Cytomorphological Study in Genus *Cenchrus* L.: An Important Medicinal Plant from North India (Family: Poaceae)

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Summary The present study deals with the four species of genus *Cenchrus* L. based on population analysis from different localities in Haryana and adjoining hills of Shiwalik area. These species *i.e.*, *C. biflorus*, *C. ciliaris*, *C. pennisetiformis* and *C. setigerus* differ from each other morphologically as well as cytologically. In *C. biflorus*, cytological studies have been made on 23 populations from the study area and three cytotypes ($n=16$, 17 and 18) are detected. In *C. ciliaris*, most commonly found species of the genus, 48 populations were studied and four cytotypes with chromosome numbers $n=16$, 17, 18 and 36 are found. The population analysis revealed that the tetraploid cytotype ($n=18$) based on $x=9$ is better adapted as compared to the other three cytotypes. The tetraploid and aneuploid cytotypes are almost morphologically similar, whereas octaploid shows lot of gigantism. All the studied cytotypes of *C. ciliaris* show meiotic abnormalities. In *C. pennisetiformis*, two cytotypes with $n=17$ and 18 are observed, which were found to be morphologically similar with abnormal meiotic course. In this species, $2n=34$ is a new chromosome report. The fourth species *C. setigerus*, also shows similar cytotypes with $n=17$ and 18, based on the study of 49 populations. These cytotypes are morphologically indistinct and show overlapping morphometric characters.

Key words *Cenchrus* species, Meiotic abnormality, Cytotype, Aneuploid, Haryana and Shiwalik Hills.

Family Poaceae is the third largest family among the angiosperms with about 898 genera and 10000 species (Tzvelev 1989), which is represented in India by about 268 genera and 1200 species (Moulik 1997). The family has vast economic importance and it also exhibits lot of cytological variation. The family exhibits lot of cytological diversity with most documented cytological evidences such as polyploidy, aneuploidy, apomixis, *etc.*

The genus *Cenchrus* belongs to the tribe Paniceae of Poaceae. The genus is represented with 25 species (Watson and Dallwitz 1992) and seven species are reported from Indian subcontinent (Bor 1960). It is distributed throughout the tropical and subtropical parts in world. The main characteristic features of the genus are: presence of involucre of spines and rigid bristles united at the base into a hard cup. Taxonomically, the genus *Cenchrus* is separated from the genus *Pennisetum* by involucre bristles fused at their point of origin (Nath *et al.* 1970). Some of the species of the genus are used as fodder and three species (*C. ciliaris*, *C. echinatus*, *C. myosuroides*) are considered as important weeds as highly nutritious and palatable fodder (Clayton and Renvoize 1986). Due to its resilience to harsh environmental con-

ditions, it is cultivated as one of the major forage grasses in India (Bhat *et al.* 2001).

The research on the cytology of grasses had been undertaken from Haryana and Shiwalik hills, Rajasthan, Kangra district, Pangi valley of Kullu, Kinnaur district and Kashmir (see Kaur and Gupta 2016a, 2016b, Gupta *et al.* 2017).

Materials and methods

Materials for the meiotic studies are collected from number of localities from Haryana and adjoining Shiwalik hills (Table 1). Voucher specimens are deposited in the Herbarium, Department of Botany, Punjabi University, Patiala (PUN). Meiotic studies are carried out through standard smearing technique from young panicles fixed in Carnoy's fixative. For the analysis of meiotic abnormalities, a large number of PMCs was counted for each type of anomaly. Pollen fertility is estimated through glycerol-acetocarmine stainability. Well-filled pollen grains with stained nuclei were taken as apparently viable/fertile while shriveled and unstained pollen grains are counted as sterile. Pollen grain size is measured using ocular micrometer. Photomicrographs of chromosome counts are taken from freshly prepared slides using Nikon 80i eclipse digital imaging system.

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Table 1. Data regarding the taxa with population, locality with altitude, accession number, meiotic chromosome number, pollen fertility, pollen size and ploidy level of the studied species of *Cenchrus*.

