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RESEARCH ARTICLE

Characterization of Sorghum [*Sorghum bicolor* (L.) Moench] Germplasm for Agro-Morphological Traits

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The experiment on characterization of 2500 accessions of sorghum germplasm including indigenous and exotic collections representing 42 countries was conducted at Indian Council of Agriculture Research-Indian Institute of Millets Research (ICAR-IIMR), Hyderabad, India. The experiment was laid in Augment Block Design with two checks. These accessions were characterized for yield and yield attributing traits. The analysis of descriptive statistics showed that wide range of variability for all quantitative traits. There was significant positive association between yield and yield attributing traits except for ear head length which had negative significant association with grain yield and 100-seed weight. Sorghum accessions were grouped into 10 clusters as per Ward's method and found that there was 13.65% and 86.35% of variability was found within and between clusters. This variability in the germplasm can be utilized for further sorghum improvement programme. The potential germplasm identified for different agro-morphological traits may be used to develop parents and varieties in sorghum improvement programmes.

Key Words: Sorghum, Principle Component Analysis, Genetic Diversity, Association and Clusters

Introduction

Sorghum is an important cereal crop of the semi-arid tropics, which is being grown in *Kharif* and *Rabi* season. it is fifth most important cereal crop grown in more than 100 countries worldwide. India, Nigeria, Mexico, USA, Argentina and Ethiopia are the major sorghum producing countries. The sorghum production is 63.93 mt over 44.77 mha area worldwide with the productivity of 14279 kg ha^{-1} (FAO 2016). India is the leading sorghum producing county in South Asia which covers 5.65 mha area with the production of 44 mt and productivity of 7805 kg ha^{-1} (FAO 2016). Sorghum crop is grown mainly for food and fodder in Africa, Asia and Central America. The high brix content sorghum (Sweet sorghum) is used as an alternative source for ethanol production, beer, alcohol, syrup, bakery items, industrial starch, etc. (Umakanth 2012).

It is drought hardy plant which withstands extreme environmental changes. Sorghum has diverse populations and species rich ecosystem and have greater potential to adapt to climate change. The improvement of any crop depends on the availability of diversity of the crop. Wide genetic diversity is the key for present and future. The genetic resources (germplasms and landraces) are the best sources to maintain the wide genetic diversity and sustainable crop improvement. Hence there is urgent need to conserve the genetic resources of all crops as much as possible, before we lose them permanently due to replacement of landraces by improved cultivars besides several other factors (Upadhyaya and Gowda, 2009a).

Many international and national genebanks had large collections and conservations of germplasm as well as represents the wide genetic diversity in different crops including sorghum. In recent years, decline curve observed for international efforts to collect and conserve the plant genetic resources (FAO 2009). There is need of critical assessment of collection of germplasm, identifying gaps and launching germplasm collection mission in unexplored and under explored areas. This is important to enrich the genetic variability further and enhance the efficiency of crop improvement program.

There are several genebanks in the world conserve germplasm of many crops including sorghum.

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International Crops Research Institute for Semi-Arid Tropics (ICRISAT) Hyderabad, India, conserves more than 39000 sorghum accessions from 90 plus countries including > 6200 countries from South Asia (Upadhyaya *et al*., 2016) at international level. The National Genebank at ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR) New Delhi, India conserves 4.3 lakh germplasm of all crop plants and horticulture crops as well. ICAR-Indian Institute of Millets Research (IIMR) Hyderabad India is also involved in collection and conservation of millets germplasms including sorghum, pearl millet and other six small millets, which maintain > 6000 sorghum germplasms (Elangovan *et al*., 2009). Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Telangana, Madhya Pradesh and Uttar Pradesh are major sorghum growing states. There is ample of scope to enrich the existing sorghum genetic resources and filling gap of collection, conservation and characterization. The sorghum germplasm is collected/augmented and conserved at the National Genebank (NGB), ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi; ICRISAT, Patancheru, Hyderabad; and ICAR-Indian Institute of Millets Research (ICAR-IIMR), Hyderabad. ICAR-IIMR-Hyderabad is one of the National Active Germplasm Sites (NAGS) with the collection and augmentation of sorghum, pearl millet and small millets, which includes 32000 acc. of sorghum and 15000 acc. of other millets.

