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Original Research Article

Morphological Characterization of Three Species of *Sorghum* Seedlings (*S. bicolor, S. halepense* and *S. vulgare*)

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Abstract

Seedling morphology of three species of *Sorghum* Moench (*S. bicolor, S. halepense* and *S. vulgare*) were described along with mature plants. Morphological attributes of seedlings like Coleoptile, Collet, Epicotyl, First internode, Ligule, Mesocotyl, Palea, Root, and Scutellum were found significant from taxonomic view point.

Keywords

Morphology

Seedling

Sorghum

Introduction

Sorghum is a genus with many species and subspecies, and there are several types of *Sorghum*, including grain sorghums, grass sorghums (for pasture and hay), sweet sorghums (for syrups), and Broomcorn. It is not certain, whether it was domesticated in Africa, or in India. Harlan and de Wet (1972) suggested that *Sorghum* is an African grass, originated and domesticated in the Sub-Saharan region of Africa and spread to India and China. Sub-Saharan and North East region of Africa were the primary centers of origin and diversity of *Sorghum*. It spread to India during the first millennium and was taken from there to China (Doggett, 1988). *Sorghum* is valued because of its ability to produce in areas with marginal rainfall and high temperatures where other cereals often fail. *Sorghum* is the world's fifth most important cereal crop after Maize, Rice, Wheat and Barley. It is the dietary staple of >500 million people in >30 countries (USDA, 2004; Singh and Lohithaswa, 2006).

Leading *Sorghum* growing countries are USA, India, Nigeria, Mexico, Sudan and Argentina. *Sorghum* [*Sorghum bicolor* (L.) Moench] is the fifth major cereal crop in the world. In India, it is a staple food in Karnataka, Maharashtra, Andhra Pradesh, Gujarat, Madhya Pradesh and Rajasthan. India has the largest share (32.3%) of World's area under sorghum and ranks second in production after USA (Anonymous, 2002).

Sorghum is a multipurpose and bioenergy crop; the grain, stem and glumes are the useful parts. The grain is used as human food (bread, baby food, popped, parched, flakes); livestock feed for poultry, farm animals (rabbits, ducks and pigs); alcohol production (potable and industrial), fuel; malt (malt syrup, beer, beverages; glucose liquid/powder), and other industrial productions: starch, dextrin, dextrose, glue, liquid glucose, alcohols, plastics, textiles, paper board, 'U'–foam industries; stem is used in the production of syrup, jaggery, alcohols and sugar; bagasse obtained as byproduct is used as fodder and in the manufacture of fuel, paper, particle and corrugated boards. Natural color is extracted from glumes (Rana, 2000). Sorghum is considered as an industrial and high-energy crop with its diverse uses. Sorghum alcohol, syrup, liquor, beer and malt play an important role for small industries

(Elangovan, 2005). Fortified foods, a blended food product containing grain sorghum and quality protein sources such as soybean have been developed in countries like the USA. The *kafir* beer of Africa is a traditional drink of *Bantu* people. Modern malting techniques used in the malting of barley have been successfully applied to grain sorghums (Smith and Frederiksen, 2000; Berenji et al., 2011). Sorghum is also a good source of vitamin B complex and more than 20 mineral elements and is specifically rich in phosphorus, potassium, iron and zinc. For example, *Sorghum* is a better source of Zinc, an important micronutrient for pregnant women than Corn and Wheat (Ng'uni, 2011). Sorghum truly is a miracle crop.

The grass tribe Andropogoneae includes both Maize and *Sorghum*, two of the world's most important crops (Mathews et al., 2002). Most species of the tribe Andropogoneae have pairs of spikelets in the inflorescence, one sessile and other pedicellate. The genus *Sorghum* belongs to one of the 16 subtribes of the tribe Andropogonaeae, subtribe Sorghinae of the subfamily Panicoidae of the family Poaceae (Garber, 1950; Clayton and Renvoize, 1986; Singh and Lohithaswa, 2006).

As mentioned by Mekbib (2007 and references therein) that *Sirghum* was firstly described by Linnaeus (1753) under the name of *Holcus* and classification of *Sorghum* genus was attempted by Brotero (1804), Roxburghii (1820), Steudel (1825), Chiovenda (1912), Piper (1915) and Stapf (1912), and it was named by Moench in 1794. Snowden (1935) described 31 cultivated and 17 related wild species. *Sorghum* is classified into five basic races *viz.*, *bicolor*, *guinea*, *caudatum*, *kafir* and *durra* (Harlan and de Wet, 1972).

The main aim of the present study was to record the seedling morphology of three species of *Sorghum* Moench, *viz.*, *S. bicolor*, *S. halepense* and *S. vulgare* and to identify their taxonomic significance.

