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Morphology of diaspores of some range grasses of Punjab

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Abstract

Subtropical vegetation coupled with agrarian land use accounts for predominance of grasses in Punjab. With cereal crops occupying most part of the agricultural lands, fodder crops get a marginal share resulting in shortage of fodder, particularily in the winter season. This shortage may be met through facilitated propagation of various grass species in the rangelands. After the initial success of growing guinea grass, *Panicum maximum* Jacq. in social forestry lands, the stage has been set for trying out propagation of other grass species viz. *Brachiaria ramosa* (L.) Stapf, *B. reptans* (L.) Gardner & Hubbard, *Sorghum halepense* (L.) Pers. etc. on a variety of soil and moisture conditions. In view of the expanding desert line in the state, these efforts are urgently required. Propagation to new areas may be brought about by vegetative means in caespitose and sod forming types, but in single culm and bunch grasses, amphimictic propagules contained in the diaspores (the dispersal units) provide the only method. Present studies have brought to light the diversity of structure and mechanism of dispersal of diaspores of about forty grass species in the area of study. This information may be utilized in devising strategies for facilitated propagation of these species in rangelands to boost fodder production in the state.

Key words: Anthoecium, Awn, Diaspore, Dispersal, Establishment, Fodder Grass, Spikelet.

Introduction

The economic and ecological significance of grasses is too well known to need any emphasis and recapitulation. Apart from being the staple cereals of the world, they provide cover to nearly one fifth of the land surface of the planet (Shantz, 1954). At the global level about 10,000 grass species have been inventorized. Thus the grass family Poaceae is ranked as the fourth largest in number of species (Clayton and Renvoize, 1986). Though grass species occur in every possible habitat, they are the dominant elements in certain managed and unmanaged ecosystems. The agro-ecosystems constitute the most important component in the managed category. To the unmanaged category, belong all natural ecosystems that lack a stratified structure dominated by a tree canopy. They include prairies, savannas, rangelands and habitats marked by extremes of climatic and edaphic conditions.

Punjab has an agrarian economy and a (sub) tropical ecology which together account for predominance of grasses in the Punjab flora. Despite tremendous significance, grasses have found very little attention in the floristic compilations of Punjab (Stewart, 1869; Bamber, 1916; Sabnis, 1940; Nair, 1978). Systematic study of the grass flora started rather late (Sharma and Khosla, 1989) and has made a slow progress ever since. Among all the aspects of study, fruits and diaspores are the least studied. Even in the illustrated descriptions of grasses of Punjab, only an occasional reference is made to the characters of the caryopsis (Sharma and Khosla, 1989).

Apart from a gap in the taxonomic description of Punjab grasses, this neglect has repercussions on rangeland management and fodder production as well. The available data in the land records of the state indicate a shortage of fodder production (Anonymous, 2009). This shortage results from a restricted cultivation of fodder. For the entire Himalayan region marginal and small holdings is held to be the main reason (Dev, 2001). Low availability of green nutritious fodder has lead to a low productivity of the livestock specially in the hilly areas (Deb Roy *et al.* 1989, Deb Roy, 1993). This scenario on the fodder production in the country leads to two alternatives. The first of these is to increase area under fodder crops. Alternatively, the rangelands should be developed as green pastures for grazing. In view of the ever increasing demand of higher food production for human consumption, the second one is only option for which strategies need to be developed. Even though propagation of caespitose and sod forming species may be brought by vegetative means, introduction of single culm and bunch grasses to new habitats has to be effected through amphimictic propagules whose mechanisms of dispersal and establishment need to be understood. The term ódiasporeö, first suggested by Sernander (1927) to designate the units of dispersal of the amphimictic propagules has gained wide currency in recent literature. In grasses, diaspores are generally units larger than the caryopses which are one seeded fruits and constitute the units of propagation. The present paper reports our findings on the structure of diaspores of about forty grass species in relation to mechanism of dispersal.

