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RESEARCH ARTICLE

Collection, GIS mapping and conservation of broomcorn sorghum from Uttarakhand, India

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Abstract

Directorate of Sorghum Research (DSR) and GBPUA&T has explored Uttarakhand state and a total of thirty broomcorn sorghum accessions were collected from five districts. The maximum frequency of 9 accessions were collected from Almora and Chamoli districts, followed by Bageshwar (6), Rudraprayag (5) and Nainital comprising only one accession. The germplasm collection represented with all basic races of sorghum viz., *bicolor* (3), *bicolor caudatum* (3), *durra* (1), and *guinea-bicolor* (18). The variability within the collections is very high. Most of the accessions are very tall (16) in plant height, very loose ear head (21), bold seeded (29) and grayed orange colour seed (24). Almora, Bageshwar and Nainital districts having (1.8934 – 2.000) with highest landraces diversity, whereas in Rudra Prayag and Chamoli districts showed medium (1.000 – 1.8229) landraces diversity. Almora, Bhageshwar and Nainital districts having high races diversity (0.66 –1.00); whereas in Rudraprayag and Chamoli districts having least (0-0.65) races diversity. Rudraprayag and Chamoli districts showed high diversifying area with (3-4) races richness followed by Nainital, Bhageshwar and Almora districts having (1-3) racial richness.

INTRODUCTION

Exploration and collection of germplasm are primarily aimed to augment the diversity in plant genetic resources which are the basic raw materials to meet the current and future requirements of crop improvement programmes. These resources of known or potential use to man constitute a broad spectrum of diverse gene pools representing assemblage of landraces, primitive cultivars, varieties of traditional agriculture as well as wild and weedy relatives of crop plants (IPGRI, 1996). Sorghum is of African origin (Kimber, 2003) and Africa has largest diversity of cultivated and wild sorghum (Doggett, 1988; de Wet, 1977). In the Indian sub-continent, the discovery of evidences for early cereal cultivation at an archaeological site in Western parts of *Rojdi* (Saurashtra) which dating back to about 4500 before present (Damania, 2002). Therefore, India is considered to be the secondary center of origin of sorghum (Vavilov, 1992).

Uttarakhand is the home of the largest number of traditional crops. The state is an important region in the country with its different kinds of ecosystem and diversity of communities. Farmers have played a significant role in preserving and conserving traditional plant varieties. It is located between $28^{0}43' – 31^{0}27'$ N latitudes and $77^{0}34' – 81^{0}02'$ E longitudes. The state of Uttarakhand, embodying two administrative divisions, Kumaon and Garhwal Himalayas with a geographical area of about 53,485 sq.km consisting 13 districts with supports a human population of 1,01,16752 persons (Census, 2011). Within an altitudinal variation ranging from 200m to more than 8000m above

msl, the state comprises five litho-tectonically and physiographically distinct subdivisions namely, the Outer Himalaya comprising the Tarai and Bhabhar, Sub-Himalayan belt of the Shivalik, the Lesser Himalaya, the Great Himalaya and the Trans-Himalaya or Tethys. Human habitation is found up to an altitude of 3500m above msl; however, the zone between 1200 - 2000 m, largely falling in the Lesser Himalaya (1500 – 2500m above msl) is densely populated. Agriculture sector provides the major source of income to the population of the state and the major crops in this state are Paddy, Wheat, Sugarcane, and Potato. Agriculture along with Animal husbandry is still the principal occupation and source of livelihood for over 70% of its population. The state is well endowed with a variety of livestock, plays a vital role in the rural economy largely based on different marginal, sub-marginal and landless farmers of the state. Nearly half of the arable farming in the state takes place in the hilly slopes, on tiny terraced plots of land, often as small as 100 m^2, almost all of it rainfed. Arable farming in the hills depend entirely on the small non-descript working bullocks for farm power and no mechanization of agriculture in this area is possible in the foreseeable future. Due to small size of farm holdings and lack of irrigation facilities seasonal fodder grasses and broomcorn sorghum is being cultivated in the hilly parts of the state. A primary centre of genetic diversity of any cultivated species harbors many valuable genes such as resistance to diseases, insect pests, physiological stress and quality characteristics. It could provide genetic material that may prove valuable in any plant breeding programme. And right behind this boon for our future food security lies the years of selection, breeding and conservation initiatives of the farmers for generations in an ambience of supporting ecosystems.
This study will provide baseline data for further gap-analysis on exploration, collection, conservation and use of germplasm of landraces and wild crop relatives as well as for studies on the factors that explain the geographic distribution of sorghum landraces.