Materials and methods

Seeds of *Sorghum bicolor*, *S. halepense* and *S. vulgare* have been collected from mature mother plants after correct identification (Haines, 1921-1925; Bor, 1960; Roy, 1984; Moulik, 1997) cultivated in Vindhyan Region (Chandauli, Mirzapur and Sonbhadra districts) of Uttar Pradesh, India (82º and 83º 23' E long. and 22º 45' N 24º 34' N lati.). The collected seeds were grown in Petri dishes (20 cm × 5 cm) on moist filter paper at temperature of 20-25ºC in permanent light, and in sandy soil in the green house. The different stages of development of each seedling up to 3rd leaf stage were considered for preparing a complete description out of ten individuals. Seedlings were analyzed under Stereoscopic Binocular Microscope (Olympus-Magnus MSZ-Bi) and sketches have been prepared (Fig. 1). The gross morphological features of the seedlings were described following the terminology proposed by Tillich (2007). Mature specimens have also been described taxonomically and provided in the text. Distinguishing attributes of mature plants and seedlings of reported taxa are provided in Table 1 and Table 2, respectively. Mature plants and Seedling vouchers have been deposited in the Herbarium, Department of Botany, Udai Pratap College (Autonomous), Varanasi, Uttar Pradesh, India.

Table 1. Distinguishing attributes of Mature plants among *Sorghum bicolor, S.halepens* and *S. vulgare.*

Attributes	*Sorghum bicolor*	*S. halepense*	*S. vulgare*
1. Root	Non-rhizomatous, densly hairy	Rhizomatous, sparsely hairy	Non-rhizomatous, hairy
2. Leaf blade	Broadly linear with moderate light green mid-vein	Narrowly linear with thin and white mid vein	Broadly linear with massive light green mid vein
3. Ligule	Membranous with apical fringe of hairs	Membranous	Hairy
4. Inflorescence	Compressed and compact, ovate, rachis multiangular and wavy	Lax and loose, pyramidal, rachis terete and straight	Medium compressed and compact, pyramidal, rachis winged and wavy
5. Spikelet	Paired, milky white, glabrous, sessile spikelet awnless	Paired, dark pink hairy, sessile spikelet awned; 1cm long	Paired, light pink hairy at margins, sessile spikelet awned; 0.5 cm long
6. Lodicules	Nerveless, hairy at apex	Nerveless, hairy at apical corners	Nerved, glabrous
7. Caryopsis	Orbicular, 0.5x0.4, white-yellow	Oval, 0.5×0.3, dark brown	Orbicular, 0.5×0.4, dull white

Results

1. *S. bicolor* (L.) Moench, Meth. Pl. 207. 1794. Based on *Holcus bicolor* L., Mant. Alt. 301. 1771; Bor, Grass. Bur. Cey. Ind. Pak. 227. 1960; Roy, Grass. M. P. 150. 1984; Shreekumar & Nair, Fl. Kera. Grass. 191. 1991; Moulik, Grass. Bamb. Ind. 1:252. 1997; *Sorghum vulgare* Pers. Syn. Pl. 1: 101. 1805. *S. margaritiferum* Stapf in Prain, Fl. Trop. Afr. 9: 125. 1917; *Andropogon bicolor* Roxb. Fl. Ind.1: 272. 1820; Uniyal et al. The Grasses of U. P.-A checklist 83. 1994. (Fig. 1A).

