

## Variation in Morphological Characteristics of Maize Varieties and its Implication in Plant Variety Protection

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**ABSTRACT:** The legislation on "Protection of Plant Varieties and Farmers' Rights Act (PPV & FR Act)" passed by the Indian Government in 2001, provides for protection and registration of a new variety of plant if it conforms to the criteria of Distinctiveness, Uniformity and Stability (DUS). The National Agricultural Research System (NARS) of India has released a number of maize varieties and hybrids for different agro climatic region. However, assessment of these for DUS characteristics, have not been made. Therefore, ten maize genotypes, comprising inbreds, single, double and three-way crosses and composites were evaluated at Indian Agricultural Research Institute, New Delhi in *Kharif* season, 2005 following the National DUS Test Guideline. Among these characteristics, expression of two qualitative characteristics, i.e., anthocyanin colouration of leaf sheath and the angle between the leaf blade and stem were found stable and uniform in all genotypes studied. Other characteristics exhibited variable states of expression. Among the genotypes, inbred line 193-1 and single cross hybrid Prakash showed the highest level of uniformity and lowest within the population variation for almost all characteristics. Rest of the genotypes including the inbred CM 137 exhibited lesser uniformity, indicating inherent variability in the different states of expression among characteristics. The study provided an assessment of the status of variation in characteristics expression of maize genotypes which are discussed in the light of requirements of variety maintenance and conduct of DUS test for Plant Variety Protection.

**Key words:** Distinctiveness, Uniformity, Characteristics, Variety, Maize

The application of Intellectual Property Rights (IPRs) to new varieties of plants is relatively recent in India. The key objective of Plant Variety Protection (PVP) is to promote research and innovation in plant variety development. Till the early 1990s, PVP remained almost exclusively a feature of developed countries, while developing countries generally relied on research by the public sector institutions which were freely available at the national and international level.

Article 27 (3) (b) of the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPs) deals with the plant variety protection and states that "Members shall provide for the protection of plant varieties either by patents or by an effective *sui generis* system or by any combination thereof". Having research and variety development both in the public and private sectors, India has adopted a novel *sui generis* system in the form of legislation on "Protection of Plant Varieties and Farmers' Rights (PPV & FR) Act in 2001 providing effective protection of plant varieties [1].

Under the Act, a new variety shall be registered if it conforms to the criteria of Distinctiveness, Uniformity and Stability (DUS). The new variety must be clearly distinguishable by one or more essential characteristics from any other variety whose existence is a matter of common knowledge at the time when the protection is applied for. The variety is deemed uniform if subject to the variation that may be expected from the particular features of its propagation, and is sufficiently uniform in its relevant characteristics.

Appropriate morphological and agronomic descriptions of cultivars and varieties have been the basis of tests for DUS internationally [2]. Indian guidelines have been developed for DUS testing in different crops including maize [3]. The Indian maize research programme, under the All - India Coordinated Maize Improvement Project (AICMIP) of the Indian Council of Agricultural Research (ICAR) has released more than 173 open-pollinated varieties and hybrids [4]. The private sector maize

improvement programme is also very active in India, leading to the release of a large number of hybrids every year [5].

Hybrid maize being popular, a large number of applications for protection of hybrids, parental lines including inbred and varieties are received for protection. At the same time the Act also provides a scope for registration of extant varieties of maize including hybrids notified under Seeds Act, 1966. Hence, a study was undertaken with the objectives:

- (a) To characterize the popular inbreds, hybrids (single, double and three-way crosses) and open-pollinated varieties on the basis of the Draft National DUS Test Guidelines of maize and
- (b) To assess the variation with respect to qualitative and quantitative characteristics of some representative varieties for testing distinctness and uniformity.

## MATERIALS AND METHODS

Seeds of ten maize cultivars, comprising of two inbreds (CM-137, 193-1), one single cross (Prakash), two three-way crosses (Shaktiman 1 and Ganga 11), three double cross (Seed Tech 2324, Bio-9681 and Deccan 105) and two composites (Prabhat and NLD) obtained from authentic sources (Table 1) and were planted in *Kharif* season of 2005 in the research farm of Indian Agricultural Research Institute, New Delhi in a randomized complete block design with three

replications. Each plot had 20 rows each of 5 meters length keeping the spacing between rows and plants at 75 cm and 20 cm, respectively. All recommended package of practices were followed to raise a normal crop.