Materials and Methods

A total of 2500 accessions of sorghum germplasm representing 42 countries obtained under the Consortium Research Platform on Agrobiodiversity on Sorghum were used for agro-morphological characterization. In which, data of 2460 accessions were used for analysis and the rest of them did not germinate or could not collect the complete phenotypic data. Among the 2460 accessions represents, 842 accessions of indigenous collections and 1616 accessions of exotic collections. The characterization was done at ICAR-Indian Institute of Millets Research (IIMR) Hyderabad with the geographical coordinate of 17.3207°N latitude, 78.3959°E longitude and 476.5 meters above M.S.L. The experimental was conducted in augmented block design along with two checks CSV 29R and M35-1 which were repeated in every 100 accessions. The plot was with 1 m long row with 60 cm distance between each row. The distance between the plants was maintained at 10 cm after two weeks of thinning. Fertilizers were applied at the rate of 80 kg/ha N and 40 kg/ha P_2O_5 in during crop growth and all necessary package of practice were followed for good crop stand. Regular irrigation was given to maintain sufficient moisture and the crop was protected from weeds, pest and diseases.

Observations recorded

The accessions were characterized for 9 quantitative traits during crop growth durations. The days to 50% flowering was calculated plot based in which 50% plants completes its 50% of the panicle flowers from days after sowing. The other traits were total number of leaves, leaf length (cm), leaf width (cm), ear head length (cm), ear head width (cm), plant height (cm), grain yield (g/plant) and 100-seed weight. The observations were collected from 3 representative plants.

Data analysis

The data was analysed for calculating the mean, range and variance for all the quantitative traits using GENSTAT, association analysis using SPSS software, Principle Component Analysis (PCA) and clustering Analysis using Gen Alex software.

Results

Range: The wide range of variation has been observed for quantitative traits under the study (Table 1) for both Exotic and Indigenous collections for days to 50% flowering, total number of leaves, leaf length, leaf width, ear head length, ear head width, plant height, grain weight and seed weight. Variation was found in the indigenous collection for days to 50% flowering (47 to 96 days), total number of leaves (3.8 to 13.6), leaf length (36.46 to 91.18 cm), leaf width (2.5 to 10.36 cm), ear head length (8.1 to 48.94 cm), ear head width (3.3 to 14.2 cm), plant height (64 to 296 cm), grain yield (3.25 to 144.5 g/plant) and 100-seed weight (1.00 to 6.23 g). Whereas wide range in the exotic collections was observed for days to 50% flowering (44 to 97 days), total number of leaves (2.2 to 14.5), leaf length (23.2 to 88.5 cm), leaf width (2.46 to 10.85 cm), ear head length (7.82 to 73.2 cm), ear head width (2.2 to 19.2 cm), plant height (66 to 348 cm), grain yield (2.5 to 149 g/plant) and 100-seed weight (1.00 to 6.39 g).

Mean: The mean was calculated to compare the indigenous and exotic germplasm (Table 1). The exotic collection germplasm were significantly higher for all the quantitative traits except ear head length. The indigenous germplasm were significantly early flowering (62.28

days) type compare to exotic germplasm (66.62 days). The exotic germplasm had higher total number of leaves (9.17) when compare to indigenous (8.03). Leaf length and leaf width will determine the canopy coverage and photo synthetic area in which exotic germplasms are having longer leaf (68.84 cm) and wider leaf (7.29 cm) than indigenous germplasms (62.64 cm and 6.68 cm respectively). The yield of the plant is decided by the length and width of the ear head, the exotic germplasm had wider ear head (7.13 cm) compare to indigenous (6.15 cm), However, indigenous germplasm reported for longer ear head (25.47 cm) than exotic (18.28 cm).