Material and methods

Directorate of Sorghum Research (DSR) has explored Uttarakhand state to collect the broomcorn sorghum during kharif (rainy season) 2011. There were five districts explored and 30 broomcorn sorghum accessions collected from these districts *viz.*, Almora, Bageshwar, Chamoli, Nainital and Rudraprayag. The collection programmes were planned to cover the unexplored area and areas explored in the past. The exploration mission was made originating from GBPUA&T, Pantnagar. The attempt was made to collect an accession every 20 to 30 miles. The altitude, longitude and latitude of the collection site were recorded with the help of Garmin Oregon 550 Global Positioning System (GPS). The data were plotted using DIVA-GIS software to study the distribution, diversity and richness of sorghum landraces (Hijmans et al., 2005). Farmers, informants, and shepherds were interviewed to collect information on history, cultivation practices, and other details. Panicle samples were collected by selective sampling method either from the standing crop or from heaps in fields after harvest and seed material from fields and naturalized wild taxa. The explorations were jointly undertaken by the DSR, Hyderabad and GBPUA&T, Pantnagar. The prime objective of the mission was to review the most important aspects of broomcorn sorghum occurrence, traditional cultivation practices, utilization and collection with special reference to novel uses such as food and fuels and to its cultivation and use in Uttarakhand.

Botanical classification and morphological description

Sorghum is classified under the genus Sorghum (Clayton and Renvoize, 1986). The genus is classified into five taxonomic sections or subgenera: *Eu-Sorghum, Chaetosorghum, Heterosorghum, Para-Sorghum* and *Stipo-sorghum* (Garber, 1950). De Wet (1977 and 1978) recognized *S. bicolor*, representing all annual cultivated, wild and weedy sorghums along with two rhizomatous taxa, *S. halepense* and *S. propinquum*. *Sorghum bicolor* was further broken down into three subspecies: *S. bicolor* subsp. *bicolor*, *S. bicolor* subsp. *drummondii*, and *S. bicolor* subsp. *verticilliflorum*. Cultivated sorghums are classified as four groups based on agronomic traits such as grain sorghum (as food and feed), sweet stalk sorghum (as forage and for animal feed), Sudan grass (for forage and pasture) and broom corn (for making brooms) (Berenji and Dahlberg, 2004). Several authors have discussed the systematics, origin, and evolution of sorghum (de Wet and Harlan, 1971 and 1972; de Wet and Huckabay, 1967; Harlan, 1975; Snowden, 1936). Dahlberg (2000) provides an excellent overview of the present-day classification using an integrated classification system to describe the variation found within cultivated sorghums. The cultivated sorghum originated in Africa in the region of present-day Sudan and Ethiopia (Harlan, 1972). It includes five basic races, *viz.*, *bicolor*, *guinea*, *caudatum*, *kafir* and *durra*, these basic races are further classified into ten intermediate races *durra caudatum, durra guinea, durra kafir, durra bicolor, caudatum guinea, caudatum kafir, caudatum bicolor, guinea kafir, guinea bicolor,* and *kafir bicolor* (Harlan, 1972; Harlan and de Wet, 1972). These 15 races of cultivated sorghum are recognizable on spikelet/panicle morphology alone, and can be linked back to their specific environments and the nomadic peoples that first cultivated them (Smith and Frederiksen, 2000). Traditional plant breeding has produced sorghum cultivars with increased yield, enhanced grain quality, or improved resistance to abiotic and biotic stresses (Smith and Frederiksen, 2000). Sorghum is used not only for human food, but also an important source of fodder and feed for animals, building material, fencing, or for brooms (Doggett, 1988; House, 1985; Rooney and Waniska, 2000).

Results and discussion

A total of thirty broomcorn sorghum accessions were collected from five districts in the Uttarakhand state. The maximum frequency of 9 accessions were collected from Almora and Chamoli districts, followed by Bageshwar (6), Rudraprayag (5) and Nainital comprising only one accession. The germplasm collection represented with all basic races of sorghum viz., *bicolor* (3), *bicolor caudatum* (3), *durra* (1), and *guinea-bicolor* (18) (Table.1). The variability within the collections is very high. Most of the accessions are very tall (16) in plant height, very loose ear head (21), bold seeded (29) and grayed orange coloured seed (24). Majority of the plants 3.5m to 4.2 m in height and baring very lax panicles (Figure. 1) with 60 cm to 75 cm. Most of the popular broomcorn sorghum in these collections has its specific useful traits and traditional utilities. We need to exploit and utilize these accessions in the breeding programs to evolve trait specific genotypes.