Area of study

The entire state of Punjab located between 29^{o} 30óto 32^{o} 32ôNorth and 73^{o} 55 to 76^{o} 50ôEast constituted the area of study. The state is bounded by J&K in the North, Himachal Pradesh in the North East and Haryana in the south. It shares International border with Pakistan on the western side. The main vegetation type of Punjab is the óTropical Dry Deciduous Forestô with small stretches of óSub Tropical Pine Forestô and óHimalayan Moist Forests in hill areas (Champion and Seth, 1968). The area between the rivers Ravi and the Beas is the Bari Doab (Majha) and the stretch between Beas and Sutlej is the Bist or Jalandhar Doab and the vast semi arid stretch south of Satluj is Malwa. The highest point bordering Himachal Pradesh is 930m asl. The flood plains of the rivers and streams are separated from the raised (interfluvial) plain by a change in relief on the edges called Dhaiyas. According to Koppen (1923) classification, Punjab falls in the Cwg group (Warm temperate, monsoon climate with winter dry). Average elevation of the plain region is 200-300m asl with hills rising upto 500-600m asl.

Materials and Methods

Diaspores were collected at the time of maturity when they were ready for dispersal. They were stored along with parts of the inflorescence for easy identification of the material. Herbarium sheets were prepared and deposited in the Department of Botanical & Environmental Sciences, Guru Nanak Dev University, Amritsar.

Morphology & Micromorphology

Diaspores were subjected to stereoscopic examination to study their structure *vis-à-vis* disarticulation from the inflorescence. Except for some species wherein the caryopsis separates at maturity and by itself constitutes the diaspore, the species were classified according to the structural make up of the diaspores which include progressively the sterile and fertile palea, lemmas, rachilla segments, sterile spikelets, rachis segment and finally the entire inflorescence. Table 1 summarizes this series of diaspores complexity. Though a host of terms are available for each stage of the series, only commonly understood terms related to inflorescence structure have been employed. For accurate and rapid recording of size, images of fruits and diaspores were clicked at appropriate magnifications with the help of Microscope Image Projecting System (MIPS) camera attached to the stereoscope. Computer prints of the images were taken and sizes were measured by comparison to a calibrated scale.

Results and Discussion

A close scrutiny of Table 1 reveals a wide range of diversity in the structural organization of diaspores *vis-à-vis* inflorescence organization. This diversity seems to be related to both taxonomy and habitat preference of the species. In the present sample, members of the subfamily Chloridoideae represented by *Sporobolus diander* (Retz.) P. Beauv. (Fig. 1) and *Eragrostis ciliaris* (L.) R. Br. , *E. diplachnoides* Steud., *E. interrupta* (Steud.) Stapf and *E. tenella* (L.) P. Beauv. ex Roem. & Schult. represented the lower end of the scale of complexity, where the caryopsis itself was found to comprise the dispersal unit (Table 1). In these species, the caryopses keep free of the accessory bracts; they are released and dispersed by wind. Being small in size, they are easily buried by soil particles brought by whiffs of wind. In the classification proposed by Peart (1979, 1984) such diaspores belong to the category of óunawned diasporesô for which wind dispersal is the preferred method. In the classification scheme of fruits and diaspores on the basis of ódispersal syndromesô they fall in the category of anemochorous type (Ozinga *et al.*, 2004).

Next on the scale of structural complexity are the species where óanthoeciumô is the diaspore (Table 1). In such diaspores, caryopses found enclosed by fertile palea and lemma were occasionally, subtended by a reduced floret. Among members of the subfamily Pooideae, the weedy species *Phalaris minor* Retz. represents this stage (Fig. 2). The anthoecia in this species are unawned. However, in *Lolium temulentum* var. *temulentum* (L.) the fertile lemma of the anthoecia bears an awn. Similarly, in some members of the subfamily Chloridoideae, namely *Cynodon dactylon* (L.) Pers. and *Desmostachya bipinnata* (L.) Stapf, anthoecia constituted the dispersal units. In Peartös (1984) classification, they belong to the category of ódiaspores with passive awnsô. Awned

