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Trait-specific Amaranth Germplasm — Potentialities to Combat Climate Change

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Amaranth has great potential to combat climate change and malnutrition. It is receiving attention now-a-days because of its high nutritional value, rapid growth, adaptability to a wide range of climatic and soil conditions. It has traditionally been part of barter system in the Himalayan region. ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR) has base collection of 5,804 accessions of amaranth representing 26 species. This vast genepool is available to the breeders, but due to large size of the collection and lack of detailed information on unique traits, there has been minimum use of germplasm in breeding programmes to develop new varieties and hybrids. Hence, genebank curators collated the trait-specific information from different sources to make an useful compilation for the breeders. A total of 623 accessions of amaranth representing different biotic and abiotic stress resistance (12), quality traits (106), agronomic traits (449), other traits (27), released varieties (27) and registered germplasm (2) are conserved in National Genebank (NGB). This compilation will enhance the utilization of diverse amaranth germplasm in future crop improvement programmes to develop climate-resilient varieties.

Key Words: ***Amaranthus* spp., Conservation, Germplasm, Trait-specific material, Utilization**

Introduction

Amaranth belongs to the genus *Amaranthus* of the family Amaranthaceae. About 70 species have been reported in this crop (Sauer, 1967). The genus *Amaranthus* is unique in having species which are economically important and used for grain, leafy vegetable, fodder and ornamental purposes. *Amaranthus tricolor*, *A. dubius, A. lividus* (syn. *A. blitum*), are important leafy types (Peter *et al.*, 2011) and widely cultivated throughout India, especially during the summer and rainy seasons. Because of its low production cost, rich nutrition and availability at cheaper rate, it is often used by common people (Varalakshmi, 2004). The leaves are rich in dietary fibre, protein, vitamins and minerals (Shukla *et al*., 2003). Hence, *Amaranthus* species can help in alleviating under-nutrition and malnutrition, especially in developing countries (Rastogi and Shukla, 2013). It can contribute greatly to the nutritional well-being of rural and economically week people by providing the essential nutrients required for body growth and for prevention of diseases associated with nutritional deficiencies such as iron and vitamin A (Dua *et al*., 2009). The grain amaranth species are considered by many as the crop of the future because of the diversified purposes and superior nutritional quality of grain with high protein content in the range 13-18% and relatively high lysine content in comparison with common cereals (Janovska *et al*., 2012; Rastogi and Shukla, 2013). Amaranth shows a wide variation in morphological diversity both among and within certain species. Modern plant breeders are concerned about genetic diversity but farmers are most interested in morphological and agronomical variation (Mwase *et al*., 2014). Improving crops, therefore, requires diverse trait-specific germplasm and wild species for utilization in crop improvement programme to develop the climate-resilient varieties. The information about the base collection at National Genebank (NGB), ICAR-NBPGR, comprises 5,804 amaranth germplasm including 623 potential trait-specific accessions, will enhance the utilization of diverse germplasm including wild species in breeding programme to develop short duration, high yielding, bold seeded, non-shattering and non-lodging varieties particularly in the context of climate change.

Materials and Methods

The main objective of this study was to collate the information about various traits present in the germplasm available in the genebank. To begin with a list of the germplasm available in NGB along with the passport information was taken and classified on the basis of their use into three categories *viz.* vegetable type, grain type and wild/weedy types. The information on the specific traits like dwarfness, early maturity, non-lodging, drought tolerant, resistance to pest and diseases, high leaf and grain yield, high protein and lysine content etc. were

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collated. The collated information was based on literature review of published sources like books, catalogues, research papers, ICAR-NBPGR annual reports and AICRP report of underutilized crops. A total of 5,300 amaranth germplasm was characterized and evaluated using the descriptor states developed by NBPGR (3,050 accessions) and Bioversity (2,250 accessions) from 1981 to 1990 at NBPGR, Regional Station, Phagli, Shimla, India, respectively (Joshi 1981, 1991).