Association studies: Grain yield is positively associated with all the traits except ear head length. Days to 50% flowering had positive significant association with total number of leaf, leaf length, leaf width, plant height, grain yield and 100-seed weight. However, it had negative correlation with ear head width. Total number of leaves had significant positive correlation with all quantitative traits under the investigation except for ear head length which showed negative correlation. Leaf length had positive significant association with all traits. Leaf width had positive association with remaining quantitative traits, whereas, it had negative correlation with ear head length. Ear head length had positive association with leaf length and plant height; whereas, it associated significant negatively with total number of leaves, leaf width, ear head width, grain yield and 100-seed weight. Plant height, grain yield and 100-seed weight had positive significant association with each other as well as with other quantitative traits, simultaneously grain yield and 100-seed weight had negative significant association with ear head length (Table 2).

Phenotypic diversity using Principle Component Analysis (PCA): The first three principle components considered for the variability because of having more than one as Eigen value. These principal components had contributed 61.51%, 65.38% and 64.38% variability of exotic, indigenous and in total respectively. The first principle component was most important due to its highest contribution for phenotypic variation in the germplasm.

Table 1. Descriptive statistics of quantitative traits of sorghum accessions

	Range				
Traits	Mean	Minimum	Maximum	Standard deviation	SE
Days to 50 % flowering	63.77	44	97	8.323	0.168
Ear head length (cm)	23.01	7.82	73.2	8.324	0.168
Ear head width (cm)	6.493	2.2	19.2	1.442	0.0291
Grain yield (g/plant)	39.35	2.5	149	16.8	0.339
leaf length (cm)	64.77	23.2	91.18	9.258	0.187
Leaf width (cm)	6.895	2.46	10.85	1.258	0.0254
Plant height (cm)	188	64	348	52.43	1.058
100-Seed weight (g)	2.85	1	6.39	0.927	0.0187
Total number of leaves per plant	8.425	2.2	14.5	1.644	0.0331

Table 2. Association of quantitative traits of Sorghum accessions

	DTF	TNL	LL	LW	EHL	EHW	PH	GW	SW
DTF	1	0.539**	0.475**	0.296**	-0.03	-0.071**	0.460**	0.223**	0.014
TNL		1	0.520**	0.485**	-0.10**	0.114**	0.515**	0.399**	0.058**
LL			1	0.516**	0.092**	0.191**	0.596**	0.425**	0.015
LW				1	-0.09**	0.288**	0.281**	0.506**	0.073**
EHL					1	-0.033	0.068**	-0.12**	-0.182**
EHW						1	0.152**	0.377**	0.110**
PH							1	0.334**	0.063**
GW								1	0.110**
SW									1

DTF= Days to 50 % flowering, EHL= Ear Head Length (cm), EHW= Ear Head Width (cm), GW= Grain Yield (g/plant), LL= Leaf Length (cm), LW= Leaf Width (cm), PH= Plant Height (cm), SW= 100-Seed weight and TNL= Total Number of Leaves per plant

The first principal component had contributed more variability through days to 50% flowering (0.41), total number of leaves (0.63), leaf length (0.65), plant height (0.52) and grain yield (0.45). Second, third and fourth PCs contributes largest cosine for the characters viz., ear head width (0.35), ear head length (0.42) and seed weight (0.51) respectively (Table 3).