Panicle exertion, length and shape of the panicle are also distinct from plant to plant. In some accessions the plant flag leaf sheath is barrier for panicle exertion. Panicle exertion is very important for broomcorn types. Flag leaf sheath barrier plants produce dwarf panicles and open flag leaf sheath plants produces larger panicles. Seeds are enclosed by pubescent. The awned glumes are with different colours *viz*., red, brown, yellowish, tan. The seeds are also in different colours like brown, pale yellow, red etc. The harvested panicles with seed on them are referred to as un-threshed, while cleaned panicles with the seed removed are referred to as threshed. The difference between the unthreshed and threshed weights is the seed weight. The mass of unthreshed and threshed panicles and the seed mass are expressed as dry mass. Threshed panicles are ready for manufacturing into corn brooms. The root system of broomcorn is extensive and contributes to its drought tolerance. The terms "scopaeology" (from the Latin word "*scopea*" meaning broom and Greek "*logos*" meaning science) for the science dealing with all aspects of brooms including corn brooms, and "*planta scoparia*" (i.e., broom making plants) for plants suitable for making brooms including broomcorn. Historically broom brushes of different sizes, shapes, and purposes based on broomcorn fibers are called corn brooms. Broomcorn resembles corn more than any other sorghum, except for the panicle. The stalk is made up of nodes, except the terminal node, which is known as the peduncle. Plant height is measured as the total sum of the stalk, plus the panicle. The panicle length is the sum of the length of the peduncle and length of the fibers on the top of the peduncle (Berenji et al., 2011; Newton et al., 2012).

The broomcorn was developed from material coming from India or Africa via the Middle East (Doggett, 1988). Broomcorn is thought to have evolved simultaneously by repeated selection for long fibers of the panicle throughout various regions worldwide. Forms of sorghum that somewhat resemble broomcorn were found in Korea and Japan but were classed as bearing very poor brush (Ball, 1910). Fragments of broomcorn panicles were collected by Bullock in Kiukiang, China, and by Veitch in Japan. In China, the first documented writings concerning broomcorn appear as early as the 3rd century C. E. In the records of Natural Science by Zhanghua, the "*Sichuan broomcorn millet*" described in the manuscript might be sorghum (Snowden, 1936). Uttarakhand state is located along the northern border of the country with China and Nepal. In this point of view it might be broomcorn sorghum originated from India or China or Nepal. It might be transported during the dates back in seed exchange programmes between the countries.

Landraces often have survived and adapted to different biotic and abiotic stresses in cultivation and thus offer a good source of genes with potential resistance, making them important for modern plant breeding. Collection and characterization of sorghum germplasm is an important activity for identifying potential germplasm for utilization in the varietal improvement programme and avoids duplication (Rosenow DT & Dahlberg, 2000); Elangovan et al., (2004a, b&c; 2005; 2009). Based on the altitudinal variations sorghum cultivation varied from 813 m to 1975 m. mean above sea level (msl). It seems, the cultivation practices done near to the higher altitudinal regions of Himalayas and genotypes are proved as tolerant for cold.

Collection and conservation of sorghum germplasm has been accelerated in the past four decades to prevent the extinction of landraces and wild relatives of cultivated sorghum. Since then, germplasm collection and conservation have become integral components of crop improvement programs at both national and international levels. The sorghum local landraces are cultivated by the farmers over the decades. Majority of the accessions collected were fodder types. Further, characterization of these collections will be helpful in exploiting them in breeding for cold tolerance and other potential traits.

Many areas traditional farmers have developed complex farming systems adapted to the local conditions helping them to sustainable manage the harsh environments to meet their subsistence needs without depending on external inputs or technologies of modern agriculture. Using knowledge gained through experience and locally available resources, indigenous farmers have developed integral and diversified production poly-culture systems adapted to the different ecological systems. A wider genetic base thus helps the breeders in the development of improved crop varieties designed to combine high yield potential with superior quality, resistance to diseases and pests, and also better adaptation to abiotic stress environments. The traditional varieties or landrace population are often highly variable in appearance, but each is identifiable, having particular properties or characteristics, such as early or late maturing, adaptability to a particular soil type, etc. Green leaves and stems of potato crop are utilized as green fodder in some districts. Fodder security increased many folds by introducing high yielding varieties of grasses such as hybrid Napier, *Setaria*, *Guinea*, Deenanath, Anjan, Tall fescue, Brome and Rye grass etc,. Instead of that broomcorn sorghum expected to fill the fodder security in these localities. It provides triple benefits to the marginal farmers (fodder, grain and broom). The leaves and young shoots of broom corn are palatable to cattle. As a feed crop, making brooms, broomcorn has become a good economic source for additional income to the farmers in Uttarakhand.