Table 1 : Structural organization of the grass diaspores

Taxa	Name of species	Caryopsis	Palea	Lemma	Reduced florets	Rachilla fragment	Glumes	Sterile/ male spikelets	Rachis segment	Pedunde
Subfamily : **Pooideae**										
Tribe: Aveneae	*Avena sativa* L.	+	+	+[a]	–	–	–	–	–	–
	Phalaris minor Retz.	+	+	+	+[L]	–	–	–	–	–
Tribe: Poeae	*Hordeum vulgare* L.	+	+	+[a]	–	–	–	+	–	–
	Lolium temulentum L.	+	+	+[a]	–	+	–	–	–	–
	Poa annua L.	+	+	+	–	+	–	–	–	–
Subfamily: **Aristoideae**										
Tribe: Aristideae	*Aristida adscensionis* L.	+	+	+[a]	–	–	–	–	–	–
Subfamily: **Arundinoideae**										
Tribe: Arundineae	*Arundo donax* L.	+	+	+	–	+	–	–	–	–
	Phragmites australis (Cav.) Trin. ex Steud.	+	+	+	–	–	–	–	–	–
	P. karka (Retz.) Trin. ex Steud.	+	+	+	–	–	–	–	–	–
Subfamily: **Panicoideae**										
Tribe: Paniceae	*Brachiaria ramosa* (L.) Stapf	+	+	+	+[L]	–	+	–	–	–
	Brachiaria *reptans* (L.) Gardner & Hubbard	+	+	+	+[L]	–	+	–	–	–
	Digitaria abludens (Roem. & Schult.) Veldk.	+	+	+	+[L]	–	+	–	–	–
	D. ciliaris (Retz.) Koel.	+	+	+	+[L]	–	+	–	–	–
	Echinochloa colona (L.) Link	+	+	+	+[L]	–	+	–	–	–
	E. crus-galli (L.) P. Beauv.	+	+	+	+[L]	–	+	–	–	–
	Panicum antidotale Retz.	+	+	+	+[L]	–	+	–	–	–
	Panicum maximum Jacq.	+	+	+	+[L]	–	+	–	–	–
	Panicum capillare L.	+	+	+	+[L]	–	+	–	+	+
	Cenchrus ciliaris L.	+	+	+	+[L]	–	+	+	+	BUR
	Cenchrus setigerus Vahl	+	+	+	+[L]	–	+	+	+	BUR
	Setaria verticillata (L.) P. Beauv.	+	+	+	+[L]	–	+	–	–	–
	Setaria italica (L.) P. Beauv.	+	+	+	+[L]	–	+	–	–	–
Tribe:Arundinelleae	*Arundinella nepalensis* Trin.	+	+	+[a]	–	–	–	–	–	–
Tribe: Andropogoneae	*Bothriochloa pertusa* (L.) A. Camus	+	+	+[a]	+[L]	+	+	+	–	–
	Chrysopogon serrulatus Trin.	+	–	+[a]	+[L]	–	+[a]	+	+	–
	Cymbopogon citratus (DC.) Stapf	+	+	+[a]	+[L]	–	+	+	+	–
	C. martinii (Roxb.) Watson	+	+	+[a]	+[L]	–	+	+	+	–
	D. annulatum (Forssk.) Stapf	+	–	+[a]	+[L]	+	–	–	+	–
	D. caricosum (L.) A. Camus	+	–	+[a]	+[L]	+	–	–	+	–
	Heteropogon contortus (L.) P. Beauv. ex Roem. & Schult.	+	+	+[a]	+[L]	–	+	+	–	–
	Imperata cylindrica (L.) Raeuschel	+	+	+	+[L]	–	+	–	+	–
	Sorghum *halepense* (L.) Pers.	+	–	+	+[L]	+	+	–	+	–
	Themeda quadrivalvis (L.) O. Ktze.	+	+	+[a]	+[U]	–	–	–	–	–
Subfamily: **Chloridoideae**										
Tribe: Cynodonteae	*Chloris barbata* Sw.	+	+	+[a]	+[U]	–	–	–	–	–
	Cynodon dactylon (L.) Pers.	+	+	+	+[U]	–	–	–	–	–
Tribe:Eragrostideae	*Eleusine indica* (L.) Gaertn.	+	+	+	–	+	–	–	–	–
	Eragrostis ciliaris (L.) R. Br.	+	–	–	–	–	–	–	–	–
	Eragrostis diplachnoides Steud.	+	–	–	–	–	–	–	–	–
	Eragrostis interrupta (Steud.) Stapf	+	–	–	–	–	–	–	–	–
	E. tenella (L.) P. Beauv. ex Roem. & Schult.	+	–	–	–	–	–	–	–	–
	Desmostachya bipinnata (L.) Stapf	+	+	+	–	–	–	–	+	–
	Leptochloa chinensis (L.) Nees	+	–	–	–	–	–	–	–	–
	L. panicea (Retz.) Ohwi	+	–	–	–	–	–	–	–	–
Tribe:Sporoboleae	*Sporobolus diander* (Retz.) P. Beauv.	+	–	–	–	–	–	–	–	–

