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Flowering phenology and seed biology of selected tropical perennial grasses

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Abstract: Phenological variations, seed yielding components, seed and germination characteristics were investigated in fourteen perennial tropical grasses during monsoon growth (1995 and 1996). *Brachiaria brizantha* and *Panicum antidotale* were the earliest flowering grasses with floral initiation during August first week, after about 40-45 days of monsoon initiated growth from June end. Six grasses flowered and produced 'seeds' during September - October, while another six species started inflorescence exsertion during the second half of November under short day response, after > four months vegetative growth. Seeds are florets with two spikelets or a group of spikelet with or without appendages. Caryopses are enclosed in the husk and dispersed intact. Five grasses place a high premium in the enclosure of caryopsis as weight of husk exceeds the weight of caryopsis. Seed setting was poor in exotic species compared to indigenous. Seed set was also poor to nil in grasses flowering during winter under short day conditions. Germination in 'seeds' was low depending upon per cent seed set, while germination in caryopses was much higher up to 92 percent.

Resumen: Se investigaron las variaciones fenológicas, los componentes de la producción de semillas y las características germinativas en 14 pastos tropicales perennes durante el crecimiento de monzón (1995 y 1996). *Brachiaria brizantha* y *Panicum antidotale* fueron los pastos que florecieron más temprano, con el inicio de la producción de flores durante la primera semana de agosto, después de alrededor de 40 - 45 días de crecimiento iniciado por el monzón desde finales de junio. Seis pastos florecieron y produjeron 'semillas' durante septiembre-octubre, mientras que en otras seis especies la emergencia de la inflorescencia se dio durante la segunda mitad de noviembre en respuesta al acortamiento de los días, después de más de cuatro meses de crecimiento vegetativo. Las semillas son florecillas con dos espiguillas o un grupo de espiguillas con o sin apéndices. Las cariopsis están encerradas en la vaina y son dispersadas intactas. Cinco pastos dan un gran valor a la envoltura del cariopsis, ya que el peso de la vaina supera al peso del cariopsis. La producción de semillas fue pobre en las especies exóticas en comparación con las nativas. La producción de semillas también fue pobre o incluso estuvo ausente en los pastos que florecen durante el invierno, en condiciones de día corto. La germinación en 'las semillas' fue baja dependiendo de producción porcentual de semillas, mientras que la germinación en las cariopsis fue mucho mayor, hasta 92%.

Resumo: As variações fenológicas, componentes do rendimento em sementes, características da semente e da germinação foram investigadas em catorze ervas perenes tropicais durante a estação de crescimento na monção (1995 e 1996). A *Brachiaria brizantha* e a *Panicum antidotale* foram as primeiras ervas a florir com uma iniciação

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floral durante a primeira semana de Agosto, depois do início da estação de monção de cerca de 40-45 dias a partir do fim de Junho. Seis ervas floriram e produziram "sementes" durante Setembro-Outubro, enquanto outras seis espécies iniciaram a protrusão da inflorescência durante a segunda metade de Novembro sob resposta dos dias curtos, depois de mais de quatro meses de crescimento vegetativo. As sementes são flósculos com duas espigas ou um grupo de espigas com ou sem apêndices. As cariopses estão inclusas no folhelho e dispersas intactas. Cinco ervas relevam uma elevada importância na inclusão da cariopse já que o folhelho excede o peso da cariopse. Em comparação com as espécies indígenas, a formação da semente nas espécies exóticas foi pobre. A formação de sementes também foi pobre ou nula em espécies que florescem durante o Inverno sob condições de insolação dos dias curtos. A germinação das sementes foi baixa dependendo da percentagem de sementes formadas, enquanto que a germinação nas cariopses foi muito mais alta atingindo até os 92 por cento.

Key words: Dormancy, flowering phenology, seed germination, seed set, structure of seeds, tropical grasses.