GIS Mapping of broomcorn sorghum in Uttarakhand

Geographical Information System (GIS) has been successfully used to study the geographic distribution of cultivated crop species as well as pests infestation assessment of agricultural crops (Hijmans and Spooner, 2001; Ganeshaiah et al., 2003). DIVA-GIS, is a GIS software designed to assist the plant genetic resources and biodiversity communities to map the range of distribution of crop species in which they are interested (Hijmans et al., 2002). GIS was successfully used by many in identifying areas of high diversity Wild Potatoes (Hijmans et al., 2000); Sorghum (Teshome et al., 2007; Mekbib, 2008); Maize (Ruiz Corral et al., 2008); *Phaseolus* bean (Jones et al., 1997); Soybean (Gai et al., 2005); and Piper (Parthasarathy et al., 2006). Hence the present study was undertaken to investigate morphological grouping of the races and racial richness, diversity and distribution maps of broomcorn sorghum collections with the help of DIVA-GIS. The spatial data was used to prepare map and describe the geographic distribution of sorghum races in Uttarakhand. This study will provide baseline data for further gap-analysis on exploration, collection, conservation and use of germplasm of landraces and wild crop relatives as well as for studies on the factors that explain the geographic distribution of sorghum landraces.

Landraces diversity and richness map was prepared using GIVA-GIS software to understand landraces distribution along the environmental gradients (Figure. 2). From the sorghum landraces diversity map (Figure. 3), it was found that two hot spot areas. One is consisting of Almora, Bageshwar and Nainital districts, and second hotspot region consisting Rudra Prayag and Chamoli districts. Almora, Bageshwar and Nainital districts having (1.8934 – 2.000) with highest landraces diversity, whereas in Rudra Prayag and Chamoli districts showed (1.000 – 1.8229) medium landraces diversity. From the sorghum landraces richness map (Figure. 4), it was found that one diversifying area, consisting of Almora and Chamoli districts representing nine landraces, followed by Bageshwar (6), Rudraprayag (5) and Nainital consisting only one landrace.

The sorghum races diversity map (Figure. 5) showed very high races diversity (0.66 –1.00) in Almora, Bhageshwar and Nainital districts; whereas in Rudraprayag and Chamoli districts having least (0-0.65) races diversity. The results of races richness map (Figure. 6) revealed that Rudraprayag and Chamoli districts showed high diversifying area with (3-4) races richness followed by Nainital, Bhageshwar and Almora districts having (1-3) racial richness.

Agriculture has undergone significant developments since the time of the earliest cultivation. The Fertile Crescent of Western Asia, Egypt, and India were sites of the earliest planned sowing and harvesting of plants that had previously been gathered in the wild (Gammage, 2011). This GIS mapping also help to relate the present germplasm exploration data points with the oldest agricultural civilization areas for further investigation.