Results and Discussion

The genetic resources of amaranth have a wide spectrum of variability of both qualitative and quantitative nature. Availability information on conserved germplasm resources is key to its utilization. The entire collections of 5,804 accessions of amaranth germplasm were categorised based on passport information into grain type (4,569), vegetable type (442), wild/weedy relatives (90) that are conserved at -18°C in NGB. The details of the species along with the number of accessions are presented in Table 1. The most promising genotypes in both indigenous and exotic germplasm for various biotic and abiotic stress resistances, variability in agronomic and quality characters have been identified and catalogued

Table 1. Species-wise amaranth germplasm conserved in National Genebank, New Delhi, India (as on 30th June 2015)

S.No.	Common name	Botanical name	No. of accession
1.	White pigweed	*Amaranthus albus* L.	1
2.	Purple amaranth	*Amaranthus blitum* L.	23
3.	Love lies-bleeding	*Amaranthus caudatus* L.	224
4.	Pendant amaranth	*Amaranthus caudatus* var. *albiflorus* Moq.	1
5.	Velvet flower	*Amaranthus caudatus* var. *atropurpurea* Roxb.	1
6.	Crispleaf amaranth	*Amaranthus crispus* Terrac.	1
7.	Red amaranth	*Amaranthus cruentus* L.	147
8.	Spleen amaranth	*Amaranthus dubius* Mart. ex Thell.	53
9.	Quilete	*Amaranthus edulis* Speg.	2
10.	Fringed amaranth	*Amaranthus fimbriatus* S.Watson.	1
11.	Smooth amaranth	*Amaranthus flavus* L.	1
12.	Elephant head amaranth	*Amaranthus gangeticus* L.	21
13.	Mediterranean amaranth	*Amaranthus graecizans* L.	26
14.	Red amaranth	*Amaranthus hybridus* L.	75
15.	Prince-of-Wales- feather	*Amaranthus hypochondriacus* L.	4099
16.	Tumble pigweed	*Amaranthus leucocarpus* S. Watson.	2
17.	Lividi amaranth	*Amaranthus oleraceus* L.	23
18.	Palmer's amaranth	*Amaranthus palmeri* S.Watson.	1
19.	Foxtail amaranth	*Amaranthus paniculatus* L.	17
20.	Tropical amaranth	*Amaranthus polygonoides* L.	4
21.	Powell amaranth	*Amaranthus powellii* S.Watson	2
22.	Red-root amaranth	*Amaranthus retroflexus* L.	4
23.	Prickly amaranth	*Amaranthus spinosus* L.	27
24.	Chinese amaranth	*Amaranthus tristis* L.	4
25.	Joseph's-coat	*Amaranthus tricolor* L.	305
26.	Green amaranth	*Amaranthus viridis* L.	36
27.	Amaranth	*Amaranthus* spp.	703
		Total	**5804**

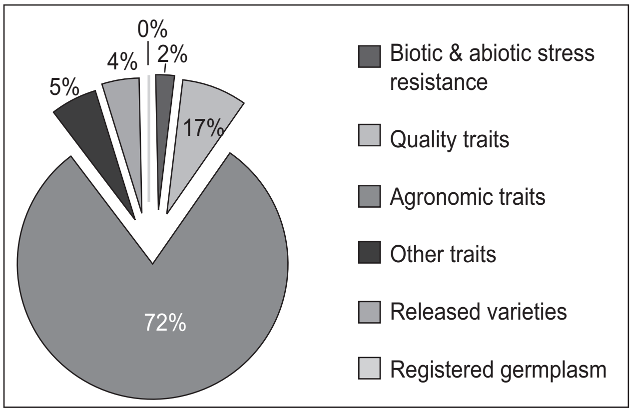

Fig. 1. Status of trait-specific amaranth germplasm conserved in NGB

by several workers (Ahuja *et al*., 1991; Joshi and Rana, 1991; *Varalakshmi,* 2004; Joshi *et al*., 2011). This trait-specific information was identified. About 623 accessions of potential germplasm are available in NGB, which will be of interest to the breeders. Promising accessions identified in different categories include agronomic traits (449), quality traits (106), sources against biotic and abiotic stress resistance (12), other traits (27), released cultivars (27) and registered genetic stock (2) (Fig.1). Genotypes resistance to various biotic and abiotic stresses constitutes merely 2%, whereas agronomic and quality traits constitute 72% and 17%, respectively, of the total trait-specific germplasm conserved in NGB and the details of unique traits are presented in Tables 2 and 3. Under the biotic stresses the main traits available in the NGB were root-knot nematode, leaf spot, leaf blight, steam borer and white rust which occur commonly in India. Trait-specific germplasm for abiotic stress such as drought tolerance (3 acc.) and suitable for arid zone (1 acc.) are also conserved in NGB. In addition, the germplasm for important quality traits such as high protein content from 11.0- 15.95 % (54 acc.), high oil content from 6.0-12.7% (46 acc.; Raiger *et al*., 2012), high lysine content >5.0-7.5 mg/100g (3 acc.) and other desirable traits such as non-shattering, non-lodging, suitable for inter-cropping, dual purpose and hard thrashability have been identified for use in breeding programmes to develop climate-resilient varieties.