Reduced Florets Lower (L) / Upper (U); a = awned

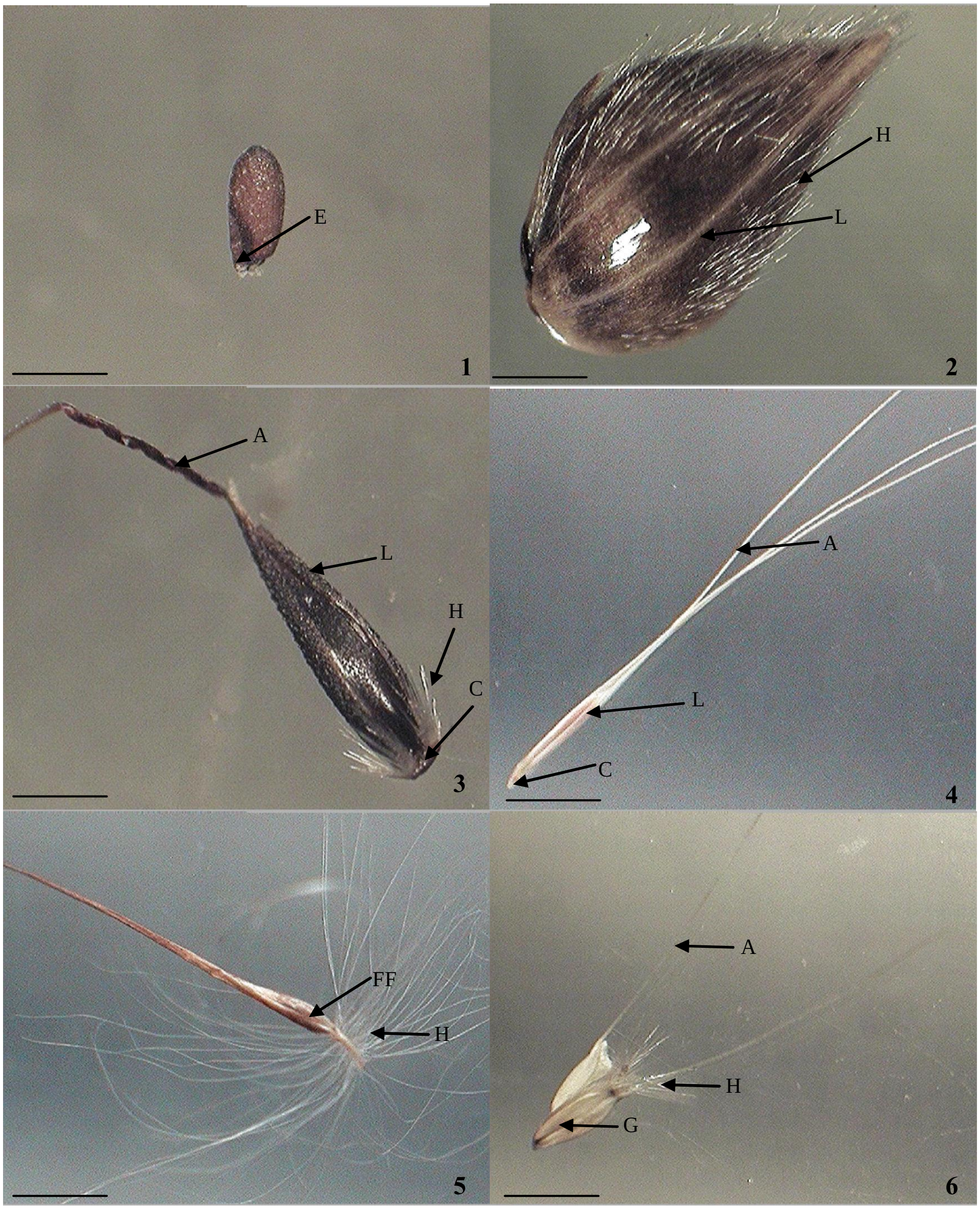

PLATE-I

Plate- I **Diaspores of some grasses of Punjab**

1.	*Sporobolus diander*	(Bar = 0.5mm)
2.	*Phalaris minor*	(Bar = 0.5mm)
3.	*Arundinella nepalensis*	(Bar = 0.5mm)
4.	*Aristida adscensionis*	(Bar = 1mm)
5.	*Phragmites karka*	(Bar = 1mm)
6.	*Chloris barbata*	(Bar = 1mm)