Fig. 2 Sorghum landraces spatial distribution in Uttarakhand

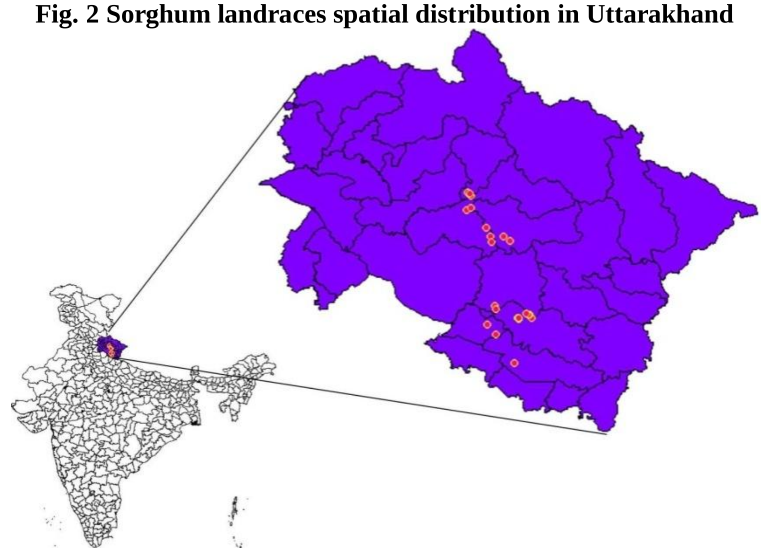


Fig. 3 Sorghum landraces diversity in Uttarakhand

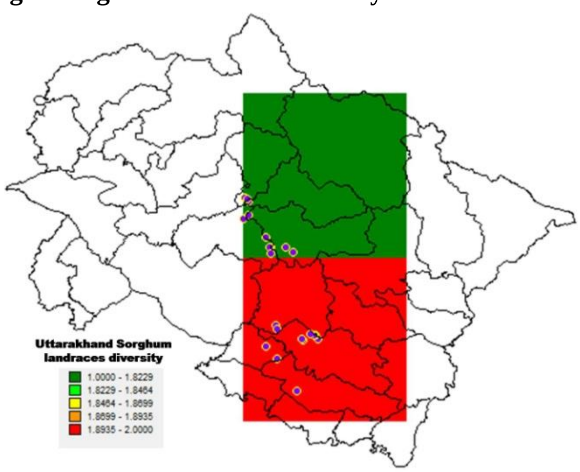


Fig. 4 Sorghum landraces richness in Uttarakhand

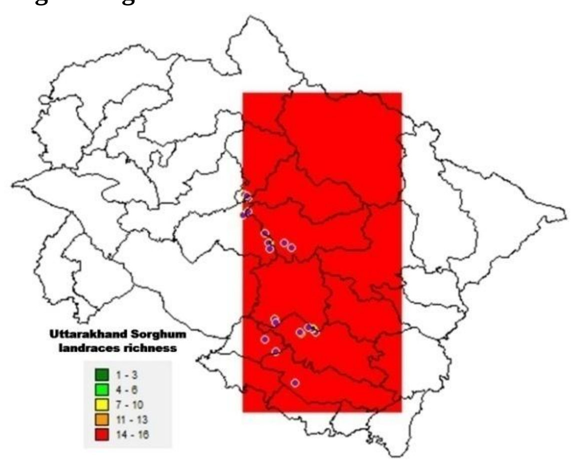


Fig. 5 Sorghum races diversity in Uttarakhand

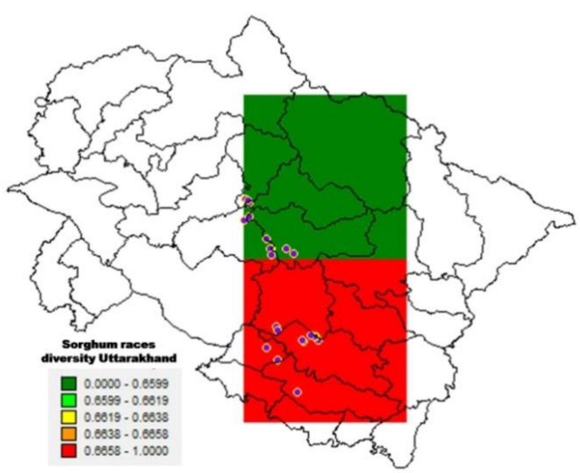
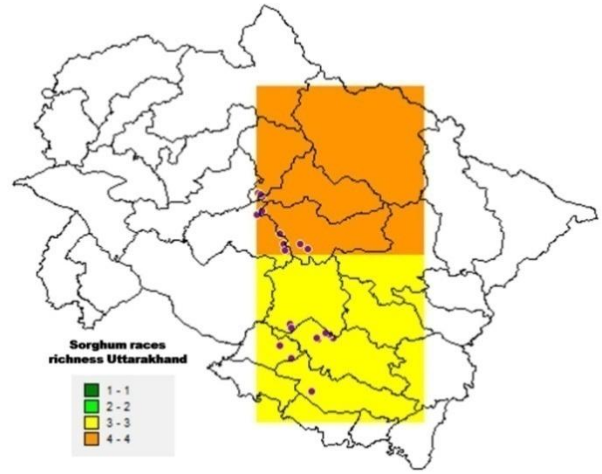


Fig. 6 Sorghum races richness in Uttarakhand



Panicle variation in broom corn sorghum collected from Uttarakhand

Cultivation in high altituteds

Broom corn in wild habitat

Inter cropping with finger millet

Broom corn seeds

Brooms made with threshed panicles

Broom corn large panicles

Fig 1. Broom corn sorghum collection, evaluation and conservation from Uttarakhand state.

Table 1: Passport details of broom corn sorghum collected from Uttarakhand.