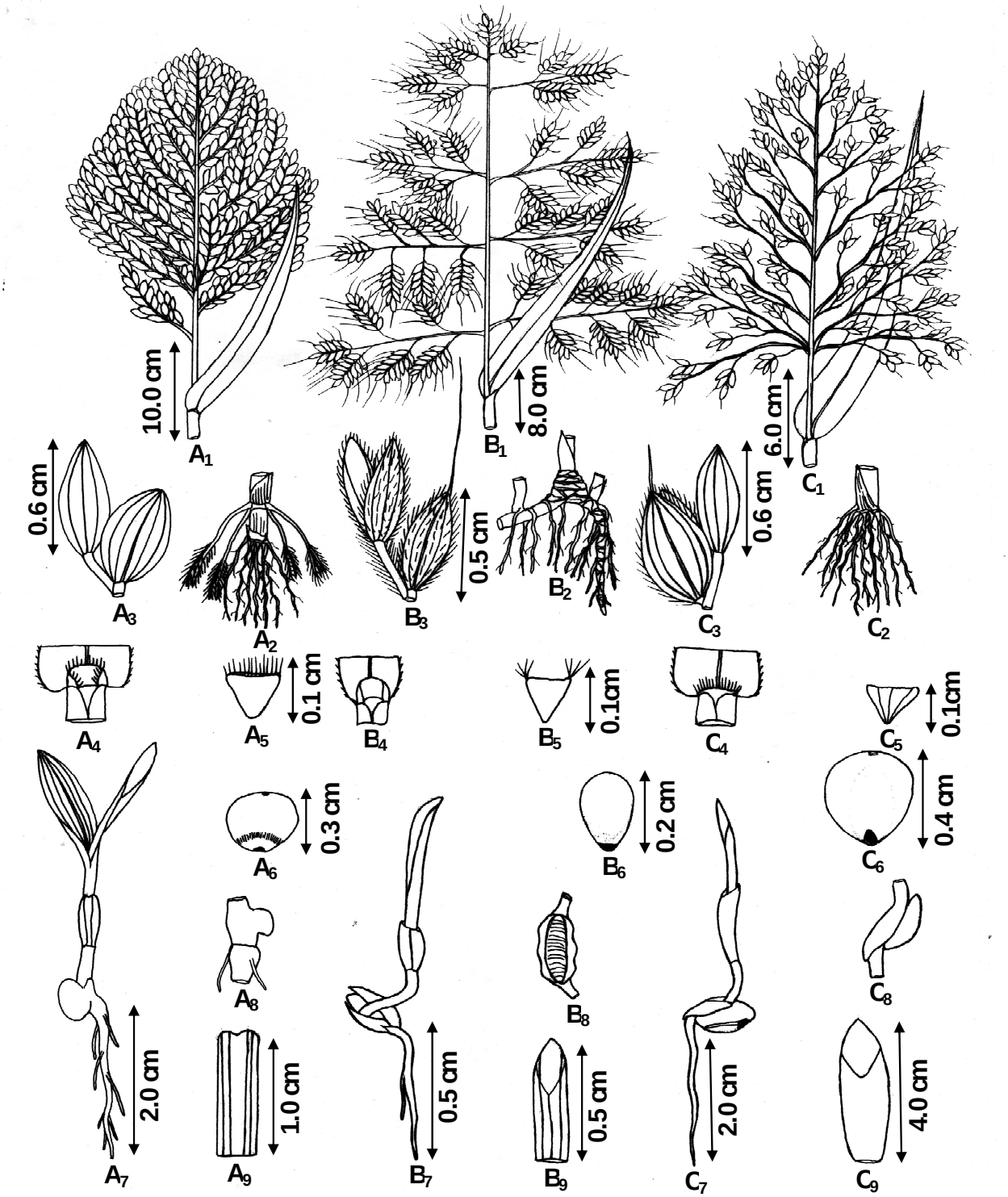
An annual rhizomatous grass. Root fibrous, dull white, hairy, 12.0–15.0 cm long. Stilt roots present (Fig. $1A_2$). Culms green, glabrous, solid, terete, and 1.8–2.0 m long. Nodes green, glabrous and slightly swollen. Internodes green, glabrous, 20 cm long. Leaf sheath green, glabrous, membranous, tight, margins membranous, transparent, glabrous, enrolled, and 20.0–25.0 cm long. Collar green, scabrous, 0.4 cm long. Auricle absent. Ligule ovate, membranous, apex hairy; hair base broad, apex acute, 0.5 cm long (Fig. $1A_4$). Leaf blade liniar-lanceolate, 75.0-85.0 × 5.0-5.7 cm, mean length to width ratio (L/W) 15, base truncate, apex acuminate, margins membranous and denticulate, surface green and glabrous. Venation parallelodromous; multicostate reticulate; veins 15-19, mid vein moderate and light green. Prophyllum oblong, 1.0 × 0.4 cm, mean L/W 2.5, base truncate, apex acute, margins hyaline, glabrous, membranous, translucent and hairy; base broad, apex acute, 0.1 cm long; binerved; nerves green and winged; wings hyaline and hairy; hairs as on prophyllum. Inflorescence paniculate (Fig. $1A_1$). Rachis green, multiangular in cross section and hairy; hair base broad, apex acute, 0.50 cm long. Spikelets in pair (Fig. $1A_3$), one sessile and other pedicelled. Sessile spikelet ovate, 0.50 × 0.25 cm, mean L/W 2.0, base rounded, apex obtuse, surface green, glabrous and globose. Lower glume ovate, 0.50 × 0.25 cm, mean L/W 2.0, base truncate, apex obtuse, margins membranous and glabrous, surface green, membranous and glabrous, veins 11; veins green, distinct and glabrous. Upper glume obovate, 0.50 × 0.25 cm, mean L/W 2.0, base truncate, apex obtuse, margins same as lower glume, surface green and pubescent; hair base broad, apex acute, 0.1 cm long, veins 9; green, distinct and glabrous. Lower lemma ovate, 0.40 × 0.20 cm, mean L/W 2.0, base truncate, apex obtuse, margins hyaline, glabrous and enrolled, surface light green, membranous and glabrous, veins 3; green, distinct, and scabrid. Upper lemma ovate, 0.40 × 0.30 cm, mean L/W 1.3, base truncate, apex acute, margins membranous, hairy; hairs as on upper glume; surface green, membranous and glabrous, vein single; light green and glabrous. Upper Palea elliptical, 0.30 × 0.12 cm, mean L/W 2.5, base and apex emarginate, margins hyaline and hairy; hair base swollen, apex acuminate, 0.20 cm long, surface light green, hyaline, veins 2; green, distinct and glabrous. Lodicules 2, base obtuse, apex truncate and hairy; hair base broad, apex acute, 0.1 cm long (Fig. $1A_5$). Stamens 3; anthers dithecous, versatile, dorsifixed, oblong, glabrous, green, 0.20 cm long. Ovary ovate, glabrous, translucent, 0.10 cm long; style 2, linear, terete, glabrous, 0.10 cm long; stigma plumose, colourless and transparent. Caryopsis orbicular, 0.30 × 0.15 cm, mean L/W 2.0, base and apex rounded, white-yellow and glabrous (Fig. $1A_6$). Pedicelled spikelets lanceolate, 0.55 × 0.20 cm, mean L/W 2.7, green, staminoid, other features same as sessile spikelets except pedicel; pedicel green, flat, glabrous and 0.2 cm long.