Three hundred plants (100 plants in each replication) in each genotype were tagged randomly for recording the morphological characteristics.

### *Characteristics observed*

UPOV's DUS Test Guidelines [6] and Draft National DUS Test Guidelines for the Conduct of Test for Distinctiveness, Uniformity and Stability (DUS) of maize (*Zea mays* L.) were followed for the trial layout and recording of data. In the Draft National Guidelines 27 morphological and physiological characteristics are provided, out of which 23 characteristics were selected for the study, which included visually observed qualitative and quantitative traits and also measured quantitative characteristics.

### *Recording and scoring of characteristics*

The appropriate numerical notes to different states of expression for different characteristics as provided in the Draft National DUS Test Guidelines were used for recording and scoring of characteristics.

### *Statistical analysis*

The expression of characteristics was calculated in percentage based on number of plants observed in

**Table 1. List of maize inbred lines and varieties included in the study**

Inbred/variety	Pedigree	Source
CM-137	IPA 9-7-f-⊗-≠-⊗-⊗	NSC, New Delhi
193-1	Selection from CML 193	HAU, Karnal
Prakash	(CM139 × CM140)	DMR, New Delhi
Shaktiman- 1	[(CML142 × CML150) × CML176]	DMR, New Delhi
Ganga-11	[(CM202 × CM111) × CM501]	NSC, New Delhi
Seed Tech 2324	D.C (parentage unknown)	DMR, New Delhi
Bio-9681	[(BioFF1 × BioMF1) × (BioFM1, BioMM1)]	DMR, New Delhi
Deccan-105	[(CM119 × CM120) × (CM211 × CM131)]	NSC, New Delhi
Prabhat	(Partap × Suwan1) × Partap	DMR, New Delhi
NLD	Selected materials and bulked	NSC, New Delhi

each state, as mentioned in the Draft National Guideline. In case of quantitative characteristics, Least Significant Difference (LSD) at 5% probability, Co-efficient of Variation (CV) and Standard Deviation (SD) were also calculated using SPSS 10.0 statistical package.

## RESULTS AND DISCUSSION

In maize, there are 17 distinct loci that affect the qualitative, quantitative, and distribution of anthocyanin and related pigments in various plant and seed tissues [7]. These are widely distributed all over the genome and present in all the chromosomes except chromosome 8.

### *Qualitative characteristics*

*Anthocyanin coloration of leaf sheath, brace roots, base of glume, anthers and silks:* Genotypes were classified into two categories on the basis of presence (1) or absence (0) of anthocyanin pigmentation. None of the ten genotypes exhibited anthocyanin coloration on the leaf sheath therefore we recorded 100 percent absence of anthocyanin pigmentation on the leaf sheath among the maize inbreds and varieties studied (Table 2).

Most of the varieties showed high frequency of plants with anthocyanin coloration of brace roots. Prakash, Deccan-105, Shaktiman-1 and Ganga-11

recorded 93-96% plants with anthocyanin coloration whereas, inbred 193-1 and double cross hybrid Bio-9681 showed almost equal number of plants with presence and absence of anthocyanin pigmentation on brace roots (Table 2).

Single cross hybrid Prakash was distinct with predominance of anthocyanin coloration at the base of glume (97% in 290 plants) whereas in rest of the genotypes both the expression states were recorded in almost equal proportions (Table 2).

The expression of anthocyanin coloration of anther was variable in eight of the ten genotypes, whereas it was present in inbred line 193-1 (98%) and predominantly absent in hybrid Deccan-105 (93%). Only two varieties i.e., Seed Tech 2324 and Prakash showed a clear single group of plants having 100% presence of anthocyanin and 96% absence of anthocyanin colouration of silks, respectively. Other genotypes exhibited differential expression of this characteristic also (Table 2).

*Attitude of leaf blade and angle between blade and stem:* Two states of expression i.e. straight and droopy were recorded. Single cross hybrid, Prakash showed 100% plants with droopy leaf blades, followed by Deccan-105 (99%). A higher variation for this character was observed in Shaktiman-1, a three-way cross hybrid. Other varieties showed > 85% uniformity with respect to attitude of leaf blade (Table 3).