Introduction

In tropical grasses, flowering phenology, seed production potentials and seed purity (as reflected by percent seed set in the spikelets), dormancy and germination are affected by site characteristics (viz., latitude and altitude etc.) as biological seed production potentials of each geographic region, as determined by the climate is species specific (Ferguson *et al.* 1983). The 'seeds' of grasses are spikelets or a group of spikelets and caryopsis enclosed in the husk. The spikelets (florets) are dispersed intact from the branches of panicles as a result of fracture below the glumes. A sizeable portion of 'seeds' remains empty due to low seed setting (in the spikelets) resulting into poor germination (Boonman 1993; Crowder & Chheda 1982).

Flowering penology, dispersal unit, dormancy and germination characteristics of eight tropical perennial grasses belonging to tribe *Andropogoneae* were described earlier (Parihar *et al.* 1999). In the present communication, similar characteristics for another fourteen fodder grasses of *Paniceae* and *Chlorideae* are being described. The species studied were: *Brachiaria brizantha* (A. Rich.) Stapf. (palisade grass), *Brachiaria decumbens* Stapf. (signal grass), *Brachiaria mutica* (Forsk.) Stapf. (para grass), *Brachiaria ruziziensis* Germain and Everard (ruzi grass), *Cenchrus ciliaris* L. (buffel grass), *Cenchrus setigerus* Vahl. (birdwood grass), *Chloris gayana* Kunth. (rhodes grass), *Melinis minutiflora* Beauv. (molasses grass), *Panicum antidotale* Retz. (blue panic), *Panicum maximum* Jacq. (guinea grass), *Paspalum notatum* Flugge (bahia grass), *Pennisetum pedicellatum* Trin. (dinanath grass), *Pennisetum polystachion* (L.) Schult. (thin napier grass) and *Setaria sphacelata* (Schumach.) Stapf. and Hubbard (setaria). All these belong to tribe *Paniceae* except *Chloris* of *Chlorideae*. *Paniceae* is abundant in the tropics and sub-tropics with greater abundance in areas having temperature and low rainfall (Skerman & Riveros 1990). These grasses, extensively used for pasture improvement in the tropics and sub-tropics, play a major role in increasing productivity from ruminants. Para grass is of special interest because of its adaptability to swamps and shallow streams. Species of *Brachiaria*, *P. maximum, Chloris* and *Setaria,* native to tropical Africa, are introduced in moist tropical region of the world (Skerman & Riveros 1990). *M. minutiflora* is distributed in the tropical and southern Africa and Brazil, while *P. notatum* originated in south America (Skerman & Riveros 1990). Thin napier came into prominence in Hebbel farm at Bangalore (India) during forties as a very drought resistant grass

(Narayanan & Dabadghao 1972). Perennial dinanath is a selection made out of annual types, which was introduced from Bihar (India) (Parihar & Shankar 1997). The species of *Cenchrus* are native to India and Africa and forms the dominant species of *Dichanthium* - *Cenchrus* - *Lasiurus* grass cover of India (Dabadghao & Shankarnarayan 1973). *P. antidotale,* native to India, is common on sand dunes of western India as an associate of *Dichanthium* - *Cenchrus* - *Lasiurus* grass cover. Study focused on (i) the time of initial head emergence (IHE) and peak inflorescence density period after the commencement of monsoon initiated growth from June end, (ii) seed yielding components, (iii) structure and form of 'seeds' and resource allocation in the 'seeds', and (iv) dormancy and germination characteristics.

Materials and methods

The experimental site is located in the Central Research Farm of the Indian Grassland and Fodder Research Institute, Jhansi, India (latitude 25^{o} 31' N, longitude 78^{o} 32' E and altitude 237 m above msl). Soil characteristics, rainfall and temperature during growth, flowering and seeding have been discussed elsewhere (Parihar *et al.* 1998, 1999; Parihar & Tomer 2001).