Seedling mesogeal type (Fig. $1A_7$). Primary root fibrous, much branched, more developed than shoot, hairy, dull white, terete in cross section, 1.4 cm long at coleoptile stage, 2.1 cm, 3.5 cm and 3.9 cm long at 1st, 2nd and at 3rdleaf stages respectively; secondary and transitional node roots same as primary roots. Collet distinct, dull white, hairy and slightly swollen. Hypocotyl white, hairy, terete in cross section, 2.0 cm long. Scutellum dull white, glabrous, convex, 0.2 cm long Fig. $1A_8$). Caryopsis compressed, spherical 0.4 x 0.45 cm, mean L/W 0.9, base rounded; dark black; apex rounded, margins entire, white, glabrous. Mesocotyl white, glabrous, terete in cross section, 0.2 cm long. Coleoptile oblong, light pink, transluscent, glabrous, tight, base truncate, apex emarginate, binerved, 0.5 cm long (Fig. $1A_9$). Epicotyl green, glabrous, terete in cross section, 1.0 cm, 1.8 cm and 3.0 cm long at 1st, 2nd and at 3rdleaf stages respectively. Internodes (at 3rd leaf stage): First one 1.0 cm long, later internodes elongating. Leaf sheath green, glabrous, margins entire and hyaline, 0.8 cm long. Ligule distinct after first leaf stage. Leaf blade elliptical, 2.3 x 0.7 cm, mean L/W 3.3, base attenuate, apex acute, margins entire, both surface green and glabrous. Venation parallelodromous; multicostate striated; several primary veins distinct, all reaching blade apex. Second and subsequent leaves same as that of 1st leaf but leaf blade linear.

Flowering and fruiting: August-October.

Distribution: Africa, Australia, India, Southeast Asia, and the United States.

Fig. 1: A. *Sorghum bicolor* : A_1. Inflorescence, A_2. Root, A_3. Single spikelet, A_4. Ligule, A_5. Lodicule, A_6. Caryopsis, A_7. Seedling at second leaf stage, A_8. Scutellum, A_9. Coleoptile; B. *S. halepense* : B_1. Inflorescence, B_2. Root, B_3. Single spikelet, B_4. Ligule, B_5. Lodicule, B_6. Caryopsis, B_7. Seedling at First leaf stage, B_8. Scutellum, B_9. Coleoptile; C. *S. vulgare* : C_1. Inflorescence, C_2. Root, C_3. Single spikelet, C_4. Ligule, C_5. Lodicule, C_6. Caryopsis, C_7. Seedling at First leaf stage, C_8. Scutellum, C_9. Coleoptile.



2. *S. halepense* (L.) Pers., Synops. 1, 101: 1895; Bor, Grasse. Bur. Cey. Ind. Pak. 222. 1960; Moulik, Grass. Bamb. Ind. 1: 249. 1997; Haines, Bot. Bih. & Or. 1033.1925; Blatter & McCann, Bomb. Grass. 55.1984; *Holcus halepense* L. Sp. Pl. 1047. 1753. *Andropogon halepensis* L. Brot. Fl. Luist. 1: 84. 1804; Hook. f. Fl. Brit. Ind. 7: 182. 1986; Fisher in Gamble Fl. Pres. Madr. 3: 1203. 1957; Cope in Nasir & Ali, Fl. W. Pak. 143. 259. t. 32; Uniyal *et al.* The Grasses of U.P.-A checklist 84.1994. (Fig. 1B).