**Table 2. Expression (%) of anthocyanin coloration in different plant parts of maize inbreds and varieties**

Inbred /Variety	No. of plants observed	Leaf sheath		Brace roots		Base of glume		Anther		Silk	
		Absent	Present	Absent	Present	Absent	Present	Absent	Present	Absent	Present
CM-137	277	100	0	14	86	61	39	36	64	47	53
193-1	220	100	0	53	47	26	74	2	98	68	32
Prakash	290	100	0	7	93	97	3	88	12	96	4
Shaktiman-1	226	100	0	5	95	52	48	83	17	17	83
Ganga-11	282	100	0	6	94	55	45	57	43	42	58
Seed Tech 2324	260	100	0	13	87	62	38	63	37	0	100
Bio-9681	278	100	0	45	55	52	48	57	43	28	72
Deccan-105	283	100	0	4	96	54	46	93	7	27	73
Prabhat	249	100	0	20	80	55	45	51	49	18	82
NLD	273	100	0	27	73	71	29	68	32	58	42

**Table 3. Expression (%) of leaf characteristics of maize inbreds and varieties**

Inbred /Variety	No. of plants	Attitude of blade		Angle between blade and stem		
		Straight	Droopy	Small	Medium	Large
CM-137	277	11	89	0	100	0
193-1	220	9	91	0	100	0
Prakash	290	0	100	0	100	0
Shaktiman-1	226	37	63	0	100	0
Ganga-11	282	7	93	0	100	0
Seed Tech 2324	260	10	90	0	100	0
Bio-9681	278	15	85	0	100	0
Deccan-105	283	1	99	0	100	0
Prabhat	249	4	96	0	100	0
NLD	273	11	89	0	100	0

*Angle between leaf blade and stem:* Based on UPOV Guidelines [6] three states of expression viz., small, medium and large were recorded for this characteristic. All the varieties were grouped as medium (Table 3). However, it could not establish distinctness between the maize genotypes because of broad range of angle prescribed for its characteristic.

*Ear: shape:* Three states of expression (i.e. conical, conico-cylindrical and cylindrical) were recorded for ear shape. None of the genotypes showed 100% uniformity for this characteristic. Five genotypes showed two states of expression, and four genotypes exhibited three states of expression. Bio 9681 and

Deccan-105 exhibited conico-cylindrical shape of ear having more than 90 *per cent* uniformity. Conical shape was not predominant in any genotype, though Prakash recorded 34% plants with conical ears (Table 4). On the other hand, 193-1 and Shaktiman-1 had higher number of plants with cylindrical ears (74 and 59 *per cent* respectively). Three distinct ear shapes were observed in CM-137, Prabhat and NLD (Table 4).

*Ear: type of grain:* Based on grain type, four varieties were predominantly (92-100%) flint type and one was semi flint/dent type (193-1). Seed Tech 2324 exhibited all three types of grain with considerable proportions. Three grain type classes were also seen

**Table 4. Expression (%) of ear and grain characteristics of maize inbreds and varieties**

Inbred /Variety	No. of plants	Ear shape			Type of grain		
		Conical	Conico-cylindrical	Cylindrical	Flint	Semi flint/dent	Dent
CM-137	277	19	58	23	99	1	0
193-1	220	0	26	74	0	99	1
Prakash	290	34	66	0	100	0	0
Shaktiman-1	226	0	41	59	66	32	2
Ganga-11	282	0	79	21	97	3	0
Seed Tech 2324	260	0	83	17	39	41	20
Bio-9681	278	3	97	0	32	65	3
Deccan-105	283	0	90	10	73	27	0
Prabhat	249	8	71	21	92	8	0
NLD	273	13	70	17	29	70	1

**Table 5. Expression (%) of grain and cob characteristics of maize inbreds and varieties**

Inbred /Variety	No. of plants	Colour of top of grain			A.C of glumes of cob		
		White	Yellow	Orange	White	Light purple	Dark Purple
CM-137	277	0	100	0	100	0	0
193-1	220	0	100	0	100	0	0
Prakash	290	0	0	100	100	0	0
Shaktiman-1	226	96	4	0	99	1	0
Ganga-11	282	0	7	93	36	0	64
Seed Tech 2324	260	0	79	21	100	0	0
Bio-9681	278	0	88	12	1	2	97
Deccan-105	283	0	94	6	9	5	86
Prabhat	249	0	11	89	76	0	24
NLD	273	100	0	0	100	0	0

in Shaktiman-1, Bio-9681 and NLD (Table 4).