Taxa	Locality with altitude	Accession number (PUN)	Chromosome number (<i>n</i>)	Pollen fertility (%)	Pollen size (μm)	Ploidy level	Remarks in meiosis
<i>Cenchrus biflorus</i> Roxb.							
Cytotype A (<i>n</i> =16)							
P-1	Nanhari, Yamunanagar (255 m)	49920	16	25.7	24.3–26.3×24.4–26.3	4x	ABN
P-2	Kalka, Shiwaliks (624 m)	49927	16	37.2	18.8–20.6×20.6	4x	ABN
Cytotype B (<i>n</i> =17)							
P-3	Guhla, Kaithal (219 m)	49919	17	15.4	24.3–26.3×22.5–24.4	4x (Aneu.)	ABN
P-4	Naror, Kaithal (219 m)	49931	17	49.6	20.6–22.5×22.5	4x (Aneu.)	ABN
P-5	Cheeka, Kaithal (219 m)	49932	17	52.4	24.4–26.3×26.3	4x (Aneu.)	ABN
P-6	Pehowa Road, Kaithal (219 m)	49933	17	64.6	24.4–26.3×24.4–26.3	4x (Aneu.)	ABN
Cytotype C (<i>n</i> =18)							
P-7	CCS Univ., Hissar (216 m)	49921	18	12.5	24.4–26.3×26.3	4x	ABN
P-8	Lalru, Ambala (272 m)	49922	18	34.6	20.6–22.5×20.6–22.5	4x	ABN
P-9	Nizampur, Mahendragarh (261 m)	49923	18	18.4	18.8–22.5×18.8	4x	ABN
P-10	Nahan, Sirmour (932 m)	49924	18	52.7	20.6–22.5×22.5	4x	ABN
P-11	Thanesar, Kurukshetra (350 m)	49925	18	34.7	24.4–26.3×24.4–26.3	4x	ABN
P-17	Narayangarh, Ambala (272 m)	49935	18	25.4	20.6–22.5×20.6–22.5	4x	ABN
P-18	Firozpur, Jhirka, Mewat (200 m)	49936	18	42.8	30.0–33.8×30.0–33.8	4x	ABN
P-19	Agroha, Hissar (216 m)	49937	18	39.2	30.3–33.8×33.0	4x	ABN
P-20	Nilokheri, Karnal (252 m)	49938	18	50.2	26.3–30.0×30.0	4x	N
P-21	HAU, Hissar (216 m)	49939	18	62.4	22.5–24.4×24.4	4x	N
P-22	Radaur, Yamunanagar (255 m)	49940	18	48.2	26.3×24.4–26.3	4x	ABN
P-23	Ganaur, Sonipat (219 m)	49941	18	52.7	22.5–24.4×22.5–24.4	4x	N
<i>C. ciliaris</i> L.							
Cytotype A (<i>n</i> =16)							
P-1	Indri, Karnal (252 m)	49874	16	0.0	24.4–26.3×22.5–24.4	4x	ABN
P-2	Babain, Kurukshetra (350 m)	49912	16	50.4	22.5–24.4×20.6–22.5	4x	N
Cytotype B (<i>n</i> =17)							
P-3	HAU, Hissar (216 m)	49881	17	54.7	26.3–30.0×30.0	4x (Aneu.)	ABN
Cytotype C (<i>n</i> =18)							
P-4	Mullana, Ambala (272 m)	49871	18	0.0	20.6–22.5×20.6–22.5	4x	ABN
P-5	Barog, Solan (1350 m)	49872	18	39.3	22.5–39.4×22.5–39.4	4x	ABN
P-6	Nanhari, Yamunanagar (255 m)	49873	18	23.7	22.5–24.4×22.5	4x	ABN
P-7	Guhla, Kaithal (219 m)	49875	18	0.0	22.5–24.4×20.6–22.5	4x	ABN
P-8	CCS, Univ, Hissar (216 m)	49876	18	3.75	22.5–24.4×18.8–22.5	4x	ABN
P-9	Mirpur, Rewari (242 m)	49877	18	27.9	18.8–22.5×18.8	4x	ABN
P-10	KUK, Kurukshetra (350 m)	49878	18	0.0	24.4–26.3×22.5–26.3	4x	ABN
P-11	Jyotisar, Kurukshetra (350 m)	49879	18	6.9	26.3–33.8×26.3–30.0	4x	ABN
P-12	Agroha, Hissar (216 m)	49880	18	22.8	22.5–24.4×22.5–24.4	4x	ABN
P-13	Gharaunda, Karnal (252 m)	49882	18	55.2	22.5–24.4×20.6–22.5	4x	N
P-14	Narnaul, Mahendragarh (261 m)	49883	18	35.9	22.5–24.4×22.5	4x	ABN
P-15	Sanauli, Panipat (218 m)	49884	18	65.4	20.6–22.5×20.6–22.5	4x	N
P-16	Devsar, Bhiwani (224 m)	49885	18	37.4	24.4–26.3×22.5–26.3	4x	ABN
P-17	Radaur, Yamunanagar (255 m)	49886	18	30.5	18.8–22.5×18.8	4x	ABN
P-18	Lalru, Ambala (272 m)	49887	18	52.9	26.3–30.0×30.0	4x	ABN
P-19	Naggal, Ambala (272 m)	49888	18	42.4	22.5–24.4×22.5	4x	ABN
P-20	Samalkha, Panipat (218 m)	49889	18	67.4	26.3–33.8×26.3–30.0	4x	N
P-21	Gohana, Sonipat (219 m)	49890	18	65.2	26.3–30.0×26.3–30.0	4x	ABN
P-22	Sunariya, Rohtak (213 m)	49891	18	58.4	24.4–26.3×26.3	4x	ABN
P-23	Bahadurgarh, Jhajjar (219 m)	49892	18	62.3	18.8–20.6×18.8–20.6	4x	ABN
P-24	Nizampur, Mahendragarh (261 m)	49893	18	49.7	26.3–30.0×30.0	4x	ABN
P-25	Shazadpur, Ambala (272 m)	49894	18	72.6	22.5–24.4×22.5	4x	N
P-26	Parwanoo, Solan (1350 m)	49895	18	60.7	20.6–22.5×20.6–22.5	4x	ABN
P-27	Trilokpur, Shiwaliks (932 m)	49896	18	74.0	26.3–33.8×26.3–30.0	4x	N
P-28	Kala amb, Ambala (272 m)	49897	18	59.2	18.8–20.6×18.8–20.6	4x	N
P-29	Mandi Dabwali, Sirsa (204 m)	49898	18	31.4	22.5–24.4×22.5–24.4	4x	N
P-30	Gohana, Sonipat (219 m)	49899	18	26.7	24.4–26.3×24.4–26.3	4x	ABN
P-31	Naror, Kaithal (219 m)	49900	18	0.0	24.4–26.3×24.4	4x	ABN
P-32	Shahpur, Ambala (272 m)	49901	18	52.6	18.8–22.5×18.8	4x	ABN
P-33	Nilokheri, Karnal (252 m)	49902	18	32.9	30.0×30.0	4x	N
P-34	Narwana, Jind (226 m)	49903	18	0.0	26.3–30.0×30.0	4x	ABN
P-35	Jagadhri, Yamunanagar (255 m)	49904	18	26.4	26.3–33.8×26.3–30.0	4x	ABN
P-36	Kalanaur, Yamunanagar (255 m)	49905	18	25.0	26.3–30.0×26.3–30.0	4x	N
P-37	Kalka, Shiwaliks (624 m)	49906	18	17.6	24.4–26.3×22.5–26.3	4x	ABN
P-38	Barara, Ambala (272 m)	49907	18	27.6	24.4–26.3×22.5–24.4	4x	ABN
P-39	Firozpur Jhirka, Mewat (200 m)	49908	18	37.5	22.5–24.4×18.8–22.5	4x	ABN
P-40	Thanesar, Kurukshetra (350 m)	49909	18	15.7	24.4–26.3×22.5	4x	ABN
P-41	Ballabgarh, Faridabad (197 m)	49910	18	24.6	22.5–24.4×22.5–24.4	4x	ABN