Perennial, rhizomatous grass. Rhizome dull white, 6.0–8.0 cm long, root fibrous, dull white, hairy and 15.0-20.0 cm long, Stilt roots present (Fig. $1B_2$). Culms green, glabrous, tufted and 150-200 cm long. Nodes green, slightly swollen, glabrous. Internodes green, glabrous, 20.0 cm long. Leaf sheath green, membranous, glabrous, margins transparent, 30.0 cm long. Collar green, scabrous, 0.3 cm long. Auricle absent. Ligule membranous; base and apex truncate, glabrous, 0.2 cm long (Fig. $1B_4$). Leaf blade lanceolate, 80.0 × 1.5 cm, mean L/W 53.3, base truncate, apex acuminate, margins membranous and denticulate, surface green, membranous, venation parallelodromous; multicostate reticulate; veins 9, mid vein white, prominent. Prophyllum oblong, 1.0 x 0.4 cm, mean L/W 2.5, base truncate, apex obtuse, margins hyaline, glabrous and enrolled, surface membranous, translucent and hairy; hair base broad, apex acute, 0.1 cm long; binerved, nerves green and winged; wings hyaline denticulate and hairy; hairs as on surface. Inflorescence paniculate (Fig. $1B_1$). Rachis green, terete and glabrous. Spikelets in pair, one sessile and other pedicelled (Fig. $1B_3$). Sessile spikelets elliptical, 0.50 × 0.25 cm, mean L/W 2.0, base rounded, apex acute, surface green, membranous, hairy; hair base broad, apex acute, 0.1 cm long; hermaphrodite. Lower glume ovate, 0.50 × 0.20 cm, mean L/W 2.5, base truncate, apex tridentate, margins membranous, glabrous and scabrid, surface green, membranous, hairy; hairs as on sessile spikelets; veins 5; nerves green, distinct, glabrous, reaching below apex. Upper glume ovate, 0.50 × 0.25 cm, mean L/W 2, base ovate, apex obtuse, margins membranous and hairy; hairs as on sessile spikelets; surface same as lower glume; nerves 7; green, glabrous and distinct. Lower lemma lanceolate, 0.50 × 0.20 cm, mean L/W 2.5, base truncate, apex obtuse, margins membranous and hairy; hairs as on sessile spikelets; transparent and nerveless. Upper lemma ovate, 0.30 × 0.15 cm, mean L/W 2.0, base truncate, apex obtuse, margins hyaline and hairy; hairs as on sessile spikelets; surface green, membranous, glabrous and nerveless. Upper palea elliptical, 0.30 × 0.10 cm, mean L/W 3.0, base truncate, apex acute with awn; awn green, glabrous, terete and 0.8 cm long; margins hyaline and hairy; hairs as on sessile spikelets; surface hyaline, and transparent. Lodicules 2, base obtuse, apex truncate with hairs; hair base broad, apex acute and 0.1 cm long (Fig. $1B_5$). Stamens 3; anthers dithecous, versatile, dorsifixed, oblong, glabrous, pink, 0.20 cm long. Ovary ovate, glabrous, translucent and 0.10 cm long; styles 2, linear, terete, glabrous, 0.10 cm long; stigma plumose, light pink, 0.20 cm long. Caryopsis elliptical, 0.40 × 0.20 cm, mean L/W 2.0, base and apex rounded, glossy, dark brown and glabrous (Fig. $1B_6$). Pedicelled spikelets staminoide. Pedicel green, flat and hairy; hairs as on spikelets, 0.2 cm long. Lower glume lanceolate, 0.50 x 0.20 cm, mean L/W 2.5, base and apex truncate with hairy fringe; hair as on spikelets; margins membranous and hairy; hairs as on spikelets, surface green, membranous, hairy; hairs as on spikelets; vein 7; green, distinct, scabrid. Upper glume ovate, 0.50 × 0.25 cm, mean L/W 2.0, base truncate, apex acute, margins membranous and hairy; hairs as on spikelets; surface green, membranous, glabrous, 6 nerved; nerves green and glabrous. Lemma lanceolate, 0.50 x 0.20 cm, mean L/W 2.5, base rounded, apex obtuse, margins membranous and hairy; hairs as on spikelets; nerveless. Palea oblong, 0.30 × 0.20 cm, mean L/W 1.5, base truncate, apex emerginate, margins hyaline and hairy; hairs as on spikelets; surface hyaline, transparent and glabrous. Lodicules 2, base obtuse, apex truncate, glabrous, 0.01cm long. Stamens 3; anthers dithecous, versatile, dorsifixed, oblong, glabrous, green and 0.15 cm long.

Seedling mesogeal type (Fig. $1B_7$). Primary root fibrous, less developed than shoot, less branched, dull white, glabrous, terete in cross section, 3.7 cm long at coleoptile stage, and 4.3 cm, 4.8 cm and 5.0 cm long at 1^{st}, 2^{nd} and at 3^{rd} leaf stages respectively. Transitional node roots, collet and hypocotyl not distinct. Palea ovate, 0.3 × 0.2 cm, mean L/W 1.5, base and apex acute, margins entire, black-red in colour, glabrous. Caryopsis oval, 0.20 x 0.15 cm, mean L/W 1.3, base and apex rounded, red-black in colour, glabrous. Scutellum milky white, glabrous, convex and slightly winged (Fig. $1B_8$). Mesocotyl light pink, glabrous, terete in cross section, 1.0 cm long. Mesocotyl roots not distinct. Coleoptile oblong, base rounded, apex acute, membranous, tight and binerved, 0.9 cm long (Fig. $1B_9$). Epicotyl pink-green, glabrous, terete in cross section, 1.0 cm, 3.0 cm and 4.5 cm long at 1^{st}, 2^{nd} and 3^{rd} leaf stages respectively. Internodes (at 3^{rd}

leaf stage): First one 2.0 cm, second one 1.8 cm and third one 1.5 cm long. Leaf sheath green, glabrous, margins entire, 0.6 cm long. Ligule membranous, apex erose, 0.1 cm long. Leaf blade oblanceolate, 4.5 × 0.9 cm, mean L/W 5.0, base attenuate, apex acute, margins entire, both surface green and glabrous. Venation parallelodromous; multicostate striated; several primary veins distinct, reaching to blade apex. Second and subsequent leaves same as that of 1st leaf but leaf blade linear.

Flowering and fruiting: August-November.

Distribution: Asia, Africa, Central America and Caribbean, Europe, North America, Oceania, South America.