Table 2. Germplasm accessions identified for agronomic and other traits conserved in National Genebank, New Delhi, India

Traits	Trait-specific accessions identified	No. of accessions conserved
Agronomic Traits		
Early maturity type (<110 days)	IC17947, IC26264, IC32156, IC35365, IC35404, IC35407, IC35416, IC38057, IC38069, IC38127, IC38133, IC38136, IC38269, IC38271, IC38280, IC38282, IC38327, IC38353, IC38422, IC38553, IC38658, IC42258, IC42264, IC258251, IC282307, IC303068 IC328965, IC322994, IC322997, IC333241, IC423408, IC444099, IC444159, IC536740, IC612197, EC157417, EC28889, EC321563,EC333744,C359409, EC359417, EC519550	42
Early flowering (40-52 days)	IC38133	1
Days to flowering (60-101 days)	EC519521, EC519533, EC519556	3
Dwarf plant type (65-80 cm)	IC363768, IC363769, IC38541, IC38577, IC38598, IC398218, IC599589, EC169626, EC170304	9
Plant height (>130 cm)	IC38269, IC38280, IC38658, IC42255-5, IC42290-17, IC95308, IC95314, IC95315, IC95320, IC255419, IC257794, IC257796, IC278914, IC317433, IC325880, IC341509, IC347566, IC363742, IC398213, IC398215, IC398233, IC398237, IC415262, IC415264, IC444183, IC444192, IC512322, IC526828, IC540812, IC540900, EC169642	31
Number of branches > 15	IC255986, IC257796, IC526828	3
Leaf length >20cm	IC38340, IC95284, IC95320, IC415236, IC415272, IC415274, IC415297, IC421885, IC467886, IC467888, IC467894,IC467896, IC467908	13
Leaf breadth >10cm	IC257793, IC526828, IC526831	3
Inflorescence length (60-104 cm)	IC21926, IC21947, IC38052, IC38261, IC38553, IC95253, IC95308, IC363742, IC423400, IC423448, IC423468, EC157415, EC321563, EC359408	14
Drooping type of panicles	IC255500, IC363742, IC381135, IC444173	4
Spreading, robust and stem type	IC550326 (spreading), IC550330 (robust), IC395324 (stem type)	3
High leaf yielding lines 20-50 t/ha	IC257791, IC257794, IC296402, IC393730, IC469564, IC523791, IC523795, IC526828, IC550142, IC550145, IC550412, IC599591, IC612192, IC612193, IC612194	15
1000 seed wt (0.7 to > 1.0 gm)	IC21806, IC21938, IC21941, IC34749, IC38131, IC38185, IC38193, IC38250, IC38285, IC38313, IC38611, IC38665, IC282307, IC335807, IC415266, IC467897	16

Contd.

Table 2 Contd.