SN	Accession name	Indigenous Collection (IC) No.	Race	Local name	Village	Taluk	District	Latitude	Longitude	Altitude (m)	Frequency
1	ESRK 1	IC 597601	Bicolor		Salari	Bhimtal	Nainital	29.1825	79.3346	871	Abundant
2	ESRK 2	IC 597602	Guinea bicolor	Jowari	Sauni	Tarikhet	Almora	29.3774	79.2127	1839	Occasional
3	ESRK 3	IC 597603	Guinea bicolor		Toraghisan	Takula	Almora	29.4953	79.3641	1606	Abundant
4	ESRK 4	IC 597604	Guinea bicolor	Jowar bajra	Shail	Takula	Almora	29.4870	79.3698	1579	Frequent
5	ESRK 5	IC 597605	Guinea bicolor		Shail	Takula	Almora	29.4870	79.3698	1579	Frequent
6	ESRK 6	IC 597606	Bicolor		Shail	Takula	Almora	29.4938	79.3661	1613	Frequent
7	ESRK 7	IC 597607	Bicolor caudatum	Jowari	Badet Palnikot	Bageshwar	Bageshwar	29.4961	79.4607	940	Occasional
8	ESRK 8	IC 597608	Bicolor caudatum		Badet Palnikot	Bageshwar	Bageshwar	29.4962	79.4607	940	Occasional
9	ESRK 9	IC 597609	Bicolor caudatum	Jowari	Tanikhet	Bageshwar	Bageshwar	29.5183	79.4442	1040	Occasional
10	ESRK 10	IC 597610	Guinea bicolor		Kameri	Bageshwar	Bageshwar	29.5201	79.4377	1072	Abundant
11	ESRK 11	IC 597611	Guinea bicolor		Bamrari	Bageshwar	Bageshwar	29.5264	79.4174	1126	Frequent
12	ESRK 12	IC 597612	Guinea bicolor		Ghanghli	Garur	Bageshwar	29.5264	79.4174	1126	Frequent
13	ESRK 13	IC 597613	Guinea bicolor		Talwari Estate	Tharali	Chamoli	30.0235	79.3092	1975	Abundant
14	ESRK 14		Guinea bicolor		Talwari Estate	Tharali	Chamoli	30.0235	79.3092	1975	Abundant
15	ESRK 15	IC 597614	Guinea bicolor		Harmani	Narayanbagad	Chamoli	30.0566	79.2627	1242	Abundant
16	ESRK 16	IC 597615			Harmani	Narayanbagad	Chamoli	30.0566	79.2627	1242	Abundant
17	ESRK 17	IC 597616	Durra		Sili	Agasthyamuni	Rudraprayag	30.2309	79.0078	840	Rare
18	ESRK 18	IC 597617	Guinea		Chandrapuri Gapini	Agasthyamuni	Rudraprayag	30.2498	79.0383	868	Abundant
19	ESRK 19	IC 597618		Jonnel	Khumera Jurani	Ukhimath	Rudraprayag	30.3317	79.0397	1434	Occasional
20	ESRK 20	IC 597619	Guinea bicolor	Jonnel	Badson	Ukhimath	Rudraprayag	30.3585	79.0132	1740	Abundant
21	ESRK 21	IC 597620	Guinea bicolor		Khat	Ukhimath	Rudraprayag	30.3457	79.0281	1587	Frequent
22	ESRK 22	IC 597621	Guinea bicolor	Jowar bajra	Batoli	Karnaprayag	Chamoli	30.1153	79.1422	1059	Frequent
23	ESRK 23	IC 597622			Kalimati	Gairsain	Chamoli	30.0535	79.1711	1933	Occasional
24	ESRK 24	IC 597623	Guinea bicolor		Kalimati	Gairsain	Chamoli	30.0536	79.1711	1932	Frequent
25	ESRK 25	IC 597624			Maroda Kalimati	Gairsain	Chamoli	30.0518	79.1704	1884	Occasional
26	ESRK 26	IC 597625	Bicolor	Jowari	Silangi Tali	Gairsain	Chamoli	30.0163	79.1778	1416	Frequent
27	ESRK 27	IC 597626	Guinea bicolor	Jowari	Puranalobha	Chaukhutia	Almora	29.5776	79.2038	1478	Abundant
28	ESRK 28	IC 597627	Guinea bicolor	Jonnel	Puranalobha	Chaukhutia	Almora	29.5776	79.2038	1478	Abundant
29	ESRK 29	IC 597628	Guinea bicolor		Rampur	Chaukhutia	Almora	29.5565	79.2093	1027	Abundant
30	ESRK 30	IC 597629	Guinea bicolor		Nola/Jaitkhola	Bhikyasain	Almora	29.4468	79.1482	813	Abundant