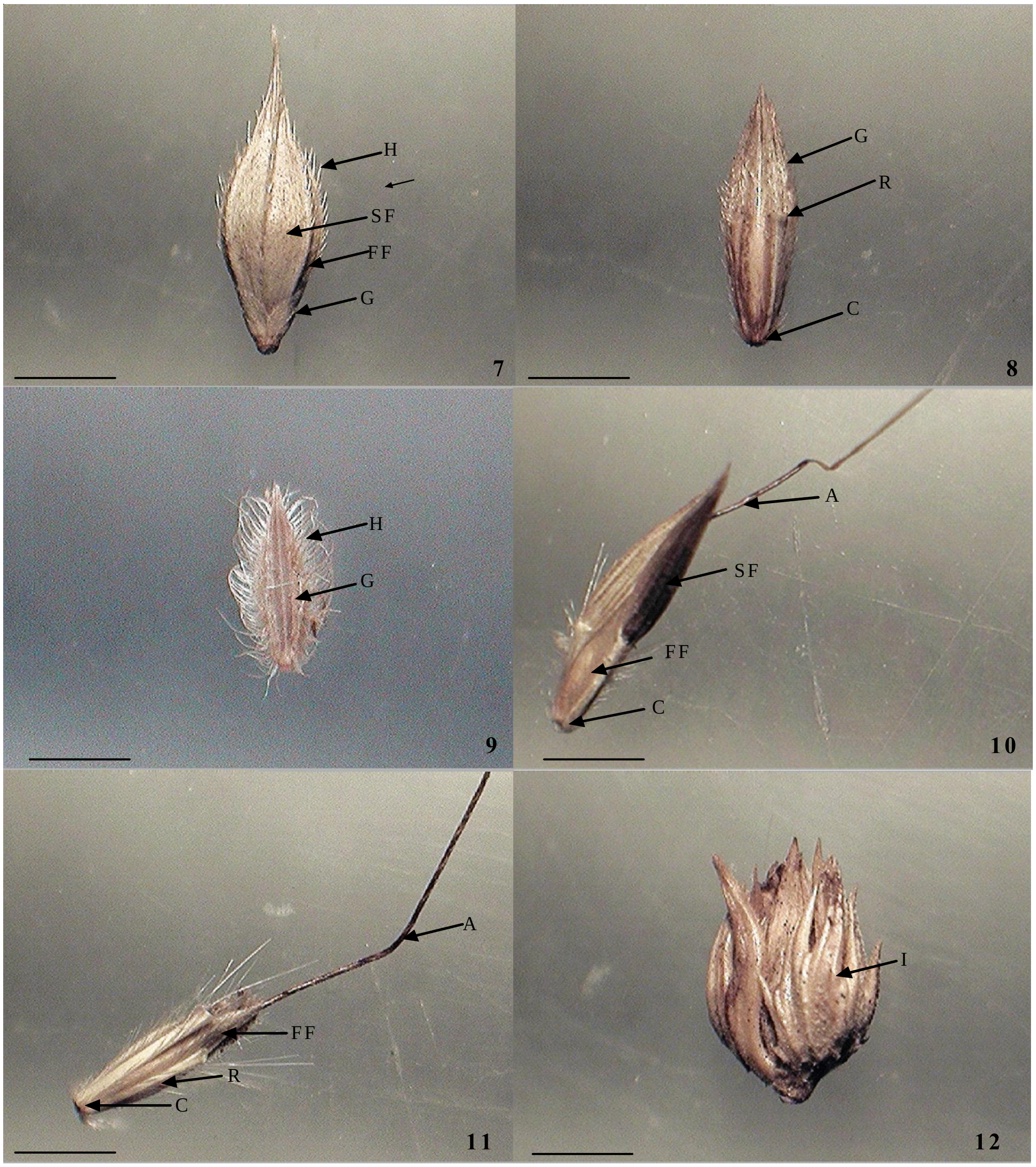

PLATE- II

Plate- II **Diaspores of some grasses of Punjab**

7.	*Echinochloa crus-galli*	(Bar = 1mm)
8.	*Sorghum halepense*	(Bar = 1mm)
9.	*Digitaria ciliaris*	(Bar = 1mm)
10.	*Cymbopogon martinii*	(Bar = 1mm)
11.	*Dichanthium caricosum*	(Bar = 1mm)
12.	*Cenchrus setigerus*	(Bar = 1mm)

A ï Awn, C ï Callus, E ï Embryo, FF ï Fertile floret, G ï Glumes
H ï Hair, I ï Involucre, L ï Lemma, R ï Rachis segment
SF ï Sterile floret

diaspores have greater potential for attachment to the dispersal agents (Romermann *et al.*, 2005).