*Color of top of grain:* Genotypes were categorized into three groups viz., white, yellow, and orange, based on the color of top of grain. Two varieties, namely NLD and Shaktiman-1 were grouped under white, with 96 to 100 *per cent* uniformity. Two inbreds (CM-137 and 193-1) and Deccan-105 had yellow color on top of grain. Prakash (100%) and Ganga-11 (93%) were classified under orange color. Three remaining varieties expressed a mixture of two color states (yellow and orange) in variable proportions (Table 5).

*Anthocyanin coloration of glumes of cob:* Almost all maize inbreds and varieties were classified clearly into two groups for this characteristic. Uniformity of expression was clear in 7 out of 10 varieties, showing

predominantly white (99-100%) or dark purple (97%) color of the glumes of cob. Prabhat and Ganga-11 showed two types of plants in different proportions, whereas all three types were observed in Deccan-105. Very few plants (up to 5%) expressed light purple glume color of cob (Table 5).

*Kernel: row arrangement:* Among ten maize varieties, majority showed pre-dominance of straight kernel rows (55 – 93%), though the spiral and irregular rows were also present in lesser extent. Seed Tech 2324 showed 100% cobs with regular kernel row arrangement, whereas the remaining varieties occurrence of irregular rows was 1-8%. Spiral kernel rows were found in 4-41% cobs among the varieties, the highest being in NLD, a composite variety (Table 6).

**Table 6. Expression (%) of kernel characteristics of maize inbreds and varieties**

Inbred /Variety	No of plants	Kernel row arrangement			Kernel shape		
		Straight	Spiral	Irregular	Round	Indented	Toothed
CM-137	277	86	10	4	87	13	0
193-1	220	93	4	3	93	7	0
Prakash	290	78	18	4	14	86	0
Shaktiman-1	226	80	19	1	0	10	90
Ganga-11	282	91	8	1	85	15	0
Seed Tech 2324	260	80	20	0	17	79	4
Bio-9681	278	84	15	1	4	38	58
Deccan-105	283	72	20	8	74	26	0
Prabhat	249	76	20	4	96	4	0
NLD	273	55	41	4	3	84	13

*Kernel: shape:* Three types of kernel shape were recorded among the ten maize varieties. These were round, indented and toothed. Six varieties showed round and indented shape kernels. Shaktiman-1 showed indented and tooth shaped kernels and the other varieties showed variable expressions of all three states (Table 6).

#### *Quantitative characteristics*

Varieties were also classified on the basis of variations expressed in seven measured characteristics (Table 7). Number of branches were ranged from 2 to 29

among ten varieties, with 193-1 having the smallest range (3-10) and the lowest coefficient of variation (18.7) and thus considered most uniform for this characteristic. In eight varieties more than 20 branches were recorded (Table 7).

Plant height among varieties ranged from 101 – 195cm with a coefficient of variation of 11.7%. For the length of peduncle, a high range (1.2-21cm) and maximum percentage of coefficient variation (35.2%) was observed among the varieties. The lowest range (2-12.1cm) and coefficient variation (27.1) were found in NLD and 193-1, respectively (Table 7).