3. *S. vulgare* Pers. Syn. Pl.1: 101. 1805; Watt. Dict. Econ. Prodr. 6: pt. 3: 289.1838; Haines, Bot. Bih. & Or. 1033.1924; *Andropogon sorghum* Brot. Fl. Luist. 1: 88. 1804; Hook. f. Fl. Brit. Ind. 7: 183. 1986; Cooke, Fl. Bomb. 2: 991. 1908. *Holcus sorghum* Linn. Sp. Pl. 1047. 1753; Grah. Cat. Bomb. Pl. 238. 1839; Dalz. & Gibs. Bomb. Fl. 99. 1861; Uniyal et al. The Grasses of U.P.-A check. 84.1994. (Fig. 1C).

An annual grass. Root fibrous, dull white, hairy, 15.0-20.0 cm long. Stilt roots present (Fig. $1C_2$). Culms green, glabrous, tufted, 150-200 cm long. Nodes green, slightly swollen and glabrous. Internodes green, glabrous, 15.0-20.0 cm long. Leaf sheath green, membranous, glabrous, margins transparent and 30.0 cm long. Collar green, pubescent; hair base broad, apex acute, 0.1 cm long. Auricle absent. Ligule represented by ring of hairs; hair base broad, apex acute, 0.2 cm long (Fig. $1C_4$). Leaf blade lanceolate, 70.0 × 6.0 cm, mean L/W 11.6, base truncate, apex acuminate, margins scabrous, surface green, membranous, pilose at base; hair base tuberculed, apex acute, venation parallelodromous; multicostate reticulate; veins 11; mid vein white and prominent. Prophyllum oblong, 1.50 × 0.6 cm, mean L/W 2.5, base truncate, apex acute, margins hyaline, glabrous and enrolled, surface membranous, translucent, hairy; hair base broad, apex acute, 0.1 cm long; binerved; nerves green and winged; wings hyaline and hairy; hairs as on surface. Inflorescence paniculate (Fig. $1C_1$). Rachis green, terete and glabrous. Spikelets in pair, one sessile and other pedicelled (Fig. $1C_3$). Sessile spikelets ovate, 0.50 × 0.25 cm, mean L/W 2.0, base rounded, apex acute, green, membranous, hairy at margins; hair base broad, apex acute, 0.1 cm long, hermaphrodite. Lower glume ovate, 0.50 × 0.20 cm, mean L/W 2.5, base rounded, apex acute, margins membranous and scabrid; hairs as on sessile spikelets; green, surface membranous, hairy at base; hairs as on spikelets; veins 9; green, distinct and glabrous. Upper glume ovate, 0.50 × 0.25 cm, mean L/W 2.0, base ovate, apex obtuse, margins membranous and hairy; hairs as on sessile spikelets; surface same as lower glume, nerves 7; green and glabrous. Lemma ovate, 0.40 × 0.20 cm, mean L/W 2.0, base truncate, apex emarginate and awned; awn green, glabrous, terete and 0.3 cm long; margins membranous and hairy; hairs as on sessile spikelets; colourless, transparent, single nerved; nerve green, distinct and glabrous. Palea ovate, 0.30 × 0.20 cm, mean L/W 1.5, base truncate, apex obtuse, margins hyaline, glabrous and transparent, surface hyaline, colourless, transparent, binerved, nerves green, distinct and hairy; hairs as on lemma. Lodicules 2, base obtuse, apex truncate, glabrous and 4-5 nerved (Fig. $1C_5$). Stamenes 3; anthers dithecous, versatile, dorsifixed, oblong, glabrous, pink, and 0.20 cm long. Ovary ovate, glabrous, translucent, 0.10 cm long; styles 2, linear, terete, glabrous, 0.10 cm long; stigma plumose, light brown, 0.20 cm long. Caryopsis ovate, 0.40 × 0.25 cm, mean L/W 1.6, base and apex rounded, surface dull white and glabrous. Pedicelled spikelets elliptical, 0.40 × 0.20 cm, mean L/W 2.0, green, staminoid, other features same as sessile spikelets except pedicel; pedicel green, flat, glabrous and 0.2 cm long.

Seedling mesogeal type (Fig. $1C_7$). Primary root fibrous, much branched, more developed than shoot, hairy, dull white, terete in cross section, 4.0 cm long at coleoptile stage, and 5.0 cm, 6.0 cm and 7.2 cm long at 1st, 2nd and at 3rd leaf stages respectively; secondary and transitional node roots same as primary roots. Collet and hypocotyl not distinct. Scutellum white, glabrous, convex, 0.2 cm long (Fig. $1C_8$). Caryopsis compressed, spherical 0.3 x 0.2 cm, mean L/W 0.9, base rounded; dark black; apex rounded, margins entire, surface glabrous and white (Fig. $1C_6$). Mesocotyl white, glabrous, terete in cross section, 0.3 cm long. Coleoptile oblong, white, transluscent, glabrous, tight, base truncate, apex acute, nerveless, 0.4 cm long (Fig. $1C_9$). Epicotyl light green, glabrous, terete in cross section, 2.7 cm, 3.0 cm and 3.8 cm long at 1st, 2nd and at 3rdleaf stages respectively. Internodes (at 3rd leaf stage): First one 2.7 cm long, later internodes elongating. Leaf sheath green, glabrous, 2.0 cm long. Ligule membranous, base truncate, apex erose, 0.5 cm long. Leaf blade oblanceolate, 4.5 x 0.7 cm, mean L/W 6.5, base attenuate, apex acute, margins entire, both surface light green and glabrous. Venation parallelodromous; multicostate striated; several primary veins distinct, all reaching to blade apex. Second and subsequent leaves same as that of 1st leaf but leaf blade linear.