Traits	Trait-specific accessions identified	No. of accessions conserved
High seed yield (40-100g/plant)	IC17923, IC17926, IC17936, IC17940, IC17947, IC17953, IC17956, IC21803-A, IC27790, IC35407, IC35467, IC35482, IC35501, IC35614, IC35624, IC35661, IC35696, IC37316, IC38047, IC38053, IC38066, IC38096, IC38123, IC38230, IC38243, IC38267, IC38269, IC38271, IC38280, IC38299, IC38327, IC38662, IC38663, IC38664, IC38665, IC42254, IC42254-2, IC42255-5, IC42258-1, IC42264, IC42290-17, IC42293, IC42293-15, IC42309, IC42316-1, IC42323, IC42332, IC42335, IC95383, IC95430, IC95516, IC95556, IC95588, IC95638, IC303068, IC321563, IC322996, IC325877, IC325880, IC326896, IC328897, IC333241, IC335807, IC341509, IC341565, IC359412, IC359413, IC359430, IC396973, IC415232, IC415250, IC415262, IC415264, IC423400, IC423448, IC436974, IC444190, IC467887, IC467892, IC467897, IC467912, IC469564, IC512322, IC547393, IC550142, IC550145, EC321563, EC322996, EC328875, EC359412, EC359413, EC359417, EC359430	93
Bold seed (1000 seed wt > 1 gram)	IC17947, IC35415, IC38280, IC38282, IC38285, IC38269, IC38353, IC38600, IC38658, IC38661, IC38665, IC42258, IC42258-1, IC42264, IC43264, IC398214, IC406573, IC444146, IC444153, IC444159, IC444162, IC549660, EC321557, EC321563, EC359412, EC359417	26
Early maturity, bold seed and high yielding	IC17947, IC38269, IC38280, IC38282, IC38353, IC38658, IC42258-11, IC42264, EC321563, EC359417	10
Black seed	IC35488, IC35489, IC35490, IC35415, IC35645, IC38131, IC38661, IC255538, IC255554, IC25555, IC261949, IC261952, IC26197, IC278509, IC313269, IC319613, IC324045, IC324475, IC328951, IC331733, IC33863, IC341371, IC343034, IC343035, IC347983, IC347984, IC381062, IC385772, IC427411, IC427461	30
Red/brown seed	IC16636, IC16637, IC35491, IC49887, IC49888, IC264820, IC264854, IC278232, IC278248, IC278510, IC316031, IC319612, IC321027, IC326899, IC356403, IC361327, IC362203, IC383571, IC383663, IC383594, IC396956, IC396963, IC412748, IC412833, IC423468, IC469601	26
Cream/ white/ golden seed	IC16635, IC49618, IC255428, IC255446, IC255452, IC255453, IC255481, IC255482, IC255493, IC255512, IC255523, IC255555, IC255556, IC261957, IC261958, IC261961, IC261964, IC261965, IC261970, IC261980, IC261988, IC261992, IC262001, IC264805, IC278221, IC278285, IC278304, IC278315, IC278356, IC281427, IC281430, IC281434, IC281436, IC281440, IC281449, IC281455, IC281457, IC281461, IC281470, IC281474, IC281490, IC281744, IC281749, IC282307, IC282786, IC313253, IC316045, IC317455, IC319571, IC319816, IC319817, IC325587, IC326898, IC326901, IC326903, IC328559, IC328893, IC333211, IC335807, IC337330, IC337341, IC341364, IC355772, IC355777, IC355789, IC356393, IC356401, IC356407, IC361117, IC361129, IC361331, IC362201, IC362257, IC383578, IC383683, IC396949, IC396953, IC396955, IC396961, IC396970, IC396971, IC396972, IC396992, IC396997, IC398478, IC412770, IC415426, IC415439, IC415461, IC415591, IC415592, IC430340, IC444144, IC444148, IC444149, IC444152, IC444171, IC444176, IC444183, IC447625, IC526834, IC536740, IC612195	103
Purple seed	IC255608, IC278305, IC317456, IC599590	4
Total		**449**
Other traits		
Aneuploid	IC38261	1
Highly branched with multiple inflorescence	IC0447624	1
Non-lodging type	IC303068, IC35407, IC536740	3
Non-shattering (moderately resistance)	IC35407	1
Dual purpose	IC0545091, IC599589, IC599557	3
Suitable for hills	IC35407, IC309876, IC42258-1, IC512322, IC549660	5
Suitable for plains	IC282307, IC303068, IC335807, IC536740, IC586032	5
Suitable for inter-cropping (potato and cotton)	IC321510, IC321511, IC333241, IC350249	4
Hard threshability	IC5626, IC7934, IC38136	3
Seed used to make white chapatti	IC362199	1
Total		**27**

(Source: Joshi and Rana 1991; Gautam *et al*., 2000; Dhillon *et al*., 2001; Singh 2006; Dua *et al*., 2009; Joshi *et al*., 2011; NBPGR Annual Report (1987, 2005, 2010 and 2013)