**Table 7. Intra- varietal variation in measured characteristics of maize inbreds and varieties**

Inbred/variety		No of branches	Length of main axis	Length of plant	Length of peduncle	Length of ear	Diameter of ear	Kernel size
CM-137	Min	6	26	102	1.2	8.3	2.6	158.7
	Max	25	47	170	19.5	22.1	5.4	275.9
	Mean	15.15	34.93	125.74	6.84	15.52	3.84	232.6
	S D	3.92	4.02	12.83	2.8	2.62	0.5	30.6
	CV	25.9	11.5	10.2	40.9	16.9	13.0	13.2
193-1	Min	3	17	63	3	8.1	2.4	150.9
	Max	10	27.5	120	17	16	3.8	198.9
	Mean	6.09	21.98	105.53	9.71	13.29	3.33	175.4
	S D	1.14	2.3	13.73	2.63	1.48	0.24	12.9
	CV	18.7	10.5	13.0	27.1	11.1	7.2	7.4
Prakash	Min	9	28	102	1.5	8.9	2.7	214.3
	Max	24	43	170	16.8	20.8	4.2	350.8
	Mean	15.28	36.56	134.82	6.32	16.11	3.5	283.1
	S D	3.2	3.05	15.48	3.03	1.68	0.29	35.9
	CV	20.9	8.3	11.5	47.9	10.4	8.3	12.7
Shaktiman	Min	4	22	102	2.5	7	2.6	147.3
	Max	21	46.5	175	17.4	20.4	4.6	318.6
	Mean	10.27	33.43	130.27	7.15	14.1	3.68	202.4
	S. D	3.09	4.44	14.8	2.56	2.61	0.41	44.2
	CV	30.1	13.3	11.4	35.8	18.5	11.1	21.8
Ganga-11	Min	5	23	110	2	8.4	2.7	123.1
	Max	27	47	195	14	22	4.7	276.9
	Mean	15.23	35.94	147.24	6.4	13.9	3.73	205.4
	S D	4.28	4.04	20.01	2.04	2.46	0.38	46.5
	CV	28.1	11.2	13.6	31.9	17.7	10.2	22.7
Seed Tech 2324	Min	5	24	102	2	8.2	3	138.9
	Max	20	50	165	15.2	22.5	5	351.9
	Mean	11.81	37.1	135.58	8.11	15.58	3.79	219.8
	S D	2.57	5	13.63	2.45	2.66	0.37	54.6
	CV	21.8	13.5	10.1	30.2	17.1	9.8	24.9

Contd...

Inbred/variety		No of branches	Length of main axis	Length of plant	Length of peduncle	Length of ear	Diameter of ear	Kernel size
Bio-9681	Min	2	23	110	1.7	6.6	3	154.9
	Max	15	50	180	19.1	22	5	372.5
	Mean	8.02	37.36	143.38	9.03	14.62	4.05	244.4
	Std. D	2.43	4.14	15.83	3.17	2.64	0.41	53.7
	CV	30.3	11.1	11.0	35.1	18.1	10.1	22.0
Deccan-105	Min	6	25	101	2	7.6	2.2	155.8
	Max	24	47	178	17.1	21.1	5.2	367.9
	Mean	14.27	35.02	140.41	7.17	13.98	3.6	223.6
	S. D	3.82	4.65	18.31	2.66	2.54	0.55	44.4
	CV	26.8	13.3	13.0	37.1	18.2	15.3	19.9
Prabhat	Min	3	21	115	3.3	6.6	2.4	135.3
	Max	27	50	192	21	22.5	5	315.1
	Mean	15.82	36.75	150.47	8.85	15.4	3.81	222.0
	S D	4.88	5.02	16.74	2.83	2.6	0.42	44.0
	CV	30.8	13.7	11.1	32.0	16.9	11.0	19.8
NLD	Min	4	26	102	2	6	3	136
	Max	29	45	187	12.1	23	5	389.5
	Mean	14.19	35.23	134.52	5.85	14.16	3.83	228.3
	S D	4.75	3.96	16.69	1.96	2.9	0.44	67.3
	CV	33.5	11.2	12.4	33.5	20.5	11.5	29.5
Overall range		2.0-29	17-50	101-195	1.2-21	6.0-23	2.2-5.4	123.1-389.5
Mean		12.61	34.43	134.80	7.54	14.67	3.72	223.69
S. D		3.41	4.06	15.81	2.61	2.42	0.40	43.43
<b>CV(%)</b>		<b>26.7</b>	<b>11.8</b>	<b>11.7</b>	<b>35.2</b>	<b>16.5</b>	<b>10.8</b>	<b>19.4</b>

Variety NLD had the highest variation for the length of cob and kernel size with cv values of 20.5 and 29.5%, respectively showing high degree of non-uniformity, whereas, 193-1 had the lowest coefficient variation for both the characteristics. The remaining varieties showed large variations in the populations.

Diameter of cob without husk was a stable character, which showed lowest coefficient variation (10.8%) among all the varieties. Minimum variation for this characteristic was recorded for 193-1 and Prakash than other varieties.

#### *Grouping of varieties based on quantitative characteristics*

*Time of 50 percent anthesis (AFT):* None of the ten varieties under this study showed any difference for days to 50 per cent anthesis and were classified under the late group (> 55 days) (Table 8).