Table 1. Continued

Taxa	Locality with altitude	Accession number (PUN)	Chromosome number (<i>n</i>)	Pollen fertility (%)	Pollen size (μm)	Ploidy level	Remarks in meiosis
P-42	Ratia, Fatehbad (207 m)	49911	18	40.6	22.5–24.4×22.5	4x	ABN
P-43	Narayangarh, Ambala (272 m)	49913	18	67.2	26.3–33.8×26.3–30.0	4x	N
P-44	Cheeka, Kaithal (219 m)	49914	18	42.3	26.3–30.0×26.3–30.0	4x	N
P-45	Nahan, Sirmour (932 m)	49915	18	65.4	20.6–22.5×20.6–22.5	4x	N
P-46	Panjab Univ, Chandigarh (308 m)	49916	18	45.6	22.5–22.4×22.5	4x	ABN
P-47	Pinjour, Panchkula (365 m)	49917	18	52.6	24.4–26.3×22.5–24.4	4x	ABN
Cytotype D (<i>n</i> =36)							
P-48	Jabli, Shivaliks (900 m)	49918	36	82.7	37.5–39.4×37.5–39.4	8x	N
<i>C. pennisetiformis</i> Hochst. et. Steud.							
Cytotype A (<i>n</i> =17)							
P-1	Kalka, Shiwaliks (624 m)	49991	17	19.9	22.5–24.4×22.5	4x (Aneu.)	First chromosome report ABN
Cytotype B (<i>n</i> =18)							
P-2	Sanawar, Solan (1350 m)	49990	18	27.8	18.8–22.5×18.8	4x	ABN
<i>C. setigerus</i> Vahl.							
Cytotype A (<i>n</i> =17)							
P-1	Kalanaur, Yamunanagar (255 m)	49976	17	17.5	22.5–24.4×22.5–24.4	4x (Aneu.)	ABN
P-2	Kalka, Shiwaliks (624 m)	49977	17	0.0	22.5–24.4×22.5–24.4	4x (Aneu.)	ABN
P-3	Barara, Ambala (272 m)	49978	17	15.6	22.5–24.4×22.5–24.4	4x (Aneu.)	ABN
P-4	Firozpur Jhirka, Mewat (200 m)	49979	17	22.7	22.5–24.4×24.4	4x (Aneu.)	ABN
P-5	Thanesar, Kurukshetra (350 m)	49980	17	30.7	24.4–26.3×24.4–26.3	4x (Aneu.)	ABN
P-6	Ballabgarh, Faridabad (197 m)	49981	17	24.9	24.4–26.3×24.4–26.3	4x (Aneu.)	ABN
P-7	Ratia, Fatehbad (207 m)	49982	17	12.6	22.5–24.4×22.5–24.4	4x (Aneu.)	ABN
P-8	Babaur, Kurukshetra (350 m)	49983	17	21.9	22.5–24.4×22.5–24.4	4x (Aneu.)	ABN
P-9	Narayangarh, Ambala (272 m)	49984	17	30.6	24.4–26.3×24.4	4x (Aneu.)	ABN
P-10	Cheeka, Kaithal (219 m)	49985	17	16.4	24.4–26.3×24.4–26.3	4x (Aneu.)	ABN
P-11	Nahan, Sirmour (932 m)	49986	17	0.0	24.4–26.3×22.5–24.4	4x (Aneu.)	ABN
P-12	Panjab Univ., Chandigarh (308 m)	49987	17	24.8	22.5–24.4×22.5–24.4	4x (Aneu.)	ABN
P-13	Pinjour, Panchkula (365 m)	49988	17	13.2	24.4–26.3×24.4–26.3	4x (Aneu.)	ABN
P-14	Jabli, Shiwaliks (900 m)	49989	17	0.0	24.4–26.3×24.4–26.3	4x (Aneu.)	ABN
P-15	Ganaur, Sonipat (219 m)	49992	17	26.1	22.5–24.4×22.5–24.4	4x (Aneu.)	ABN
Cytotype B (<i>n</i> =18)							
P-16	Mullana, Ambala (272 m)	49942	18	0.0	22.5–28.1×22.5–26.3	4x	N