Clustering: The Wards method of clustering followed to group the germplasm accessions. There were 10 clusters formed. The cluster mean were calculated and presented in the Table 4. The cluster I was best performed for total number of leaves, leaf width, ear head width, grain yield and 100-seed weight, whereas, cluster V was superior for late flowering, leaf length, ear head length and plant height. All clusters include both indigenous and exotic germplasm and there was 86.35% variability between the clusters and 13.65 % within clusters. Indigenous germplasm belongs to cluster I, II, IV and V were majorly from Karnataka, Maharashtra, Andhra Pradesh, whereas most of the exotic germplasm belongs to African countries viz., Mali, Sudan, Uganda, Chad, Ethiopia and Burkina Faso as well as United States of America. The clusters III, VI, VII and VIII consists of indigenous germplasm from Madhya Pradesh, Gujarat, Orissa, Bihar and Uttar Pradesh, whereas most of exotic germplasm were from United States of America, South Africa, Mali, Ethiopia, Burkina Faso and Uganda. Clusters IX and X consists of exotic germplasm from United States of America, Mexico, Zimbabwe and with mixture from African countries.

Discussion: The germplasm is the basic source of all characters and base for all breeding programmes. Plant genetic resources are important component of biodiversity. They include diverse genetic material in terms of traditional varieties, modern cultivars, crop wild relatives, germplasm and landrace etc. They are the source material of all traits including morphological, physiological, biochemical, biotic and abiotic stress

Table 3. Percentage of variation explained by the first seven principal components (PCs) in sorghum accessions evaluation at ICAR-IIMR, Hyderabad

PC	Eigenvalue	Variability (%)	Cumulative %	DTF	TNL	LL	LW	EHL	EHW	PH	GW	SW
F1	3.32	36.84	36.84	0.4134	0.6279	0.6531	0.5112	0.0049	0.1159	0.5195	0.4544	0.0155
F2	1.37	15.19	52.03	0.1745	0.0172	0.0383	0.0519	0.2616	0.3544	0.07	0.1459	0.2533
F3	1.11	12.35	64.38	0.1216	0.0426	0.0169	0.0136	0.4292	0.2691	0	0.0328	0.1856
F4	0.87	9.69	74.07	0.0001	0.011	0.0071	0.0546	0.1903	0.0054	0.0765	0.0196	0.5074
F5	0.64	7.07	81.14	0.001	0	0.0012	0.225	0.0763	0.1229	0.1657	0.0068	0.0373
F6	0.50	5.61	86.75	0.071	0.024	0.0058	0.0229	0.0014	0.1253	0.0449	0.2091	0.0003
F7	0.47	5.24	91.99	0.1285	0.0043	0.0915	0.0509	0.0268	0.0049	0.0344	0.1302	0.0001

DTF= Days to 50 % flowering, EHL= Ear Head Length (cm), EHW= Ear Head Width (cm), GW= Grain Yield (g/plant), LL= Leaf Length (cm), LW= Leaf Width (cm), PH= Plant Height (cm), SW= 100-Seed weight and TNL= Total Number of Leaves per plant.

Table 4. Cluster mean for quantitative traits of sorghum accessions evaluated at ICRA-IIMR Hyderabad

Cluster	DTF	TNL	LL	LW	EHL	EHW	PH	GW	SW
I	69.15	10.16	73.09	8.14	19.19	7.57	256.18	74.52	3.13
II	66.08	9.34	71.17	7.74	20.28	7.30	206.64	64.74	2.90
III	65.06	8.50	66.87	6.83	23.27	6.39	210.13	34.88	2.72
IV	68.69	9.46	69.65	7.37	21.33	6.71	242.47	42.38	3.10
IX	59.16	7.59	57.04	6.52	24.00	6.17	125.22	34.60	2.87
V	70.74	9.85	73.83	7.27	30.94	6.48	275.39	39.50	2.83
VI	60.75	7.48	59.10	5.84	23.11	5.97	173.35	24.58	2.73
VII	61.41	8.10	65.69	7.18	20.78	6.77	167.87	46.68	2.84
VIII	59.98	7.49	58.52	6.30	23.13	6.14	145.96	27.39	2.92
X	58.87	7.32	56.67	6.59	23.62	6.18	99.67	30.77	2.66

DTF= Days to 50 % flowering, EHL= Ear Head Length (cm), EHW= Ear Head Width (cm), GW= Grain Yield (g/plant), LL= Leaf Length (cm), LW= Leaf Width (cm), PH= Plant Height (cm), SW= 100-Seed weight and TNL= Total Number of Leaves per plant.

resistances and necessary to improve the status and lively hood of the mankind.