Table 3. Germplasm accessions identified for biotic, abiotic and quality traits conserved in National Genebank, New Delhi, India

Traits	Trait-specific accessions identified	No. of accessions conserved in NGB
Biotic Stress		
Resistant to leaf spot	IC597082	1
Resistant to leaf blight	IC512322, IC599586	2
Moderately resistant to white rust	IC393729, IC395327, IC393730	3
Resistant to root knot nematode	IC598178	1
Resistant to stem borer	EC133839	1
Abiotic Stress		
Drought tolerant and widely adapted lines	IC42258-1, IC303068, IC335807	3
Suitable to arid zone	IC586032	1
Total		**12**
Quality Traits		
Oil percentage (6-12.7%)	IC35370, IC35415, IC35433, IC35482, IC35495, IC35496, IC35532, IC38109, IC38129, IC38156, IC38158, IC38192, IC38193, IC38196, IC38201, IC38256, IC38271, IC38281, IC38285 ,IC38289, IC38308, IC38310, IC38316, IC38340, IC38371, IC38375, IC38379, IC38380, IC38386, IC38408, IC38451, IC38456, IC38460, IC38480, IC38487, IC38496, IC38518, IC38522, IC38525, IC38555, IC38556, IC38561, IC42316, IC42328, IC120572, IC309876.	46
High protein content (11.7-15.95%)	IC16636, IC17926, IC35370, IC35482, IC35495, IC35496, IC35532, IC38129, IC38156, IC38158, IC38192, IC38193, IC38196, IC38201, IC38256, IC38271, IC38281, IC38285, IC38289, IC38308, IC38310, IC38316, IC38340, IC38371, IC38375, IC38379, IC38380, IC38386, IC38408, IC38451, IC38456, IC38460, IC38480, IC38487, IC38496, IC38518, IC38522, IC38525, IC38555, IC38556, IC38561, IC42302, IC42328, IC42258-1, IC120572, IC549660, IC599589, EC170317, EC289389, EC289412, IC309876, EC322032, EC328889, EC359442.	54
High lysine content (>5.0-7.5 mg/100g)	IC303068(5.23), IC586032 (5.8), IC599589(7.5)	3
Palmitic acid (15-21%)	IC35678	1
Stearic acid (0.7-5.6%)	IC274446	1
Linolic acid (41-52%)	IC274445	1
Total		**106**

Source: Joshi and Rana, 1991; Gautam *et al*., 2000; Dhillon *et al*., 2001; Dua *et al*., 2009; Joshi *et al*., 2011; Raiger *et al*., 2012, NBPGR Annual Report, 1987, 2005, 2010 and 2013

Amaranth seeds varies from white, gold, brown, pink to black and have great potential for application in various agro-industries such as cosmetic (seed oil is rich in squalene: a cosmetic ingredient), pharmaceuticals (pharmaceutical formulations to reduce the drug dosage and the related side effects), natural dye manufactures (red pigment extracted from red/magenta/brown seed is used as a food dye) and cattle feed (black seeded genotypes). Because of high forage yields, high protein, low levels of oxalates and nitrates in amaranth, there is good scope for its utilization as a promising forage crop (Ahuja *et al*., 1991). In general, cream, white and golden colour seeds are used in culinary preparation. Popped grains are mixed with sugar syrup to prepare laddoo and porridge, which is consumed during fasting in India; it is also used for making chapatti/bread/biscuits, flakes and lysine rich baby foods (Joshi and Rana, 1991). The NGB holds 163 germplasm of *Amaranthus* species of which 103 accessions belong to cream/white/golden colour seeds, followed by 30 of black seed, 26 of red/brown seed and four of purple seed. Many of the identified germplasm are multiple traits and the accessions with more than one trait are repeated against each trait separately. The NGB holds 27 released varieties of *Amaranthus* species of which 14 belong to vegetable type with multi-cut, high leaf yield and suitable for different planting seasons, 12 are of grain type with high yield (12 to 23 q/ha), high protein (13 to 15.95%) and oil content (9.2 to 12%), and one dual purpose variety CO 4 (Table 4). Released varieties constitute 5% of the total conserved germplasm. Analysis of breeding methods of amaranth cultivars revealed that 85 % of them are the result of selection from local germplasm, 7.5% through pure line selection from exotic introduction and merely