P-17	Barog, Solan (1350 m)	49943	18	12.5	22.5–24.4×24.4	4x	N
P-18	Nanhari, Yamunanagar (255 m)	49944	18	68.9	24.4–26.3×22.5–24.4	4x	ABN
P-19	Indri, Karnal (252 m)	49945	18	52.7	22.5–24.4×22.5–24.4	4x	ABN
P-20	Guhla, Kaithal (219 m)	49946	18	47.4	24.4–26.3×24.4–26.3	4x	N
P-21	CCS Univ., Hissar (216 m)	49947	18	17.5	24.4–28.1×22.5–24.4	4x	ABN
P-22	Mirpur, Rewari (242 m)	49948	18	25.4	24.4–26.3×24.4–26.3	4x	ABN
P-23	KUK, Kurukshetra (350 m)	49949	18	24.4	22.5–24.4×22.5–24.4	4x	ABN
P-24	Jyotisar, Kurukshetra (350 m)	49950	18	15.9	24.4–26.3×24.4–26.3	4x	ABN
P-25	Agroha, Hissar (216 m)	49951	18	32.6	22.5–24.4×22.5–24.4	4x	ABN
P-26	HAU, Hissar (216 m)	49952	18	0.0	24.4–26.3×22.5–24.4	4x	ABN
P-27	Gharaunda, Karnal (252 m)	49953	18	69.2	22.5–24.4×22.5–24.4	4x	N
P-28	Narnaul, Mahendragarh (261 m)	49954	18	55.2	24.4–26.3×22.5–24.4	4x	ABN
P-29	Sanauli, Panipat (218 m)	49955	18	70.2	24.4–26.3×24.4–26.3	4x	N
P-30	Devsar, Bhiwani (224 m)	49956	18	45.0	24.4–26.3×26.3	4x	ABN
P-31	Radaur, Yamunanagar (255 m)	49957	18	39.2	24.4–28.1×24.4	4x	ABN
P-32	Lalru, Ambala (272 m)	49958	18	0.0	22.5–26.3×22.5–24.4	4x	ABN
P-33	Naggal, Ambala (272 m)	49959	18	46.7	22.5–24.4×22.5–24.4	4x	ABN
P-34	Samalkha, Panipat (218 m)	49960	18	32.6	22.5–26.3×26.3	4x	ABN
P-35	Gohana, Sonipat (219 m)	49961	18	59.2	24.4–26.3×26.3	4x	N
P-36	Sunariya, Rohtak (213 m)	49962	18	61.7	26.3–28.1×22.5–26.3	4x	N
P-37	Bahadurgarh, Jhajjar (219 m)	49963	18	32.4	26.3–28.1×24.4–26.3	4x	ABN
P-38	Nizampur, Mahendragarh (261 m)	49964	18	69.2	24.4–26.3×26.3	4x	N
P-39	Shahzadpur, Ambala (272 m)	49965	18	58.4	24.4–26.3×24.4–26.3	4x	N
P-40	Parwanoo, Solan (1350 m)	49966	18	29.2	22.5–24.4×22.5–24.4	4x	ABN
P-41	Trilokpur, Shiwaliks	49967	18	64.9	22.5–24.4×22.5–24.4	4x	N
P-42	Kala amb, Ambala (272 m)	49968	18	52.9	24.4–26.3×24.4–26.3	4x	N
P-43	Mandi Dabwali, Sirsa (204 m)	49969	18	32.6	26.3–28.1×26.3	4x	ABN
P-44	Gohana, Sonipat (219 m)	49970	18	19.4	24.4–26.3×26.3	4x	ABN
P-45	Naror, Kaithal (219 m)	49971	18	15.7	24.4–28.1×24.4–26.3	4x	ABN
P-46	Shahpur, Ambala (272 m)	49972	18	62.8	24.4–26.3×24.4–26.3	4x	N
P-47	Nilokheri, Karnal (252 m)	49973	18	25.6	22.5–24.4×22.5–24.4	4x	ABN
P-48	Narwana, Jind (226 m)	49974	18	74.9	26.3–28.1×26.3–28.1	4x	N
P-49	Jagadhri, Yamunanagar (255 m)	49975	18	52.4	24.4–26.3×24.4–26.3	4x	N