Conservation of these germplasm sources are very important to meet the requirement of exploding population and rapid climate changes which leads the man to seek resilient and nutritious food crops. The wild relatives, landraces and germplasm are necessary to bring under domestication to make desirable changes to meet breeder's objectives and to enhance the variability.

In India, ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi; International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad and ICAR-Indian Institute of Millets Research (IIMR), Hyderabad are the nodal institutes which are having the mandate of collection and conservation of sorghum and other millets. In collaboration with the Consortium Research Platform on Agro-Biodiversity (CRP-AB) on Sorghum, ICAR-NBPGR-New Delhi, ICAR-IIMR had conducted an experiment on characterization of 2500 sorghum germplasm accessions during *Rabi* (post-rainy) 2015-16. These accessions include indigenous and exotic collections of sorghum germplasm. They were the representative sample accessions from 42 countries worldwide and all the accessions with FAO in trust.

The variability can also estimate by range. Sufficient genetic variability has been observed (Elangovan *et al*., 2009) which will helps breeders to select diverse genotypes for the breeding programme. There is differential expression of indigenous and exotic germplasms, the exotic germplasms shows higher variability than indigenous accessions.

Representation of the sorghum germplasm from 42 countries indicates that wide genetic diversity (Upadhyaya *et al*., 2016). In India, the accessions were representative of 17 states which covers almost 60% of Indian states. In which, Maharashtra (127 acc.) had represented with highest number of accessions, followed by Andhra Pradesh (75 acc.), Madhya Pradesh (65 acc.), Gujarat (46 acc.) and Karnataka (41 acc.). The list of representative countries of exotic collections and states of India is presented in Table 5. Elangovan *et al*. (2007, 2012) collected and characterized 157 and 107 sorghum accessions from Karnataka and Gujarat respectively and identified suitable accessions for yield and yield related traits. Ganesamurthy *et al*. (2010) evaluated 130 genotypes for genetic diversity and identified different clusters for different traits as well as identified suitable genotypes for grain yield and fodder yield.

Table 5. representative countries of exotic collections and states of India

Country	Number of germplasms	Country	**Number of germplasms**
United States of America	714	Central African Republic	2
India	495	Japan	2
Sudan	238	Kenya	2
South Africa	77	Argentina	1
Ethiopia	73	Cameroon	1
Mali	62	Greece	1
Nigeria	57	Iraq	1
Uganda	57	Myanmar	1
Burkina Faso	53	Pakistan	1
China	36	Sierra Leone	1
Mexico	32	Thailand	1
Zimbabwe	26	**India (States)**	
Chad	17	Maharashtra	127
Zaire	15	Andhra Pradesh	75
Tanzania	12	Madhya Pradesh	65
Egypt	10	Gujarat	46
Korea	8	Karnataka	41
Senegal	8	Rajasthan	28
Botswana	7	Uttar Pradesh	26
Ghana	6	Orissa	14
Zambia	6	Tamil Nadu	13
Indonesia	5	Haryana	11
Italy	5	Punjab	9
USSR	5	Bihar	8
Iran	4	Bihar (Jharkhand)	6
Malawi	4	Kerala	5
Taiwan, Province of China	4	Jammu & Kashmir	3
Algeria	3	West Bengal	2
Afghanistan	2	Bihar (Chhattisgarh)	1
Australia	2		