Flowering and fruiting: August-November.

Distribution: Africa, Asia, Europe and North America.

Discussion

According to Thangavel et al. (2005), varietal identification is becoming exceedingly important in the operation of modern crop production. The ability to discriminate between and identify varieties of agricultural and horticultural crops is fundamental for the smooth operation of modern seed trade. They discriminated twelve sorghum (*Sorghum bicolor* (L.) Moench) cultivars including nine varieties, one hybrid and its parental lines by seed and seedling morphology and chemical response tests. The tests revealed that the hybrid and its parents responded differently to various chemical tests. According to them it is essential to develop the alternate tests, which address the question of the environmental factor as in case of morphological way of characterization. Different cultivars are identified on the basis of the taxonomical differences in seed, seedling and mature plant (Singh, 1977). Some authors namely Sharma et al. (1990) in rice and Shaista Halim and Saxena (1995) in pearl millet reported various morphological characters, which are useful to identify the cultivars. Wanjari and Bhoyar (1977, 1980) also observed Coleoptile length in *Sorghum*.

With this background, the present investigation was carried out with the objectives of identifying three species of *Sorghum* Moench at seedling stage, based on morphological attributes.

Warwick and Black (1983) reported that young plants of *Sorghum halepense* cannot be distinguished from other *Sorghum* species, whereas older plants may be distinguished from annual sorghums by the presence of rhizomes and smaller seeds. During present investigation we have identified nine attributes to distinguish the reported taxa at seedling stage (Table 2 and Fig. 1)). We have also identified seven attributes to distinguish the reported taxa at maturity (Table 1). During study seedling morphology of reported taxa were recorded up to third leaf stage.

Table 2. Distinguishing attributes of Seedlings among *Sorghum bicolor, S. halepense* and *S. vulgare*.

Attributes	*Sorghum bicolor*	*S. halepense*	*S. vulgare*
1. Root	(a). 1.4 cm and 3.9 cm long at Coleoptile and 3rd leaf stages respectively. (b). Transitional node root same as primary root.	(a). 3.7 cm and 5.0 cm long at Coleoptile and 3rd leaf stages respectively. (b). Transitional node root not distinct.	(a). 4.0 cm and 7.2 cm long at Coleoptile and 3rd leaf stages respectively. (b). Transitional node root same as primary root.
2. Collet	Collet slightly swollen	Collet not distinct	Collet not distinct
3. Mesocotyl	White, 0.3 cm long.	Light pink, 1.0 cm long.	White, 0.3 cm long.
4. Palea	Absent	Present	Absent
5. Coleoptile	Light pink, apex emarginate, binerved.	Dull white, apex acute, binerved.	White, apex acute, nerveless.
6. Scutellum	Dull white, dome shaped.	Milky white, convex and slightly winged.	White, convex.
7. First Internode	0.5 cm long.	2.0 cm long.	2.7 cm long.
8. Epicotyl	Green, glabrous, 3.0 cm long at 3rd leaf stage.	Pink – green, glabrous, 4.5 cm long at 3rd leaf stage.	Light green, glabrous, 3.8 cm long at 3rd leaf stage.
9. Ligule	Ligule not distinct in first leaf.	Ligule distinct in first leaf.	Ligule distinct in first leaf.

The root length in seedlings was <4.0 cm in *S. bicolor*, whereas in *S. halepense* and *S. vulgare* >5.0 cm. The Collet was found distinct only in *S. bicolor*. Mesocotyl was light pink in *S. halepense* but white in *S. bicolor* and *S. vulgare*. Similarly Palea was present only in *S. halepense* but absent in the remaining taxa. Coleoptile was light pink only in *S. bicolor* but white/dull white in the remaining taxa. The apex and venation of Coleoptile were also found suitable for the discrimination among reported taxa. The Coleoptile apex was recorded acute in *S. halepense* and *S. vulgare* but emarginate in *S. bicolor* (Table 2, Fig. 1). Similarly Coleoptile was nerveless in *S. vulgare* but it was binerved in the remaining two taxa. Scutellum was convex and slightly winged in *S. halepense* but was dome shaped or convex in *S. bicolor* and *S. vulgare* respectively (Table 2, Fig. 1). The first internode was 0.5 cm long in *S. bicolor* but it was 2.0 cm and 2.7 cm long in *S. halepense* and *S. vulgare* respectively. Epicotyl was found peculiar due to pink-green colour in

S. halepense but green/light green in the remaining reported taxa. The Ligule was not distinct in first leaf of *S. bicolor* whereas it was distinct in others.