Studies were conducted on 2 - 3 year old established pasture of each species during 1995 and 1996. The sward growth was monitored regularly after the start of monsoon in June end. The time IHE was recorded for all species, when inflorescence exsertion started and about 10 heads m^{-2} had emerged. The time of peak inflorescence density (which coincided with the commencement of seed shedding) was also noticed for all species. Length and diameter of fertile tiller, panicle length and 'seeds' per panicle and per tiller were measured in randomly selected 25 tillers from three quadrats of one m^{2} each (25 × 3). Seeds were also collected from the rest of the field when shedding was on the way and stored in polyethylene bags at room temperature. While dehusking the 'seeds' for determining the percent seed set (also for germination studies of caryopses), 'seeds' were categorised into filled (caryopsis and husk) and empty (no caryopsis). Weight of 1000 caryopses and their husk (glumes, palea, lemma, bristles and awns) and weight of 1000 empty seeds was recorded to determine the weight differences between a filled and an empty seed and contribution of husk and caryopses towards total seed weight. Percent seed set was determined by dehusking 500 seeds (100 x 5). Germination studies were conducted using seeds and caryopses, obtained by dehusking the seeds. Standard conditions were used for all germination tests as per ISTA procedures (Ellis *et al.* 1985). The experiment was carried out in a seed germinator at 20/30^{o}C (16h/8h) with 8 h photo-period (3 x 40 W fluorescent tubes), during upper temperature per day. Seeds/ caryopses were spread evenly on a 9 cm diameter, thick filter paper, placed in Petridishes. Filter paper was soaked in required quantity of distilled water (excess water was drained). No sterilisation treatments were applied to seeds or caryopses before germination tests. For each species, four replications each having 100 seeds or caryopses were used. In each case twenty-one days were taken as a standard period for germination.

Results and discussion

Flowering phenology

Growth of pastures started immediately after the commencement of monsoon during June end and by the end of July the sward height of *Setaria* and *P. maximum* exceeded 90 cm, while in other species it varied from 60 - 80 cm. *B. brizantha* and *P. antidotale* were the earliest flowering grasses (IHE August first week), after about 40- 45 days of monsoon initiated growth with peak head density towards August last week (Table 1). Six grasses showed IHE around September second week as soon as the weather became sunny after the rainy season with peak head density in October first half. Another six grasses exhibited floral initiation during November after > 4 months of vegetative growth. *Melinis* was last to flower as inflorescence exsertion started during fourth week of November as a result of about five months vegetative growth. No variation in IHE was observed during the years.

The two main controls of flowering in tropical grasses are photoperiod and

Table 1. Flowering phenology of tropical fodder grasses.

Species	Initial head emergence (IHE)	Day length during IHE (h)	Temperature during IHE (^{O}C)[1]	Period of peak head density
B. brizantha	Aug. 1st week	13.28	30.3 / 24.4	Aug. 4th week
B. decumbens	Sept.2nd week	12.25	32.6 /23.3	Oct. 1st week
B. mutica	Nov.1st week	11.06	31.1 /12.9	Dec. 1st week
B. ruziziensis	Nov.1st week	11.06	31.1 /12.9	Dec. 2nd week
C. ciliaris	Sept.2nd week	12.25	32.6 /23.3	Oct. 2nd week
C. setigerus	Sept.2nd week	12.25	32.6 /23.3	Oct. 2nd week
C. gayana	Nov.3rd week	10.46	29.9 /10.85	Dec. 3rd week
Melinis	Nov.4th week	10.38	27.5 /8.2	Dec. 4th week
P. antidotale	Aug.1st week	13.28	30.3 /24.4	Aug.4th week
P. maximum	Sept.2nd week	12.25	32.6 /23.3	Oct. 2nd week
P. notatum	Sept.2nd week	12.25	32.6 /23.3	Oct. 2nd week
P. pedicellatum	Nov. 1st week	11.06	31.1 /12.9	Nov.4th week
P. polystachyon	Nov.3rd week	10.46	29.9 /10.85	Dec. 4th week
S. sphacelata	Sept.2nd week	12.25	32.6 /23.3	Oct. 1st week

[1] Mean weekly maximum and minimum temperature (average of two years).