The association of traits are helpful for breeders to select traits which contributes to grain yield and yield attributing traits (Fig. 1). In the present study, grain yield traits under the study were associated with each other, where grain yield had positive significant association with all traits except ear head length with which negative association was observed (Elangovan *et al*., 2009). The days to 50% flowering, total number of leaves per plant, leaf length, leaf width, plant height, grain weight and seed weight had positive significant association among themselves, which indicates that all the traits are contributing positively to yield and improvement of one traits influences the improvement of other traits as well (Elangovan *et al.,* 2007, 2009, 2013, Jain *et al*., 2009, 2011). Ear head length had negative association with total number of leaves per plant, leaf width grain weight and seed weight, which indicates that improvement in ear head length will reduce the leaf width and total number of leaves, which may be due to more photosynthets required for the ear head length. Hence, the total energy will be utilized for the elongation of ear head length and may fail to accumulate in to grain.

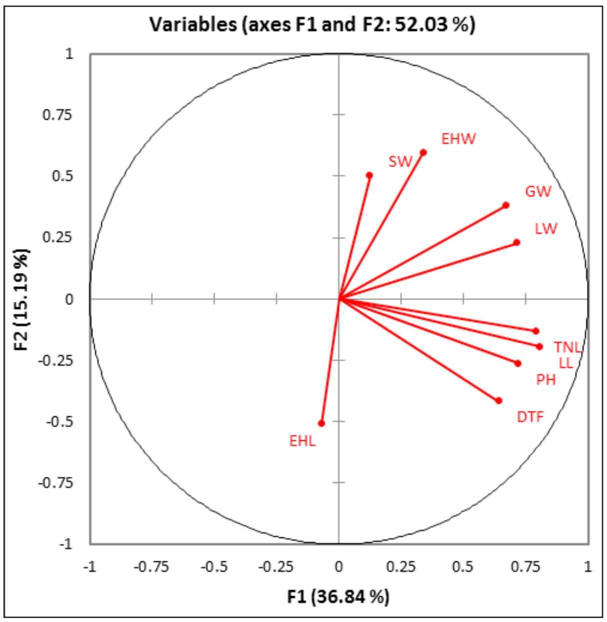

Fig. 1. Sorghum quantitative trait association evaluated at ICAR-IIMR Hyderabad

Clustering of all accession were done according with ward's method to group the genotypes with minimum variance. According to ward's method all accessions grouped in to 10 different clusters with maximum of 451 genotypes in cluster III and minimum of 89 accessions in cluster I (Elangovan *et al.,* 2007, 2009, 2013, Jain *et al.,* 2009, 2011). Within clusters there was minimum of 13.65% variance observed and 86.35% between clusters (Table 6). Cluster mean will help the breeder to select the diverse genotypes from different clusters. The cluster I showed better mean performance for total number of leaf, leaf width, ear head width, grain yield and 100-seed weight. The breeders can select their genotypes from the cluster I for grain yield. Similarly cluster V had performed better mean for leaf length, ear head length, plant height and longer days to 50% flowering, which are suitable for the high biomass fodder yield. The list of better performing top 20 accessions was presented in Table 7. The accession EC 483357 was better performed for grain yield and ear head length and EC 483872 was good for plant height and 100-seed weight, hence these two accessions can serve as parent for the grain yield improvement breeding programmes. EC 484133 was better for total number of leaves, leaf length and late flowering, EC 484182 and IC 289370 were good for grain yield and leaf length and width hence these accessions can be useful for the improvement of high biomass as well as grain yield. Breeding for high bio mass is gaining importance because it is mainly used as animal feed and now a days it is using for the extraction of ethanol which is utilizing as bio fuel to blend with petrol to reduce the use of petroleum products (Umakanth *et al*., 2012).

