correlation of the average radial and radial variance:

$$CMRV = \frac{RV}{R} \times 100$$

- **Shape factor:** Shape factor is the ratio of the actual perimeter to that of a circle with the area:

$$S = \frac{P}{Pc}$$

where, P is the perimeter of the object and P_c is the perimeter of a circle with the same area as the object. P_c is calculated as follows:

$$Pc = 2 (\Pi \times A) 0.5$$

where A, is the actual area of the object

- **Statistical analysis:** The collected data were statistically analyzed as method suggested by Panse and Shukhatme (1985). The cluster was formed using Jaccard's similarity coefficient matrix and to generate a dendrogram NTSYS with Unpaired Group Mathematical Average (UPGMA) was used

RESULTS AND DISCUSSION

From the result, individual seed area was recorded maximum (35.3 cm^2) in cultivar Kent and it was minimum (20.5 cm^2) in cultivar Sabzar (Table 1). Maximum perimeter of the seed was measured (29.0 cm^2) in cultivar HFO114, whereas it was minimum (17.9 cm^2) in cultivar OS7, Centriod X was observed maximum (81.6) in cultivar OS6 and minimum (-346.6) in Sabzar. Centriod Y was maximum (80.9) in OS6 and minimum (49.9) in cultivar HFO114. The length of the seed was recorded maximum (11.7 cm) in HFO114 and it was minimum (7.06 cm) in cultivar OS7. The cultivar HFO114 expressed maximum (2.98 cm) width while it was minimum (1.98 cm) in cultivar OS7. Elongation of

Table 1: Seed morphological characters measurements of oats cultivar using image analyze

	Cultivars										
Parameters	Sabzar	Kent	HFO 114	OS 6	UPO 212	OS 7	HJ 8	UPO 94	OL 9	JHO 822	OL 88
Area (cm^2)											
1) Mean	20.5	35.3	29.9	24.8	28.7	25.6	24.5	25.3	26.6	25	22.4
2) SEd	11.3	6.28	7.18	3.1	6.57	5.6	4.5	2.88	4.44	3.99	2.76
3) Co.eff. mean	55	17.8	24	12.5	22.9	21.9	18.4	11.4	16.6	16	12.3
Perimeter (cm)											
1	26.3	25.2	29	24	27.2	17.9	26.8	23.8	27.6	25.7	26.6
2	11.2	13.8	8.03	8.16	7.93	13.2	8.59	6.02	7.06	9.82	2.68
3	42.7	55	27.7	34	29.1	74.1	32.1	25.3	25.5	38.2	10.1
Centroid X											
1	-346.6	75.9	67.5	81.6	-292.8	48.3	26.8	68.5	-329.6	17	-143.6
2	1551.3	31.3	22.3	47	1029.2	32.1	124.9	39.4	1488.2	140.5	708.6
3	-447.5	41.2	33.1	57.7	-351.5	66.4	466.5	57.5	-451.5	828.4	-493.5
Centroid Y											
1	58.7	54.8	49.9	80.9	67.4	67.9	63.5	59.7	50.8	60.6	59.4
2	43.1	21.9	24	24.4	24.5	21.6	22.8	24.8	21.8	22.4	22.6
3	73.4	40	48.2	30.2	36.3	31.8	36	41.6	42.9	36.9	38.1
Length (cm)											
1	9.26	10.2	11.7	10.2	11.4	7.06	9.9	9.69	11.3	10.2	10.9
2	3.74	5.78	3.29	3.56	3.19	5.3	2.87	2.45	3.14	3.96	1.09
3	40.4	56.4	28	34.8	28	75.1	29	25.3	27.8	39	10
Width (cm)											
1	2.22	2.57	2.98	2.54	2.87	1.98	2.93	2.93	2.72	2.61	2.61
2	0.977	1.17	0.669	0.706	0.729	1.2	0.69	0.712	0.562	0.853	0.221
3	44.1	45.5	22.4	27.8	25.4	60.7	23.5	24.3	20.6	32.7	8.48
Elongation (cm)											
1	0.261	0.374	0.301	0.304	0.279	0.479	0.345	0.326	0.29	0.353	0.242
2	0.0955	0.237	0.188	0.173	0.106	0.296	0.178	0.0976	0.192	0.255	0.0288
3	36.5	63.2	62.4	56.8	38.1	61.8	51.7	29.9	66	72.4	11.9
Average radial											
1	441.8	13	7.37	18.1	372.5	33.4	56.9	19.6	409.6	58.9	211.2
2	1553.6	15.6	10.4	35.9	1023.3	40.4	117.2	33.8	1497.2	149.1	714.4
3	351.6	120.2	141.7	198.3	274.7	121	206.1	172.7	365.5	253.3	338.3
Radial variance											
1	6.78	10.1	10.1	6.49	7.07	4.47	5.95	6.85	7.43	5.37	6.84
2	8.34	9.37	6.6	2.6	3.51	4.25	2.41	5.53	3.14	3.06	2.04
3	122.9	93	65.4	40.1	49.6	95.2	40.5	80.8	42.3	57	29.9
CMRV											
1	98.6	172.7	209	172.6	152.2	63.6	115.6	134.8	178.2	112.7	191.2
2	94.9	129.6	87.5	97.4	121.6	91.7	103.1	77.5	108.7	107.9	82.8
3	96.3	75.1	41.9	56.4	79.9	144.2	89.2	57.5	61	95.7	43.3
Circularity											
1	0.95	2.52	0.908	0.997	0.971	3.76	1.2	1.01	0.924	1.68	0.492
2	1.51	3.75	1.56	1.35	1.79	4.33	2.51	1.72	1.65	3.04	0.031
3	158.8	148.9	171.7	135	183.9	115	209.3	170.7	178.9	181.3	6.25
Shape factor											
1	1.88	1.21	1.5	1.34	1.44	1.01	1.54	1.34	1.52	1.44	1.59
2	0.813	0.652	0.375	0.441	0.368	0.723	0.477	0.334	0.373	0.525	0.122
3	43.2	53.9	25	32.9	25.5	71.7	31	24.9	24.5	36.5	7.65