*Time of 50 percent silk emergence (SFT):* Nine out of the 10 varieties took more than 60 days for 50 per

cent silk emergence and were classified under the late group. Prakash was classified under the medium group with flowering time of 53 to 58 days.

*Tassel: Number of primary and lateral branches (TBN):* Varieties were grouped into two classes i.e., having few (<12) and many (> 12) primary and lateral branches. This was based on the mean value of number of branches. Four varieties were classified as having few branches and the remaining six varieties were classified as having many branches (Table 8). Inbred line 193-1 showed minimum number of branches (6) whereas Prabhat showed the highest number of branches (16).

*Tassel: Length of the main axis above lowest side branch (TLG):* There was little difference for this characteristic among the maize varieties. None was categorized into long group (> 30cm) and only inbred 193-1 was in medium group (20 to 30cm).

*Plant height (PLH):* Two varieties, CM- 137 and Prabhat were classified into medium group (120-150cm and 150-180cm, respectively) whereas the rest were grouped into short group (<120cm and <150cm for inbred lines and hybrids, respectively) (Table 8).

*Ear: Length of peduncle (PLG):* Six varieties showed 3-8 cm length of peduncle and were classified under medium group. Varieties viz., 193-1, Prabhat, Seed Tech-2324 and Bio-9681 were grouped into long group (> 8cm) (Table 8).

*Ear: Length without husk (ELG):* Varieties were classified into two groups i.e., medium (10 to 15cm) and long (> 15cm). Prakash had the longest cob with a mean length of 16.1cm and 193-1 had the shortest (13.1cm) cob length.

*Ear: Diameter without husk (EDI):* Except Bio 9681, which was classified under medium group from 4 to 5cm (Table 8) all maize cultivars belonged to small group (< 4cm).

*Ear: Number of rows of grains (RGN):* Varieties were classified having medium (10-12) and many (3-14) rows of grains (Table 8).

*1000 kernel weight (KWT):* Except 193-1, which had kernel weight between 100 – 200g and classified into small group the rest of the maize varieties were classified under medium group (200-300g).

Thus, using comparison among the characteristics, ten maize varieties could be classified into different subgroups leading to the establishment of clear distinction among these.

## DISCUSSION

Normally, the synthesis of anthocyanin pigment in maize plant requires the expression of several genes, both structural and regulatory. Among these, four are specific for anthocyanin synthesis viz., *R*, *B*, *C1* and *Pl* [8]. Pigment production in any particular part of the plant requires the interaction of a member of the *R/B* family and a member of the *C1/Pl* family. For example, anthocyanin synthesis in the body of the plant requires the *B* and *Pl* genes, whereas in the aleurone layer of the endosperm the seed-specific *R-S* gene and the *C1* gene are required [9].

The genes responsible for anthocyanin pigmentation in various plant parts are localized in different chromosomes indicating their random assortment while breeding. Therefore, presence of pigmentation in all the parts of an individual plant may not be essential.

Environmental stresses caused by low-temperature [10] or light [11], also have an impact on the production of anthocyanin in maize. Therefore, it is important to judge the characteristics carefully

**Table 8. Classification of maize inbreds and varieties based on plant and ear characteristics**

Inbred /Variety	AFT	SFT	TBN	TLG	PLH	PLG	ELG	EDI	RGN	KWT
CM-137	7	7	9	7	5	5	7	3	5	5
193-1	7	7	5	5	3	7	5	3	5	3
Prakash	7	5	9	7	3	5	7	3	5	5
Shaktiman-1	7	7	5	7	3	5	5	3	5	5
Ganga-11	7	7	9	7	3	5	5	3	7	5
Seed Tech 2324	7	7	5	7	3	7	7	3	5	5
Bio-9681	7	7	5	7	3	7	5	5	7	5
Deccan-105	7	7	9	7	3	5	5	3	5	5
Prabhat	7	7	9	7	5	7	7	3	5	5
NLD	7	7	9	7	3	5	5	3	7	5

AFT: Time of 50 percent anthesis (7: Late ); SFT: Time of 50 percent silk emergence (5: Medium,7: Late); TBN: Tassel: Number of primary and lateral branches (5: Few, 9: Many); TLG: Tassel: Length of main axis above lowest side branch (5: Medium; 7: Long); PLH: Plant height: (3: Short; 5: Medium); PLG: Ear: Length of peduncle (5: Medium, 7: Long); ELG: Ear: Length without husk (5: Medium; 7: Long); RGN: Ear: Number of rows of grains (5: Medium; 7: Many); EDI: Ear: Diameter without husk (3: Small, 5: Medium); KWT: 1000 kernel weight (3: Small, 5: Medium).

in a particular growth stage of a normal growing plant.