Conclusion

From Table 2, it is evident that the seedlings of reported taxa can be identified and differentiated, mainly on the basis of morphological attributes of Coleoptile, Collet, Epicotyl, First Internode, Ligule, Mesocotyl, Palea and Scutellum, justifying the aims and objectives of the present study. The findings of the present study indicate that morphological attributes of seedlings may form the basis for the differentiation and identification of grasses at seedling stage.

References

Anonymous, 2002. Season and Crop Report. Directorate of Economics and Statistics, Government of Tamil Nadu.

Berenji, J., Dahlberg, J., Sikora, V., Latkovic, D., 2011. Origin, History, Morphology, Production, Improvement, and Utilization of Broomcorn [*Sorghum bicolor* (L.) Moench] in Serbia. Econ. Bot. 65(2), 190-208.

Bor, N.L., 1960. The grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, New York. p. 767.

Clayton, W.D., Renvoize, S.A., 1986. Genera Graminum: grasses of the World. Her Majesty's Stationery Office, London. p. 389.

Doggett, H., 1988. *Sorghum*. John Wiley, New York. p. 512.

Elangovan, M., 2005. Diverse use of *Sorghum*. Course material for the training on Alternate Uses of *Sorghum* and Pearl Millet, 16–23 February 2005, NRCS, Hyderabad.

Garber, E.D., 1950. Cytotaxonomic studies in the genus Sorghum. Univ. Cal. Pub. Bot. 23, 283–361.

Haines, H.H., 1921-1925. The Botany of Bihar and Orissa. 3 Vols. London.

Harlan, J.R., de Wet, J.M.J., 1972. A simplified classification of cultivated sorghum. Crop Sci. 12, 172-176.

Mathews, S., Spangler, R.E., Mason-Gamer, R.J., Kellogg, E.A., 2002. Phylogeny of Andropogoneae inferred from phytochrome b, gbssi, and ndhf. Int. J. Plant Sci. 163(3), 441–450.

Mekbib, F., 2007. Infra-specific folk taxonomy in sorghum (*Sorghum bicolor* (L.) Moench) in Ethiopia: folk nomenclature, classification, and criteria. J. Ethnobiol. Ethnomed. 3, 38.

Moulik, S., 1997. Grasses and Bamboos of India. Vol. 1 & 2. Scientific Pub. (India), Jodhpur.

Ng'uni, D., 2011. Phylogenetics of the Genus *Sorghum*, Genetic Diversity and Nutritional Value of its Cultivated Species. Doctoral Thesis, Swed. Univ. Agricul. Sci. Alnarp.

Rana, B.S., 2000. Research at National Research Centre for Sorghum. In: Sorghum Utilization and the Livelihoods of the Poor in India (Eds. Hall, A.J. and Yoganand, B.). Socioeconomics and Policy Program, ICRISAT, AP, India. p. 91.

Roy, G.P., 1984. Grasses of Madhya Pradesh. Flora of India Ser-4. BSI, Howrah. p. 180.

Shaista Halim, Saxena, O.P., 1995. Identification of pearl millet hybrids and parents a comparative study of laboratory and field methods. Seed Sci. Technol. 23, 689-696.

Sharma, K.K., Ahmed, T., Baruah, D.K., 1990. Grain characteristics of some aromatic rice varieties of Assam. International Rice Research Newsletter 15(1), 13.

Singh, B., 1977. Races of maize in India. Motilal and Co., ICAR, New Delhi.

Singh, H.P., Lohithaswa, H.C., 2006. Genome mapping and molecular breeding in plants cereals and millet. Ch7: Sorghum. Pp. 257- 302.

Smith, C.W., Frederiksen, R.A., (Eds.) 2000. *Sorghum*-Origin, History, Technology and Production. John Wiley & Sons, USA.

Snowden, J.D., 1935. The classification of the cultivated *Sorghums*. Bull. Misc. Information, No. 5. Royal Botanic Gardens, Kew, England. pp. 221-255.

Thangavel, P., Bharathi, A., Natarajan N, Evera, T., 2005. Varietal Grouping in Sorghum by Seed and Seedling Morphology and Response to Chemical Testing. Karnataka J. Agric. Sci. 18(3), 664-672.

Tillich, Hans-Jurgen., 2007. Seedling diversity and the homology of seedling organs in the order Poales (Monocotyledons). Ann. Bot. 100, 1413-1429.

USDA, 2004. Sorghum-Production, Consumption, Exports, and Imports Statistics. http: www. usda. gov/wps/poral/usdahome.

Wanjari, K.B., Bhoyar, M.P., 1977. Study of coleoptile length in sorghum. Sorghum Newslett. 20, 27-29.

Wanjari, K.B., Bhoyar, M.P., 1980. Coleoptile length in sorghum. Seed Sci. Technol. 8(2), 169-174.

Warwick, S.I., Black, L.D., 1983. The biology of Canadian weeds. 61. *Sorghum halepense* (L.) Pers. Can. J. Plant Sci. 63, 97-10l4.