Table 4. Released varieties of *Amaranthus* species conserved in National Genebank, New Delhi, India

S.No	National Identity	Name of the variety	Taxonomic status	Year of release	Developing Institute/ University	Trait-specific information
1.	IC599586	CO-1	*A. dubius* Mart. ex Thell.	1968	Tamil Nadu Agricultural University (TNAU) Coimbatore, Tamil Nadu, India	Suitable for late harvest, resistant to leaf blight, leaf yield 7.8 t/ha.
2.	IC523790	CO-2	*A. tricolor* L.	1979	-do-	Suitable for early harvest, leaf-stem ratio 1.8, leaf yield 10.78 t/ha.
3.	IC523791	CO-3	*A. tristis* L.	1988	-do-	Dwarf and clipping type, 10 clippings in 90 days, good taste and cooking quality, leaf yields 30.72 t/ha.
4.	IC599589	CO-4	*A. hypochondriacus* L.	1989	-do-	Dual purpose crop, suitable for plains and hill regions of Tamil Nadu, seeds rich in protein (15.95%), lysine (7.5 mg/100g), phenylalanine (5 mg/100g), leucine (1.2 mg/100g) and isoleucine (1.8 mg/100g).
5.	IC599590	CO-5	*A. tricolor* L.	1998	-do-	High leaf yielding 40 t/ha, suitable for entire Tamil Nadu, suitable for container cultivation.
6.	IC523795	Arun	*A. tricolor* L.	1992	Kerala Agricultural University (KAU), Vellanikkara, Thrissur, Kerala, India	Photo insensitive, leaves red, leaf yield 20 t/ha.
7.	IC598178	Renusree	*A. tricolor* L.	2006	-do-	Purple stem with low anti-nutritional factors, leaf yield 15.5 t/ha.
8.	IC561286	Krishnasree	*A. tricolor* L.	2006	-do-	Red leaves with high nutritive value and low anti-nutritional factors, leaf yield (14.8 t/ha).
9.	IC612197	Konkan Durangi	*A. tricolor* L.	2002	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Agricultural University, Dapoli, Ratnagiri Maharashtra, India	Early maturing (80-90 days), high yielding 220 q/ha.
10.	IC612192	Pusa Lal Chaulai	*A. tricolor* L.	1993	ICAR-Indian Agricultural Research Institute (IARI), Pusa, New Delhi, India	Suitable for growing in summer (45 t/ha) and *kharif* (40 t/ha).
11.	IC612194	Pusa Kiran	*A. tricolor* L.	1993	-do-	Suitable for Kharif sowing, broad ovate leaves, first harvest after 21–25 days of sowing, leaf yield 35 t/ha.
12.	IC 612193	Pusa Kirti	*A. tricolor* L.	1991	-do-	Suitable for commercial cultivation in summer, first picking after 30–35 days of sowing, leaf yield 50-55 t/ha.
13.	IC393730	Arka Arunima	*A. tricolor* L.	2003	ICAR-Indian Institute of Horticultural Research, Hesaraghatta, Bengaluru, Karnataka, India	Multicut variety, leaves broad and dark purple, first picking after 30 days and leaf yield 27 t/ha.
14.	IC393729	Arka Suguna	*A. tricolor* L.	2003	-do-	Multicut variety, 5-6 cuts in 90 days, moderately resistant to white rust, leaf yield 25-30 t/ha
15.	IC555942	Utkal Mayuri	*A. tricolor* L.	2007	Odisha University of Agriculture & Technology (OUAT) Bhubaneswar, Odisha, India	Suitable for summer and *kharif* season, prolonged harvest, good taste and cooking quality.
16.	IC536740	Kapilasa (BGA-2)	*A. hypochondriacus* L.	2005	-do-	Seed yield 13.5 q/ha, matures in 95 days, large inflorescence, non-lodging type and resistant to diseases and pests.
17.	IC42258- 1	Annapurna	*A. hypochondriacus* L.	1984	ICAR-National Bureau of Plant Genetic Resources, Regional Station, Phagli, Shimla, India	Seed yield 22.50 q/ha, high protein content (15%), drought tolerant and widely adapted.