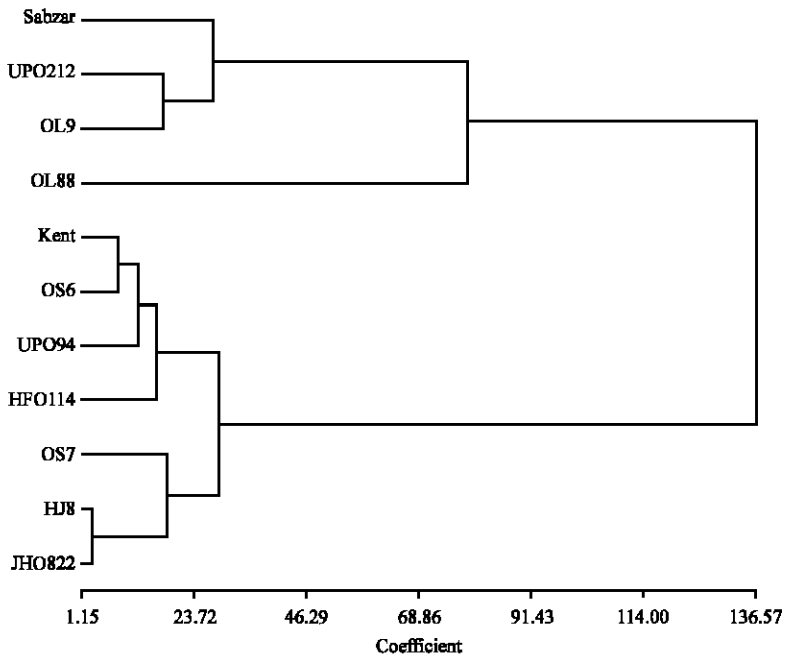

Fig. 1: Hierarchical cluster analysis for seed geometry of oats cultivars

seed was recorded maximum (0.479 cm) in cultivar OS7 and minimum (0.242 cm) was recorded in cultivar OL88. Cultivar Sabzar recorded maximum (441.8) average radial compared to other cultivars and it was minimum (7.37) in cultivar HFO114.Radial variance of seed was recorded maximum (10.1) in cultivars Kent and HFO114 and it was minimum (4.47) in OS7. The maximum (209.0) CMRV was observed in cultivar HFO114 and minimum (63.6) in OS7. The circularity of seed was recorded maximum (3.76) in OS7 and it was minimum (0.031) in cultivar OL88. The shape factor was highest (1.88) in cv. Sabzar and it was lowest (1.01) in OS7.

The cluster was formed from the recorded mean data and the cultivars were grouped based on similarity in the observed parameters. In cluster analysis two major clusters were found in respect to the measurement of geometry of seed by image analysis technique. Cultivar Sabzar, UPO212, OL9 and OL88 formed one main cluster with two sub clusters. Cultivar Sabzar, UPO212 and OL9 formed one sub cluster and cv. OL88 alone formed another sub cluster. The another main cluster includes cv. Kent, OS6, UPO94, HFO114, OS7, HJ8 and JHO822 with two sub clusters. The cultivars Kent, OS6, UPO94, HFO114 formed as sub cluster one and cv. OS7, HJ8 and JHO822 they were formed second sub cluster within second main cluster (Fig. 1).

The existence of variation in seed morphological parameters may be due to genetic nature of the parent. This variation helped for grouping of cultivars. The process of manual identification of seeds by specialized technicians is slow and has low reproducibility. A digital image analysis provides an alternative to the manual classification of biological seed by integrating an image acquisition device and a computer (Jayas *et al*., 1999). This method proved to be quick, requiring less than one minute for scanning and measurement, was repeatable and reliable and above all, it was non destructive and easily executable by non specialized technicians. This identification system does not need any kind of chemical reagents or high expensive analytical consumables, resulting in very low cost methodology (Grillo *et al*., 2011). Dehghan-Shoar *et al.* (1998) recommended image analysis for morphological characterizations that can be useful for seed certification and registration of new varieties. Sokefeld *et al.* (1999) classified the seeds of different species including winter wheat by employing digital image analysis system. Keefee (1999) and Sahoo *et al.* (2000) reported that the image analysis of seeds helped for varietal discrimination in linseed and sunflower, respectively. Mageshwaran (2010) used the image analysis system to discriminate the ten rice cultivars based on morphometric measurements. From the observations it is considered to be more accurate and consistent than manual method and produces truly objective measure of seed features.

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