SN	Accession name	Indigenous Collection (IC) No.	Associate crop	Soil colour	Soil texture	Stoniness	Land aspects	Slope	Topography	Agronomic score
1	ESRK 1	IC 597601	Mixed with blackgram, horsegram and redgram	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Good
2	ESRK 2	IC 597602	Mixed other millets	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Valley	Very good
3	ESRK 3	IC 597603	Mixed with finger millet	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
4	ESRK 4	IC 597604	Mixed with finger millet	Brown	Sandy loam	Pulverized	Rounded summit	Terrace	Closed depression	Very good
5	ESRK 5	IC 597605	Mixed with finger millet	Brown	Sandy loam	Pulverized	Rounded summit	Terrace	Valley	Very good
6	ESRK 6	IC 597606	Mixed with other grasses	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Good
7	ESRK 7	IC 597607	Mixed with black gram	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Flood plain	Very good
8	ESRK 8	IC 597608	Mixed with black gram	Brown	Sandy loam	Pulverized	Upper summit	Lower slope	Mountainous	Very good
9	ESRK 9	IC 597609	Mixed with barnyard millet	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
10	ESRK 10	IC 597610	Mixed with other millets	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
11	ESRK 11	IC 597611	Mixed with other millets	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
12	ESRK 12	IC 597612	Mixed with rice	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
13	ESRK 13	IC 597613	Mixed with other millets	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
14	ESRK 14		Mixed with other millets	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
15	ESRK 15	IC 597614	Mixed with amaranths	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
16	ESRK 16	IC 597615	Mixed with amaranths	Brown	Sandy loam	Pulverized	Level	Terrace	Mountainous	Very good
17	ESRK 17	IC 597616	Mixed with maize and pulses	Brown	Sandy loam	Pulverized	Level	Terrace	Mountainous	Very good
18	ESRK 18	IC 597617	Mixed with finger millet	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
19	ESRK 19	IC 597618	Mixed with finger millet	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Good
20	ESRK 20	IC 597619	Mixed with finger millet	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
21	ESRK 21	IC 597620	Mixed with finger millet	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
22	ESRK 22	IC 597621	Mixed with amaranthus, finger millet and blackgram	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
23	ESRK 23	IC 597622	Mixed with finger millet	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
24	ESRK 24	IC 597623	Mixed with finger millet	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
25	ESRK 25	IC 597624	Mixed with finger millet	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
26	ESRK 26	IC 597625	Mixed with finger millet	Brown	Sandy loam	Pulverized	Rounded summit	Lower slope	Mountainous	Very good
27	ESRK 27	IC 597626	Mixed with finger millet	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
28	ESRK 28	IC 597627	Mixed with finger millet	Brown	Sandy loam	Pulverized	Upper summit	Terrace	Mountainous	Very good
29	ESRK 29	IC 597628	Mixed with finger millet	Brown	Sandy loam	Pulverized	Level	Lower slope	Mountainous	Very good
30	ESRK 30	IC 597629	Mixed with other millets	Brown	Sandy loam	Pulverized	Level	Lower slope	Mountainous	Very good

SN	Accession name	Indigenous Collection (IC) No.	Useful Parts	Kind of utilization	Plant Height	Ear Head Compactness	Seed Shape	Seed Colour	Glume Colour	Remarks
1	ESRK 1	IC 597601	Seed & Stem	Fodder	Tall	Very loose	Bold	Grayed orange	Grayed red	Wild grass
2	ESRK 2	IC 597602	Seed & Stem	Fodder	Tall	Very loose	Bold	Grayed orange	Red	
3	ESRK 3	IC 597603	Seed & Stem	Fodder	Tall	Very loose	Bold	Grayed orange	Grayed red	
4	ESRK 4	IC 597604	Seed & Ear head	Roti and broom	Tall	Very loose	Bold	Grayed red	Grayed red	Roti and broom
5	ESRK 5	IC 597605	Seed & Ear head	Fodder & broom	Tall	Very loose	Bold	Grayed orange	Grayed red	Broom and forage
6	ESRK 6	IC 597606	Seed & Ear head	Fodder & broom	Tall	Very loose	Bold	Grayed orange	Grayed red	
7	ESRK 7	IC 597607	Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed red	
8	ESRK 8	IC 597608	Seed & Ear head	Fodder & broom	Tall	Semi loose	Bold	Grayed orange	Grayed red	Food, broom and forage
9	ESRK 9	IC 597609	Seed & Ear head	Fodder & broom	Tall	Very loose	Bold	Grayed orange	Grayed orange	Broom and forage
10	ESRK 10	IC 597610	Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed red	Broom and forage
11	ESRK 11	IC 597611	Seed & Ear head	Fodder & broom	Tall	Very loose	Bold	Grayed orange	Grayed orange	Broom and forage
12	ESRK 12	IC 597612	Seed & Ear head	Fodder & broom	Tall	Very loose	Bold	Grayed orange	Grayed red	Broom and forage
13	ESRK 13	IC 597613	Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed orange	Broom and forage
14	ESRK 14		Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed red	Broom and forage
15	ESRK 15	IC 597614	Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed orange	Broom and forage
16	ESRK 16	IC 597615	Seed & Ear head	Fodder & broom	Very tall	Loose	Bold	Grayed orange	Grayed red	Broom and forage
17	ESRK 17	IC 597616	Seed and Stem	Roti & Fodder	Tall	Semi compact	Bold	White	Grayed orange	Broom and forage
18	ESRK 18	IC 597617	Seed & Ear head	Fodder & broom	Very tall	Loose	Bold	Red	Grayed orange	Broom and forage
19	ESRK 19	IC 597618	Seed & Ear head	Fodder & broom	Tall	Semi loose	Bold	Grayed orange	Grayed orange	Broom and forage
20	ESRK 20	IC 597619	Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed red	Roti and broom
21	ESRK 21	IC 597620	Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed red	Broom and forage
22	ESRK 22	IC 597621	Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed red	Food and bread preparations with other millets
23	ESRK 23	IC 597622	Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed red	Broom and Cattle feed
24	ESRK 24	IC 597623	Seed & Ear	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed red	Broom and Cattle