Mauria (1997) [12] used type and colour of grain to distinguish 31 maize inbred lines and stated that numerical note/scale provides an easily-interpretable and simple description.

A difference between the class intervals given to designate a particular group or state of expression of a quantitative characteristic and the results based on the statistical analysis of the actual values of the plants for various characteristics indicated the usefulness of redefining the classification of varieties. This is valid not only for maize but also for all the crop plants. However, while doing so care must be taken to define the same with respect to a particular location or agro- ecological situation.

#### *Uniformity assessment in quantitative characteristics*

Based on various quantitative characteristics, 193-1 showed higher uniformity (99-100%) across five out of eight quantitative characteristics, whereas other characteristics also demonstrated fair uniformity (ranging from 70 to 91) in this inbred line. Inbred line, CM-137 did not show uniformity for characteristics except long main axis. Bio-9681 showed uniformity for two characteristics i.e. number of branches and length of main axis. Prabhat and NLD were non-uniform showing different states of expression for all characteristics. Length of main axis above lowest side branches was found to be a uniform characteristic among all varieties. Three varieties viz., Bio-9681, Prakash and CM-137 had 95, 97 and 100 percent plants showing long main axis respectively. None of the varieties showed sufficient uniformity for length of peduncle and ear length.

Ten quantitative characteristics were examined for characterization of maize cultivars. Among these, almost all characteristics showed significant differences among the cultivars, confirming the wide genotypic variability. Based on the mean value of these characteristics viz., 50% flowering time, length of main axis above lowest side branch, kernel size etc, most of the ten inbreds and varieties were similar, falling into one group, except inbred line 193-1 which was classified under another group. Therefore, it was difficult to distinguish among maize cultivars based

on above characteristics. To test the uniformity based on test guidelines of maize, characteristics were found to express different forms under various states showing non-uniformity among individual plants within each cultivar.

Two inbred lines i.e. CM-137 and 193-1 and single cross hybrid Prakash as expected, showed higher levels of homogeneity and uniformity. Other varieties comprised three- way cross hybrids, double cross hybrids and composite with component parental lines which showed different states of expression in the respective population.

The reason of intra- varietal variation of characteristics could be the following:

- i. The inbred lines were not selfed up to the generation in which it reached to the desired high levels of homozygosity and homogeneity for a set of characteristics making them heterozygous. This is commonly done to maintain higher productivity. Thereafter, these are intermated in isolation for multiplication purpose.
- ii. Since the inbred lines lack homogeneity the hybrids and composites showed variation in character forms.
- iii. Many of the characteristics included in the DUS test guidelines are not commonly considered by the breeder for its selection in the process of maintenance. Therefore, an unintentional variability in some of those characteristics exists in the varieties and inbreds.
- iv. The foundation and certified seed classes used in the study were not produced under direct supervision of the respective breeder, thereby increasing the presence of variables/deviants.

The accurate description and identification of varieties are established by using a set of characteristics which are useful to establish distinctness, uniformity and stability of the new variety, based on which it is given protection [13].

It is concluded from the study that two qualitative characteristics i.e., anthocyanin coloration of leaf sheath and angle between blade and stem showing 100% absence and medium level, respectively, were uniform and stable for all the maize

varieties studied, followed by attitude of blade showing high uniformity for droopy leaves. Inbred line, 193-1 and single cross hybrid, Prakash showed the lowest variation within the population for almost all characteristics. Other varieties exhibiting low uniformity and high variation of expression in characteristics were possibly due to residual heterozygosity or contaminants. Characteristics, which showed the different states of expression in a variety or the same state of expression among varieties, were not suitable for establishing distinctness. Therefore, careful maintenance breeding is necessary to ensure uniformity in each cultivar to meet the requirements of DUS testing.

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