N=Normal Meiotic course; ABN=Abnormal Meiotic course.

Figs. 1–11. Morphology of four species of *Cenchrus* on cytotype basis. *Cenchrus biflorus*, (1) Cytotype A ($n=16$), (2) Cytotype B ($n=17$), (3) Cytotype C ($n=18$). *C. ciliaris*, (4) Cytotype A ($n=16$), (5) Cytotype B ($n=17$), (6) Cytotype C ($n=18$), (7) Cytotype D ($n=36$). *C. pennisetiformis*, (8) Cytotype A ($n=17$), (9) Cytotype B ($n=18$). *C. setigerus*, (10) Cytotype A ($n=17$), (11) Cytotype B ($n=18$). Scale bar=10 cm.

Results and discussion

During the present study four species *i.e.*, *C. biflorus*, *C. ciliaris*, *C. setigerus* and *C. pennisetiformis* have been worked out cytologically. The meiosis of the pollen mother cells (PMCs) in the species is carried on population basis. The detailed meiosis with variation in morphological characters of each cytotype has been discussed in detail as under.

C. biflorus Roxb.: This species is common in sandy habitats and flowers during July–October. It is commonly known as Indian Sandbur, Bkut and Bhurat. Cytological studies have been made on 23 populations and three

cytotypes with $n=16$, 17 and $n=18$ are detected. The cytotype with $n=18$ is the most common. Morphologically, three cytotypes show fewer differences (Figs. 1–3, Table 2). Most of the populations of any cytotype show abnormal meiosis (Figs. 12–20). Meiotic abnormalities include, quadrivalents at diakinesis/metaphase-I (M-I), cytotoxicity and chromosome stickiness, laggards (zero to two per PMC) and bridges (zero to two per PMC). In some of the PMCs of the cytotype with $n=18$, unequal distribution of 19:17 is also present (Fig. 18). These meiotic abnormalities are reflected in the form of pollen sterility and variable pollen size (Table 2).

The earlier workers in India reported the normal mei-

Figs. 12–35. Meiotic chromosome number, abnormalities and pollen grains. *Cenchrus biflorus*, (12) (Cytotype A) PMC at M-I showing $3_{IV}+10_{II}$ (arrow), (13) PMC at A-I with 16:16 chromosomes, (14) (Cytotype B) PMC at diakinesis showing 17 bivalents, (15) Laggards at A-I, (16) (Cytotype C) PMC at M-I with $3_{IV}+12_{II}$ (arrow), (17) PMC at A-I with 18:18 chromosomes, (18) PMC at A-I showing 19:17 chromosomes, (19) Laggards at A-I (arrow). *C. ciliaris*, (20) (Cytotype A) PMC at M-I with 16_{II} , (21) Cytoxis (arrow), (22) Laggards at A-I (arrow), (23) (Cytotype B) PMC at M-I showing $2_{IV}+13_{II}$ (arrow), (24) PMC at A-I with 17:17 chromosomes, (25) Laggards at A-I (arrow), (26) (Cytotype C) PMC at M-I with $4_{IV}+10_{II}$ (arrow) (27) PMCs showing cytoplasmic connections (arrow), (28) Unoriented bivalents at M-I (arrow), (29) (Cytotype C) PMC showing 16:20 distribution, (30) Laggards at A-I (arrow), (31) Heterogenous sized pollen grains, (32) (Cytotype D) PMC at A-I showing 36:36 chromosomes, *C. pennisetiformis*, (33) (Cytotype A) PMC at M-I showing $2_{IV}+13_{II}$ (arrowed), (34) PMC at A-I showing 17:17 chromosomes, (35) Laggards (arrowed). Scale bar=10 μ m.

otic course in the species (Mehra 1982). The present reports of $n=16$, 17 and 18 confirm the previous chromosome reports from India (Vij and Chaudhary 1981). The species exhibits intraspecific aneuploid cytotypes with

$n=15$, 16, 17, 18 and 24.