temperature, although environmental stress also induces flowering (Hill & Loch 1993; Humphreys & Riveros 1986). A vegetative phase starts at the onset of monsoon in which shoots are produced followed by transitional phase in response to favourable climatic condition which lead to the floral initiation phase when floret initials are produced at the apex, instead of leaf initials. The floral phase, when differentiation of inflorescences occur, determines the degree of branching and number of florets formed. The end of this phase is marked by external appearance of floral buds, and followed by seed formation phase with varying degree of seed setting in the spikelets. Seed shedding phase starts after the ''seed' has ripened. Grasses flowering and producing 'seeds' during August - September may be regarded as long day plant when day length is more than twelve hours, while species with IHE during November and 'seed' production towards end of November or December, exhibited short day response and flowered when day length was < eleven hours. Cultivars of *P. notatum* and *S. sphacelata* have been found to give a definite long day response while qualitative and quantitative short day response has been observed in grasses like ruzi, para, molasses, rhodes and *Pennisetum* species (Humphreys & Riveros 1986; Ison & Hopkinson 1985, Parihar 1997; Parihar & Shankar 1997). A prolonged period of inflorescence production was observed in *Cenchrus* species, *P. maximum* and *P. notatum.* While head emergence was synchronised in late flowering grasses because of long vegetative phase of > four months.

Seed yielding components

Fertile tillers produce apical and axillary heads. Maximum tiller height and thickness was recorded in *Setaria sphacelata* followed by *P. polystachyon.* Tiller height as well as thickness was minimum in *Cenchrus ciliaris* (Table 2). Maximum seeds per head were in *P. maximum* followed by *P. antidotale* and minimum in *B. ruziziensis.* However, maximum seeds per tiller were recorded in *P. maximum* followed by *P. antidotale.* Six species produced one head per tiller. Panicles were longest in *Panicum maximum* and shortest in *P. pedicellatum.*

Structure and form of seeds

While there is little variation in the flower structure among member of *Poaceae,* their dispersal units (seeds) show considerable differences in the structure and form. The seeds of *Cenchrus, Pennisetum, Chloris, Melinis* possess one or more appendages that contribute to their 'fluffy' appearance viz. awns, hairs on the surface of the spikelet or stiff bristles around the base. In *Cenchrus* and *Pennisetum* species, seeds are fascicles (burs),

Table 2. Seed yielding components in tropical fodder grasses.

Species	Fertile tiller height (m)	Diameter of tiller (mm)	Heads/Tiller	Panicle length (cm)	Seeds/Head	Seeds/Tiller
B. brizantha	1.07 (4.5)*	3.1 (12.5)	1.15 (24.3)	15.3 (7.2)	432 (12.5)	497
B. decumbens	1.32 (3.2)	2.8 (8.3)	2.6 (28.7)	11.6 (12.5)	129 (6.5)	335
B. mutica	1.51 (5.6)	5.4 (10.5)	1	17.6 (16.5)	843 (7.3)	843
B. ruziziensis	1.06 (3.5)	2.7 (9.6)	1.6 (32.5)	10.7 (8.5)	105 (15.5)	168
C. ciliaris	0.97 (2.6)	1.8 (15.6)	1	9.8 (3.7)	124 (18.5)	124
C. setigerus	0.98 (5.2)	2.2 (18.5)	1	12.3 (4.8)	108 (3.6)	108
C. gayana	1.62 (6.5)	4.2 (21.5)	3.2 (38.3)	12.5 (10.2)	1210 (32.2)	872
Melinis	1.15 (3.2)	3.2 (8.3)	1.3 (27.2)	12.2 (9.6)	986 (18.7)	1281
P. antidotale	1.78 (18.6)	5.05 (8.0)	1	29.8 (10.2)	1376 (23.5)	1376
P. maximum	2.13 (15.2)	6.72 (6.8)	1.4 (42.0)	41.5 (20.5)	1575 (10.5)	2205
P. notatum	1.56 (6.5)	2.6 (10.5)	2.7 (43.5)	17.5 (10.2)	231 (9.2)	623
P. pedicellatum	1.64 (3.8)	5.8 (12.3)	1.6 (26.6)	8.7 (4.6)	382 (7.5)	611
P. polystachyon	2.25 (5.0)	5.5 (15.3)	1	11.7 (3.2)	271 (5.5)	271
S. sphacelata	2.56 (8.0)	6.8 (10.2)	1	34.5 (25.0)	744 (6.2)	744