			head							feed
25	ESRK 25	IC 597624	Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed red	Broom and Cattle feed
26	ESRK 26	IC 597625	Seed & Ear head	Fodder & broom	Tall	Loose	Bold	Grayed orange	Grayed orange	Broom and Cattle feed
27	ESRK 27	IC 597626	Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Grayed orange	Grayed red	Broom and Cattle feed
28	ESRK 28	IC 597627	Seed & Ear head	Fodder & broom	Tall	Loose	Bold	Red	Grayed yellow	Food and roti preparations with other millets
29	ESRK 29	IC 597628	Seed & Ear head	Fodder & broom	Very tall	Loose	Bold	Grayed orange	Grayed red	Broom and forage
30	ESRK 30	IC 597629	Seed & Ear head	Fodder & broom	Very tall	Very loose	Bold	Red	Red	Food, broom and forage

Conservation

The Directorate of Sorghum Research has the mandate to collect and conserve these local landraces and germplasm from different parts of the country. The current status of total collections / augmentation made so far by the institute is 31,746 accessions which include germplasm and breeding materials. These accessions are to be evaluated, characterized and documented for utilization in the crop improvement programme. Collection and characterization of sorghum germplasm is an important activity for identifying potential germplasm for utilization in the varietal improvement programme and avoid duplication. Conservation of these local landraces using in situ / on – farm can be successfully achieved by providing special incentives to farmers / local people for growing difficult or uneconomical material on private land or domestic gardens in Uttarakhand. The village communities may get the benefits through watershed management, wild life habitats and environmental stabilization. Complementary conservation strategies include the protection of cold tolerance genotypes, disease resistant genotypes, plant populations and traditional crop varieties where they have evolved (*in situ*) with the collection and preservation of inter and intra-specific, racial diversity in genebanks and agricultural farms. Traditional farmers' strategies emphasis crops diversification as a way of managing risks resulting from climatic vulnerability and market fluctuations. Additionally, they make use of resources available outside their fields. PGR Scientists and naturalists need to come forward in coordination to rescue the diversity of landraces from un-surveyed and surveyed areas. Trait specific collections and conservations need to be strengthened to tackle the climate change with the help of this natural wealth.

Conclusions

Broomcorn as a cultivated type of sorghum is grown for its panicles and used as food, feed and raw material for making brooms. The broomcorn improvement through breeding for various panicle quality traits viz., high grain yield, optimizing fiber length (Secondary braches), high fodder yield and the quality of grain. Broomcorn could become a suitable feed, energy, or fiber crop if improvements in seed quality, stalk biomass, juiciness, and sweetness are undertaken. The crossing programme of broomcorn with grain and sweet sorghums may help to develop high grain yield, sugar content and biomass production. This GIS map is indicative only for broomcorn sorghum collecting areas and it also showed unexplored areas with valuable germplasm from the state to be collected in future explorations..

Traditionally cultivated local landraces and identification of their distribution at the micro level will help in identifying the location specific solutions through the effective use of remote sensing based resource information combined with other socio-economic data using GIS. This is being done by survey of resources at different scales using traditional and remote sensing techniques. The collated information like slope, topography, set of resource maps; generation of action plan maps gives site specific recommendations for development and management of agriculture, genetic resources collection and conservation. State-wise sorghum genetic resources collection and distribution; collection-gaps, priority areas and wild species existence mapping has helped in expanding and intensification of agricultural activities and also in identifying the land capability classes and crop suitability indices. Re-visiting the collection areas revealed that the loss of local landraces existence due to replacement of commercial crops. Based on available literature some of the area already surveyed and past study records of the sorghum germplasm, it was felt that the unexplored areas in the region must be surveyed vigorously, which can provide very valuable germplasm material and explored areas must be re-visited to check the genetic erosion of the local landraces. The local landraces which are yet to be known fully to the users must be conserved for their future utilization.

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