C. ciliaris L.: It is also very common in sandy habitats, and flowers in July–October. Its common name is Buffleggrass. Forty eight populations have been studied

Table 2. Morphological comparison of three cytotypes of *C. biflorus*.

Characters	Cytotype A (<i>n</i> =16)	Cytotype B (<i>n</i> =17)	Cytotype C (<i>n</i> =18)
Distribution	Less frequent	Uncommon	Common
Habit	Medium sized	Medium sized	Large
Habitat	In neglected area and field	In neglected enclosures and fields	Common in waste places
Plant height (cm)	34.0–35.5	34.8–35.5	47.3–66.0
Leaf:			
Size (cm)	7.2–7.5×0.3–0.5	19.5–20.0×0.2–0.4	10.9–26.0×0.2–0.5
Number	2	4	4–5
Sheath length (cm)	5.5–6.0	4.9–5.5	7.1–12.5
Number of nodes	2	3	3–5
Internode:			
Length of uppermost internode (cm)	11.0–11.2	8.5–8.8	15.0–22.5
Length of 2nd internode from top (cm)	9.2–9.5	5.2–5.6	9.1–12.7
Inflorescence:			
Spike length (cm)	6.9–7.1	7.2–7.5	5.7–12.9
Length of spikelet (cm)	5.5–5.6	4.9–5.0	7.1–7.5

Table 3. Morphological comparison of four cytotypes of *C. ciliaris*.

Characters	Cytotype A (<i>n</i> =16)	Cytotype B (<i>n</i> =17)	Cytotype C (<i>n</i> =18)	Cytotype D (<i>n</i> =36)
Distribution	Less frequent	Uncommon	Frequently seen	Uncommon
Habit	Medium sized	Medium sized	Medium sized	Tall & tufted
Habitat	Neglected areas and fields	In neglected enclosures and fields	Common in waste place	Dry sandy areas
Plant height (cm)	42.5–44.0	48.0–49.5	42.3–55.5	80.0–95.0
Leaf:				
Size (cm)	11.2–11.5×0.3–0.5	16.8–17.2×0.5–0.7	9.1–15.0×0.2–0.4	49.8–50.0×0.5–0.7
Number	4	5	3	5
Sheath length (cm)	6.2–6.5	7.1–7.4	6.2–6.5	9.2–9.7
Number of nodes	3	4	3	5
Internode:				
Length of upper most internode (cm)	10.5–10.7	11.5–11.9	12.2–12.5	23.0–24.5
Length of 2nd internode from top (cm)	12.0–12.5	9.5–9.7	11.5–14.0	10.2–11.0
Inflorescence:				
Spike length (cm)	5.8–6.0	5.9–6.2	4.6–5.3	12.8–13.2
Length of spikelet (cm)	1.5–1.7	1.3–1.4	1.1–1.4	1.2–1.4

from different areas of Haryana and Shiwalik hills. Four cytotypes with *n*=16, 17, 18 and 36 are observed (Figs. 4–7). The tetraploid cytotype (*n*=18), based on *x*=9, is better adapted to habitat and is the most common one as compared to the other cytotypes. The tetraploid and aneuploid cytotypes showed almost similar morphology, whereas the octaploid cytotype shows lot of gigantism (Table 3).

The meiotic course is found to be abnormal in all the three cytotypes (*n*=16, 17, 18). The meiotic events in cytotypes with *n*=16 (Figs. 20–22) and *n*=17 (Figs. 23–25) show lot of abnormalities. In the cytotype *n*=18, 12 populations show normal meiosis, whereas in 32 populations meiotic course is found to be abnormal due to the presence of quadrivalents at diakinesis/M-I (Fig. 26), cytaxis at prophase-I (Fig. 27) and M-I, chromosome stickiness and non-oriented bivalents at equatorial plate at M-I (Fig. 28), unequal distribution of chromosomes (Fig. 29) and laggards (Fig. 30), and bridges at A-I/T-I. The quadrivalents range from zero to four per PMC in different populations of all the cytotypes, and their average frequency per PMC also varies. The phenomena

of cytaxis, non-oriented bivalents at equatorial plate and chromosome stickiness are present in few populations with varying frequency. The laggards (zero to four per PMC) and bridges (zero to two per PMC) are seen at A-I/T-I in fewer populations. Pollen fertility varies from almost sterile to 74.0% in the tetraploid cytotype and 54.7% in aneuploid cytotype (Table 1). However, octaploid cytotype (Fig. 31) shows normal meiosis with 82.7% pollen fertility. The pollen grains are of heterogeneous size (Fig. 32) and show variation in different cytotypes.