* Figures in parenthesis are percent coefficient of variation.

each consisting of one or more spikelets surrounded by an involucre comprising two rows of awn like wavy bristles. The bristles are longest (up to 18 mm long) in *P. polystachion* and short and fused in *C. setigerus* giving a spiny look and touch to the bur. In *Chloris*, the seed comprises the whole spikelet minus the glumes which are not shed at maturity (Loch 1993). It consists of two florets, with two rigid passive awns (arising from lemma apices on the lower two floret) and a sharp hairy callus at the base. The lemma of the lower floret is fringed with hairs forming a characteristics brush near the top, with a short prominent nerve (usually hairy) on each side. In *M. minutiflora*, the seeds are two flowered spikelets with lower male and sterile and the upper hermaphrodite (fertile) with an awn arising from upper lemma. Seeds of *Panicum*, *Brachiaria*, *Paspalum* and *Setaria* are spikelets, each with two floret of which only upper one is fertile. The caryopsis is held tightly within the hard, stiff lemma and palea. There are no awns and the surrounding glumes are hairy in species of *Brachiaria* and glabrous in *Panicum* species. The caryopses are dorsally compressed and more or less oblong in shape in *Cenchrus* and *Pennisetum* species, while in others these are somewhat elongated and dorsally compressed. In *Melinis* caryopses are lenticular and tapering at both ends. Seeds of *Panicum, Setaria, Brachiaria* spp. (except *B. brizantha*) and *C. setigerus* flow easily, while in remaining species these tend to entangle together.

The detection of a caryopsis within the grass seed structure poses difficulty for seed analyst and in majority of cases each individual seed structure is probed for the presence of a caryopsis. The caryopsis comes out easily from the bur in *Pennisetum* species, when the bur is pinched at the base or pressed against hard surface with a needle. In *Cenchrus*, it could be obtained by dehusking the burs as the bristles form a rigid cup enclosing the spikelets. The caryopsis is obtained by breaking open the husk in *Brachiaria*, *Panicum*, *Paspalum* and *Setaria* species. Separation of filled and empty seeds is not possible in majority of cases as there is no difference in seed size or structure and also minor contribution of caryopsis towards total seed weight (Table 3). However, blowing of empty seeds was possible up to some extent in *B. decumbens*, *B. ruziziensis* and *P. notatum* due to their large seed size and also due to higher contribution of caryopsis towards total seed weight. Only one caryopsis is usually present in each seed, although up to five caryopses have been reported in *Cenchrus* (Pandeya & Jayan 1978; Parihar *et al.* 1984a,b).

Tropical grasses place a high premium on enclosure of seed or in appendages (Parihar *et al.* 1999). The main function of enclosing envelope appears to be protection against infection, predation or desiccation (Clayton

Table 3. Seed setting, germination and seed weight of tropical grasses.