Table 6. the variation found within and between clusters of sorghum accessions

	Absolute	Percent
Within-class	445.2904	13.65%
Between-classes	2816.9717	86.35%
Total	3262.2620	100.00%

Conclusions

The experiment on characterization of sorghum germplasm was conducted at ICAR-IIMR-Hyderabad for 2500 indigenous and exotic germplasm collection representing 42 countries. Wide genetic diversity was observed within and between clusters identified and the superior accessions identified for all quantitative traits. These accessions can be used by the breeders as parents in the breeding programmes. Still there is need to utilize the remaining germplasm identified instead of using only few accessions for breeding programmes. There is a scope for collection and conservation of germplasm across the country and need to introduce these germplasm to new areas to increase variability and to meet nutritious food requirement of growing population.

Table 7. Best performing top 20 accessions identified for quantitative traits of sorghum evaluated at ICAR-IIMR Hyderabad

Days to 50% Flowering (early)	EC 483629, EC 483759, IC 289886, IC 289923, EC 483128, EC 483154, EC 483429, EC 483484, EC 483533, EC 483578, EC 483655, EC 483941, IC 289835, IC 289848, IC 289849, IC 289850, IC 289924, IC 289963, IC 289966 and IC 289967
Days to 50% Flowering (Late)	EC 484149, EC 484544, EC 484130, IC 289194, EC 483963, EC 483840, IC 289183, EC 483833, EC 483832, IC 289184, EC 484155, EC 484133, EC 483859, EC 484126, IC 289433, IC 289327, IC 289170, EC 484270, EC 484061 and EC 483818
Total number of leaves	EC 484133, IC 289462, IC 289412, IC 289364, IC 289251, IC 289375, IC 289371, IC 289861, IC 289857, IC 289479, IC 289425, IC 289433, IC 289582, IC 289585, IC 289280, IC 289281, IC 289450, IC 289423, EC 484037 and IC 289169
Leaf length (cm)	IC 289431, IC 289919, EC 484133, IC 289898, EC 484182, IC 289675, IC 289273, EC 484628, EC 484178, EC 483088, IC 289800, IC 289465, EC 484245, IC 289893, EC 483404, EC 483087, IC 289423, EC 483339, IC 289954 and EC 484569
Leaf width (cm)	EC 484152, EC 484129, EC 484037, IC 289613, IC 289594, IC 289284, EC 484589, IC 289273, IC 289169, IC 289370, EC 483821, EC 484146, IC 289364, EC 483615, EC 484039, EC 484157, EC 483666, IC 290005, EC 483908 and IC 289281
Ear head length (cm)	EC 483900, EC 483542, EC 483093, EC 483091, EC 483092, EC 483095, EC 483088, EC 483089, EC 483085, EC 483094, EC 483084, EC 484509, EC 483096, EC 483083, EC 483815, EC 484180, EC 483787, EC 483090, EC 483087 and EC 483086
Ear head width (cm)	EC 484053, EC 484520, EC 484747, IC 289850, IC 289834, IC 289845, IC 289918, IC 289511, EC 483357, IC 289851, IC 289813, IC 289835, EC 484494, IC 289842, IC 289859, EC 484572, IC 289848, EC 484293, EC 484180 and IC 289831
Plant height (cm)	EC 484491, EC 484106, EC 483502, EC 483509, EC 484108, EC 483599, EC 484109, EC 484107, EC 483088, EC 484672, EC 484670, EC 483503, EC 484066, EC 484114, EC 483872, EC 484111, EC 484115, EC 483087, EC 484151 and EC 483093,
Grain yield (g/plant)	EC 483357, IC 289667, EC 483915, EC 483959, EC 484182, IC 289770, EC 484482, IC 289668, IC 289953, EC 483785, IC 289370, EC 484405, EC 483961, IC 289875, IC 289286, IC 289872, IC 289352, IC 289576, IC 289867 and EC 483441
100-Seed weight (g)	EC 483541, IC 289347, IC 289959, EC 483258, EC 484171, IC 289786, EC 483300, EC 484416, EC 484434, EC 483261, EC 483592, EC 483254, EC 483263, IC 289797, EC 483872, EC 483328, EC 484486, EC 484433, EC 483252 and EC 483267

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