S.No	National Identity	Name of the variety	Taxonomic status	Year of release	Developing Institute/ University	Trait-specific information
18.	IC35407	Durga	*A. hypochondriacus* L.	2006	-do-	Seed yield 21.0 q/ha, tall plants (170 cm), tolerant to lodging, moderately resistance to shattering.
19.	IC335807	Gujarat Amaranth-1 (GA 1)	*A. hypochondriacus* L.	1991	Sardarkrushinagar Dantiwada Agricultural University (SDAU), SK Nagar Banaskantha Gujarat, India	Seed yield 19.50 q/ha, matures in 100-110 days, semi-compact inflorescence.
20.	IC282307	Gujarat Amaranth-2 (GA 2)	*A. hypochondriacus* L.	2000	-do-	Seed yield 23q/ha, matures in 98 days, suitable for rabi season.
21.	IC612195	Gujarat Amaranth-3 (GA 3)	*A. hypochondriacus* L.	2008	-do-	Seed yield 12.58 q/ha, mature in 95-100 days, creamy white seeds; 1000-seed weight (0.80g).
22.	IC303068	Suvarna	*A. hypochondriacus* L.	1992	University of Agricultural Sciences (UAS), GKVK, Bangalore, India	Seed yield 16.0 q/ha, photo insensitive and grown throughout the year and early maturing type (80-90 days).
23.	IC549660	PRA 1 (Pant Rani Amaranth 8801)	*A. hypochondriacus* L.	1997	G.B. Pant University of Agriculture & Technology, Hill Campus Ranichauri, Tehri Garhwal, Uttrakhand, India	Seed yield 14.5 q/ha, bold creamish yellow seeds, rich in protein (13-14 %) and oil content (9.2 %).
24.	IC309876	PRA-2 (Pant Rani Amaranth-2)	*A. hypochondriacus* L.	2000	-do-	Seed yield 14.5 q/ha, rich in protein (14-15%) and oil content (12.0 %).
25.	IC512322	PRA-3 (Pant Rani Amaranth-3)	*A. hypochondriacus* L.	2003	-do-	Seed yield 16.5 q/ha, field tolerance to major pests and diseases including *Rhizoctonia* sp.
26.	IC564887	RMA- 4 (Rajasthan Mandor Amaranth 4)	*A. hypochondriacus* L.	2008	Agricultural Research Station, Rajasthan Agricultural University Mandor, Jodhpur, Rajasthan, India	Seed yield 13.90 q/ha, matures in 122 days and light green inflorescence.
27.	IC586032	RMA-7 (Rajasthan Mandor Amaranth 7)	*A. hypochondriacus* L.	2008	-do-	Seed yield 14.66 q/ha and highly productive under irrigated condition of arid zone.

7.5% through hybridization. The most probable reason could be the out crossing nature of the crop (20-25%), which generates lot of variability in the germplasm leads to selection.

Indian Council of Agricultural Research (ICAR) has established a mechanism to register the trait-specific germplasm through ICAR-NBPGR in 1996 (Singh, 2006; Tyagi and Kak, 2012), to facilitate the flow of germplasm among the scientists working in crop improvement programme. Two accessions of *A. tricolor* are registered under this mechanism for the traits, thick stem type (Dantu Soppu; IC395324) and resistance to white rust (IC395327). These are also conserved in NGB for use in future breeding.

Future Thrust

Amaranthus is a wide taxonomic group with large diversity of species showing a greater range of adaptation and also exhibits up to 25% of out-crossing in nature (Walton, 1968). These events can be exploited for genetic enhancement for nutritional characters and to achieve good combinations of gene complexes to develop composite or synthetic varieties. It is important to improve the traits such as dwarfness, early maturity, resistance to lodging, non-shattering and bold seeded genotypes through breeding programmes. Development of new varieties to combat climate change as well as nutritional (cheap, alternative rich source of protein and nutrient) requirement of ever increasing population should be the target of future breeding programmes. NGB at ICAR-NBPGR conserves and distribute the potentially valuable germplasm to the farmers and breeders to popularise the same and their use in crop improvement programmes. Therefore, information available in this paper will facilitate the utilization of trait-specific germplasm conserved in the NGB by breeders in crop improvement programmes.

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