Species	Seed set (%) (average of two ears)	Germination (%)		Weight of 1000 seeds (g)		
		Seeds	Caryopses	Empty	Filled	Caryopses
B. brizantha	34 (14.5)[1]	9 (15.0)[1]	42	0.856	1.659	0.948 (57) [2]
B. decumbens	21 (16.2)	16 (18.2)	91	2.947	6.846	4.082 (60)
B. mutica	0	0	-	0.325	-	-
B. ruziziensis	22 (6.5)	18 (12.5)	92	1.427	5.581	4.542 (81)
C. ciliaris	65 (5.0)	32 (18.0)	86	1.947	2.653	0.815 (31)
C. setigerus	78 (10.5)	36 (22.5)	91	6.428	7.053	0.915 (13)
C. gayana	0	0	-	0.190	-	-
Melinis	27 (6.5)	12 (12.0)	64	0.074	0.151	0.085 (56)
P. antidotale	61 (5.3)	51 (5.0)	NR	0.273	0.801	0.658 (82)
P. maximum	72 (9.5)	62 (28.5)	NR	1.027	1.749	0.824 (48)
P. notatum	9 (22.3)	6 (11.0)	88	1.256	5.589	4.597 (82)
P. pedicellatum	22 (12.6)	16 (8.5)	91	1.197	1.578	0.409 (25)
P. polystachion	23 (12.5)	15 (22.0)	75	0.358	0.653	0.312 (43)
S. sphacelata	43 (22.0)	32 (9.5)	NR	0.416	0.971	0.416 (68)

[1] Figures in parenthesis are percent coefficient of variation.
[2] Figures in parenthesis in column 7 shows percent contribution of caryopsis towards total seed weight.
NR = not recorded.

1990). The husk accounted up to 87% of seed weight in *C. setigerus* while in other species it varied from 20 to 70% (Table 3). The husk of *Cenchrus*, *Pennisetum* and other grasses are quite rich in phenolics (viz. cyanidin glycosides, phenolic acids and hydroxy cinnamic acid derivatives) also (Parihar & Patil 1984; Parihar & Mal 1999). These secondary metabolites play an important role in the prevention of seed decay and also act as feeding deterrent or anti feedents or toxicants thus keeping a seed viable for a longer period of time in a natural ecosystem (Parihar & Kanodia 1992; Parihar & Mal 1999; Rice 1984).

Maximum weight of 1000 filled seed was in *C. setigerus* (7.053 g) and minimum (0.151g) in *Melinis* (Table 3). However*, P. notatum* produced heaviest caryopses (4.597 g) and *Melanis* the lightest (0.085 g).

Seed set, dormancy and germination

The degree of seed setting in spikelets, which is susceptible to weather condition prevailing at the time of anthesis and grain formation (Humphreys & Riveros 1986), varied from species to species (Table 3). In general, seed setting was poor in exotic species (except guinea grass) compared to indigenous grasses like *Cenchrus* species and *P. antidotale*. Seed setting was also poor to nil in grasses flowering during winter, under short day response, possibly because of low night temperature (below 10°C from November second week onwards) during seed setting, which impedes seed setting in tropical grasses (Parihar & Tomer 2001). No seed setting took place in *C. gayana* and *B. mutica*. Adverse effect of low night temperature (on seed setting) below 10 and 15°C has been observed for *C. gayana* (Tarumoto & Mochizuki 1979). Seed setting is also dependent upon internal plant controls and genetically regulated as percent seed set *in C. setigerus* varied from 8 - 61 % according to lines (Patil & Singh 1963). Pandeya & Jayan (1978) and Parihar *et al.* (1984 a, b) has also observed significant differences in germination in different lines/ecotypes of *Cenchrus* species.

Dormancy period varied from 3 - 9 months, although seeds of *C. ciliaris*, *Melinis* and *P. antidotale* germinated within one month of their collection, but germination was low, which improved with storage up to 9 months. Germination in caryopses (caryopses obtained after dehusking the seeds stored for 9 months) was much higher and varied from 42 - 92 % (Table 3). Highest germination in seeds and caryopses was recorded for *P. maximum* and *B. ruziziensis*, respectively. Caryopses germinated more rapidly, more completely because of faster absorption of moisture as husk prevents wetting of caryopsis, because chaffy husk has a marked influence on moisture relation around the caryopsis during germination (Loch 1993) or possibly hull imposes some kind of mechanical restraint or may restrict the availability of oxygen to the embryo (Simpson 1990). Phenolics present in the husk of *Cenchrus* also cause delay in germination of seeds compared to caryopses (Pandeya & Jayan 1978; Parihar & Kanodia 1984).

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