All the present cytotypes are earlier known from India. Vij and Chaudhary (1981) reported the presence of B-chromosomes in the tetraploid cytotype (*2n*=36+0-2B) from Chandigarh. The species shows lot of variation in chromosome number showing both aneuploidy and polyploidy (*2n*=18, 32, 34, 36, 40, 44, 45, 52, 54, 64, 66, 72) in the Indian populations. The normal seed setting in the population with pollen sterility might be the apomictic nature of the species. The apomixis and polyembryony are well known in the species (Fisher *et al.* 1954). Present chromosome report of *2n*=36 is in confirmation

Figs. 36–46. *C. pennisetiformis*, (36) (Cytotype B) PMC at M-I showing $2_{IV}+14_{II}$ (arrow), (37) PMC at M-II with 18 chromosomes at each pole, (38) (Cytotype B) Laggards at A-I (arrow). *C. setigerus*, (39) PMC at M-I showing $1_{IV}+15_{II}$ (arrow), (40) PMC at A-I with 17:17 chromosomes, (41) PMC at A-I showing 16:18 chromosomes, (42) Laggards at A-I (arrow), (43) (Cytotype B) PMC at A-I with $5_{IV}+8_{II}$ (arrow), (44) PMC at A-I with 18:18 chromosomes, (45) Laggards at A-I (arrow), (46) Chromatin bridges at A-I (arrow). Scale=10 μ m.

Table 4. Morphological comparison of two cytotypes of *C. pennisetiformis*.

Characters	Cytotype A (n=17)	Cytotype B (n=18)
Distribution	Continued	Common
Habit	Medium sized	Medium sized
Habitat	In neglected enclosures and field	Common in waste places
Plant height (cm)	37.2	36.8
Leaf:		
Size (cm)	12.5	31.2
Sheath length (cm)	3.2	5.3
Number of nodes	2	1
Internodal length (cm)	9.1	10.2
Inflorescence:		
Spike length (cm)	4.4	4.3
Spikelet length (cm)	1.2	2.0

with the earlier reports from India (Bir and Sahni 1985). The present count of $2n=34$ is a new report for the species. The tetraploid cytotype ($2n=36$) is more common, whereas other cytotypes ($2n=34$, 35, 42, 54) are relatively less common.

C. pennisetiformis Hochst. & Steud.: It is commonly found in hotter and drier parts. The flowering period is July–October. It is a valuable fodder grass. Two cytotypes are reported with $n=17$ (Fig. 8) and $n=18$ (Fig. 9). The cytotypes are almost similar in morphological characters (Table 4). Meiosis is abnormal in both the cytotypes, with the presence of zero to three quadrivalents (Figs. 33, 36), besides normal bivalents at diakinesis/M-I. At M-I, zero to four bivalents show non-orientation

Table 5. Morphological comparison of two cytotypes of *C. setigerus*.

Characters	Cytotype A (n=17)	Cytotype B (n=18)
Distribution	Less common	Common
Habit	Medium sized	Medium sized
Habitat	In neglected area and field	Common in waste places
Plant height (cm)	36.5–37.8	37.6–38.2
Leaf:		
Size (cm)	6.3–6.7	7.6–8.0
Number	4.9–5.2	5.2–5.5
Sheath length (cm)	6	7
Number of nodes	4	4
Internode:		
Length of uppermost internode (cm)	10.3–10.5	9.8–10.2
Length of 2nd internode from top (cm)	9.8–10.0	8.2–8.5
Inflorescence:		
Spike length (cm)	4.4–4.7	4.3–4.6
Length of spikelet (cm)	0.4–0.7	0.4–0.7

at equatorial plate in 30% of PMCs. The A-I mostly shows normal 17:17 distribution in cytotype with $n=17$ (Fig. 34) and zero to three laggards (Fig. 35) are seen in 23.6% PMCs (P-1) and 19.7% PMCs (P-2) at A-I/T-I. The pollen fertility is 27.8% in the tetraploid cytotype B ($n=18$) and 19.9% in aneuploid cytotype with $n=17$. The pollen grain size also differs in the two cytotypes (Table 1).

C. setigerus Vahl.: This species is common in all type of habitats. It flowers in July–October. This species is

a valuable pasture grass. Extensive cytological survey reveals the presence of $n=17$ and 18 (Figs. 10–11), show overlapping characters (Table 5). In the aneuploid cytotype with $n=17$, meiosis is also characterized by zero to one quadrivalent per PMC at diakinesis/M-I (Fig. 39), equal distribution of chromosomes *i.e.*, 17:17 at A-I (Fig. 40), irregular distribution of chromosomes at A-I (16:18) (Fig. 41) and few laggards at A-I/T-I (Fig. 42) in all the presently studied populations. The cytotype with $n=18$ is normal in 14 populations, whereas 20 populations show abnormal meiosis due to the presence of zero to four quadrivalents per PMC at diakinesis/M-I (Fig. 43), 18:18 chromosomes at A-I (Fig. 44) and zero to three laggards per PMC at A-I/T-I (Fig. 45). In both the cytotypes, there is difference in pollen fertility and pollen grain size in different populations (Table 1). Patil *et al.* (1961) recorded $2n=37$ from Rajasthan with the presence of $0-5_{IV}$, $0-1_{III}$, $8-18_{II}$ and $0-3_I$ in the species.