Among the panicoid grasses *Arundinella nepalensis* Trin. (Fig. 3) also bears anthoecia with a small lemma awn which helps to maintain buoyancy in the air. In members of the subfamily Aristoideae *e.g. Aristida adscensionis* L. the anthoecia bear tripartite but passive awns (Fig. 4) that help in the rotation of the diaspores in air and help them to land in an erect position. Rotation on the soil surface at a pointed callus end with antrorsely directed beard helps in penetration and establishment. Sheldon (1974) postulated that diaspore adaptations not only aid in dispersal but also help in placing the propagules in a position for maximum uptake of water for germination. In our sample of grasses, the members of subfamily Arundinoideae *viz*. *Arundo donax* L., *Phragmites karka* (Retz.) Trin. ex Steud. (Fig. 5) and *P. australis* Trin. (Cav.) ex Steud. represented the next stage of elaboration. Here, diaspores units found to be larger than the anthoecia but smaller than the entire spikelet. In these species, the entire rachilla with all the florets (reduced ones at the distal part) disarticulated above the glumes and spread as a single dispersal unit. These diaspores bore long hairs on the dorsal surface of lemma in *Arundo donax* L. and on the rachilla in *Phragmites karka* (Retz.) Trin. ex Steud. and *P. australis* (Cav.) Trin. ex Steud. These hair help in dispersal as they provide buoyancy in the air. As arundinoid grasses are tall and bear terminal inflorescence, they get sufficient exposure for air dispersal. Therefore, they are most suitable for air dispersal and are least adopted for dispersal by grazing animals. Some chloridoid grasses *e.g. Chloris barbata* Sw. show persistence of a sterile lemma with the anthoecia (Fig. 6). Next stage in the organizational complexity of diaspores was represented by the panicoid grasses that shed the entire spikelet as the dispersal unit. Further, it may be unawned as seen in *Echinochloa colona* (L.) Link, *E. crus-galli* (L.) P. Beauv. (Fig. 7), *Sorghum halepense* (L.) Pers. (Fig. 8), *Digitaria ciliaris* (Retz.) Koel. (Fig. 9) and *Panicum maximum* Jacq. However, in case of *Chrysopogon serrulatus* Trin. and *Cymbopogon martinii* (Roxb.) Watson (Fig. 10) and *C. citratus* (DC.) Stapf a cluster of three spikelets were found to comprise the dispersal unit. In the cluster, a central fertile spikelet is flanked by two sterile ones. These diaspores bore basal and hygroscopically active awns and belong to the most highly developed category in the classification of Peart (1984). Hygroscopic awns play a dual function. In the first phase of dispersal, they help in attachment with the dispersal agents but after falling to the soil they help in horizontal movements of the diaspores by twisting and untwisting movements of the awn and thus cause the second phase dispersal (Chambers and MacMahon, 1994). On reaching favourable microsites, hygroscopic movements burrow the diaspores into the soil and antrorsely directed backward beard hairs prevent their back ejection. Still more complex diaspores were seen in *Dichanthium annulatum* (Forssk.) Stapf. , *D. caricosum* (L.) A. Camus (Fig. 11) and *Bothriochloa pertusa* (L.) A. Camus. These species showed disarticulation of the rachis into diaspores which consisted not only of a fertile spikelet (which contains the caryopsis) and a sterile spikelet but also the subtending rachis segment. The fertile spikelet bore a geniculate and hygroscopically active awn which helps in animal dispersal and establishment. At the same time, diaspores have features that help in wind dispersal. The sterile spikelet (with the pedicel) and the rachis fragment increase the contact area for wind action and buoyancy which is further increased by fine hairs present on lower glumes of both the spikelets. Increased buoyancy results in a fall in the terminal velocity of such diaspores and corresponding increase in the distance covered (Johnson and Fryer, 1992). Thus these diaspores showed a mix of characters favouring anemochorous and epizoochorous dispersal. In these species, awns were found to perform another role in dispersal. As disarticulation of the rachis starts from the top of the raceme, diaspores get entangled by their awns in terminal clusters from which they are released only when wind speeds are high enough to disperse to sufficient distances. The entanglement of individual diaspores into clusters was even more close in *Heteropogon contortus* (Linn.) P. Beauv. ex Roem & Schult. In this species the spikelets were found to disarticulate individually from the rachis (which does not show fragmentation), but kept entangled by their long awns into a single mass which detaches from the parent plant and is carried around as a unit with whiffs of wind and scatters the individual spikelets enclosing the amphimictic propagules (the caryopses). The hygroscopically active awns help in horizontal soil dispersal and establishment. Diaspores in *Cenchrus ciliaris* L., *Cenchrus setigerus* Vahl (Fig. 12) were found to be multi-seeded units (MSU) comprising 2-3 fertile spikelets surrounded by an involucre bristles which are tough and account for the common name ósandbursô of these species. In *Panicum capillare* L. the entire peduncle, bearing numerous fertile spikelets (with caryopses), were found to comprise a single dispersal unit. Such species are called tumble weeds which scatter the individual spikelets (enclosing the caryopses) as they roll about. .

Conclusions

The present investigations bring to light diversity in the diaspore types in some grasses of Punjab. The diversity is not only related to their taxonomic differences but also to the specificity of habitat. Species comprising different habitats are characterized by a syndrome of features of the diaspores that help in dispersal and propagation. The potential of grasses to get dispersed and established in varied habitats makes them ideal choice for production of fodder by natural as well as facilitated propagation on the rangelands.

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