The present report of $2n=34$ and 36 is in conformity with the various reports by different workers (Kaur and Gupta 2016a). Besides, these two cytotypes ($2n=34$, 36), cytotypes with $2n=37$, 54 and 72 are known from India, and besides these, another cytotype $2n=54$ is also known from outside India. Thus, the species shows lot of intraspecific aneuploidy and polyploidy.

From globe, the genus is cytologically known with 23 species and 60 cytotypes and six species with 30 cytotypes from Indian subcontinent. Chromosome number within the genus varies from $2n=18$ –102, of which $2n=34$ is the dominating cytotype (32.78%), followed by $2n=36$ (11.47%). Earlier, the genus was said to be monobasic with $x=9$ as the primary base number (Brown 1948), further dibasic with $x=9$ and $x=17$ (Darlington and Wylie 1955). Now a days, genus is polybasic including $x=7$, 9, 12 and 17 as basic chromosome numbers (De Lisle 1964, Kharrat-Suissi *et al.* 2013). Vij and Chaudhary (1981) suggested that $2n=34$ was derived by a loss of pair of chromosomes from $2n=36$. During the present study, irregular meiosis has been observed with differed frequency of various chromosomal anomalies. The presence of multivalents along with bivalents at diakinesis and M-I in all the accessions of the presently studied species have been observed. Similar results were given by Nath *et al.* (1970) in *C. ciliaris* and some other members of the tribe Paniceae, and also suggested that they were autopolyploid in origin.

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References

- Bhat, V., Dalton, S. J., Kumar, S., Bhat, B. V., Gupta, M. G. and Morris, P. 2001. Particle-inflow-gun-mediated genetic transformation of buffel grass (*Cenchrus ciliaris* L.): optimizing biological and physical parameters. *J. Appl. Genet.* **42**: 405–412.
- Bir, S. S. and Sahni, M. 1985. Cytological investigations on some grasses from Punjab Plain, North India. *Proc. Indian Sci. Natl. Acad.* **B51**: 609–626.
- Bor, N. L. 1960. The Grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, New York.
- Brown, W. V. 1948. A cytological study in Gramineae. *Am. J. Bot.* **35**: 382–395.
- Clayton, S. D. and Renvoize, S. A. 1986. Genera Graminum. Grasses of the World. Royal Botanic Gardens, Kew, London.
- Darlington, C. D. and Wylie, A. P. 1955. Chromosome Atlas of Flowering Plants. Allen and Unwin Ltd., London.
- De Lisle, D. G. 1964. Chromosome numbers in *Cenchrus* (Gramineae). *Am. J. Bot.* **51**: 1133–1134.
- Fisher, W. D., Bashaw, E. C. and Holt, E. C. 1954. Evidence for apomixes in *Pennisetum ciliare* and *Cenchrus setigerus*. *Agron. J.* **46**: 401–404.
- Gupta, R. C., Gupta, A. and Kaur, N. 2017. Meiotic studies in some members of tribe Andropogoneae (Poaceae) from semi desert area of North India. *Cytologia* **82**: 105–113.
- Kaur, N. and Gupta, R. C. 2016a. Cytological study in some members of tribe Paniceae (Poaceae) from Rajasthan. *Cytologia* **81**: 13–17.
- Kaur, N. and Gupta, R. C. 2016b. Anomalous meiotic behavior in different populations of octaploid *Sorghum bicolor* (L.) Moench from Sirohi District (Rajasthan), India. *Chromosome Bot.* **11**: 21–26.
- Kharrat-Souissi, A., Siljak-Yakovlev, S., Brown, S. C. and Chaieb, M. 2013. Cytogeography of *Cenchrus ciliaris* (Poaceae) in Tunisia. *Folia Geobot.* **48**: 95–113.
- Mehra, P. N. 1982. Cytology of East Indian Grasses. Pramodh P. Kapur at Rajbandhu Industrial Company, New Delhi.
- Moulik, S. 1997. The Grasses and Bamboos of India. Volumes 1 and 2. Scientific Publishers, Jodhpur.
- Nath, J., Swaminathan, M. S. and Mehra, K. L. 1970. Cytological studies in the tribe Paniceae, Gramineae. *Cytologia* **35**: 111–131.
- Patil, B. D., Vohra, S. K. and Joshi, A. B. 1961. Chromosome numbers in some forage grasses. *Curr. Sci.* **30**: 393–394.
- Tzvelev, N. N. 1989. The system of grasses (Poaceae) and their evolution. *Bot. Rev.* **55**: 141–204.
- Vij, S. P. and Chaudhary, J. D. 1981. Cytological investigations in three species of *Cenchrus* L. (Gramineae). *Cytologia* **46**: 661–669.
- Watson, L. and Dallwitz, M. J. 1992. The Grass Genera of the World. CAB International, Wallingford.