

Seed production and germination in vetiver grass (*Vetiveria zizanioides*)

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Abstract

Seed yield components of vetiver grass (*Vetiveria zizanioides*) were examined during monsoonal growth for 2 years (1995 and 1996). Initial inflorescence emergence (IIE) started by mid-August, about 45 days after the start of the monsoon-initiated growth in the last week of June. Inflorescence density peaked at 139.6/m² with pure germinating seed (PGS) yield of 648 kg/ha in Year 1 and 150.2/m² with PGS yield of 418 kg/ha in Year 2. Anthesis was acropetal and lasted c. 5 days. Shedding was basipetal and started after c. 21 days of anthesis. Freshly collected spikelets showed dormancy and required an after ripening period of c. 3 months. A hull-imposed dormancy was evident as removal of the caryopsis from the enclosing husk facilitated germination. Dormancy was broken by application of gibberellic acid and potassium nitrate.

Introduction

Vetiver grass (*Vetiveria zizanioides*) is a native of tropical and subtropical Asia, distributed from south-east Asia to tropical Africa, and including India (Bor 1960). It is a perennial grass common on river banks and marshy soils, and has rhizomatous, spongy and aromatic roots. It is an important component of the *Phragmites/Saccharum* grass cover of India (Dabadghao and Shankarnarayan 1973). Recently, vetiver has attracted worldwide attention as it offers “a practical and inexpensive solution for controlling

erosion, simply, cheaply and on a huge scale on both tropical and semi-arid regions” (NRC 1993). A domesticated type of this species in south India is non-seeding, but a wild type from north India flowers and produces viable seed. However, no information is available on seed yield and germination as the species was considered non-seeding (Anon. 1987). Therefore, studies were conducted to document crop development and to assess seed yield potential on an established stand under rain-grown conditions. Seed germinability and viability of this grass were also examined.

Materials and methods

Experimental site and environment

The site was located in the Central Research Farm of the Indian Grassland and Fodder Research Institute, Jhansi, India (25°31'N, 78°32'E; 237 m altitude). The soil was sandy loam with pH 7.3, 0.36% organic carbon, available N 167 kg/ha, P 9.2 kg/ha and K 193.3 kg/ha. Rainfall during the growing season (*i.e.* the rainy season from the end of June to mid-September) was 783 mm and 870 mm during 1995 and 1996, respectively. This represents > 90% of annual rainfall. Mean weekly maximum and minimum temperatures and relative humidity from inflorescence exertion to start of ‘seed’ shedding (mid-August to mid-September) are given in Table 3. Peak maximum and minimum temperatures were 47°C (June 2, 1995), 46.3°C (June 5, 1996), 1.8°C (January 30, 1995) and 0.8°C (December 11, 1996). Maximum values of soil temperature at 5 cm depth were 56°C (June 7, 1995) and 57°C (May 23, 1996).

Experimental procedure

Rooted cuttings of local material were used for sward establishment at the start of the monsoon (1st week of July, 1995) after ploughing and levelling the field. The distance between plants, both within and between rows, was 50 cm.

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Fertiliser N (urea) and P (single superphosphate) were applied at 20 kg/ha each. Five permanent quadrats (1 × 1 m) were marked out at the onset of the monsoon. Potential seed yield was estimated in each quadrat by recording peak head density multiplied by mean seed yield per head. One additional quadrat was used for tagging the tillers after initial inflorescence emergence (IIE), when 5–8 heads/m² were visible for recording anthesis, seed setting and seed shedding. Quadrats were harvested during mid-September, when shedding was under way. Tillers were categorised as flowering or non-flowering and morphological characteristics of 10 flowering tillers selected randomly from each replicate were measured for tiller height (base to the top of the inflorescence), tiller diameter (at the middle of the lowest internode), panicle length, seed yield per head, leaf:stem ratio, etc. (Table 1).

Seed was also collected from the rest of the field, dried in shade and stored in polyethylene bags at room temperature for subsequent germination studies. Room temperature during seed storage varied from 15°C during winter (December–January) to 40°C during summer (May–June). Relative humidity of the room ranged from 29–31% in October–November 1995, when ‘seeds’ were stored in tightly closed polyethylene bags.

Table 1. Sward characteristics and components of spikelet yield in vetiver grass after c. 10 weeks growth.

Sward characteristics/ component of spikelet yield	1995	1996
Tiller density (no/m ²)	195.0 (8.3) ¹	212.6 (6.4)
Flowering tillers (%)	72.0 (8.0)	70.6 (5.7)
Flowering tiller height (cm)	182.5 (5.80)	178.0 (5.4)
Diameter of flowering tillers (mm)	4.6 (9.5)	4.2*(10.6)
Leaf area index (LAI)	3.4 (11.7)	3.1 (13.1)
Leaf:stem ratio	0.1 (22.3)	0.1 (12.1)
Dry matter yield (g/m ²)	762.6 (5.76)	801.4 (5.0)
Head density (no/m ²)	139.6* ² (6.5)	150.2* (7.6)
Panicle length (cm)	29.7*(13.4)	24.0*(18.5)
Sessile spikelet yield (mg/head)	902.0*(20.5)	596.0*(17.0)
Sessile spikelet yield (g/m ²)	126.0*(10.7)	95.0*(17.0)
Seed set (%)	62.8* (6.3)	55.8* (6.6)
Germination (%)	51.2* (5.8)	44.0*(10.0)
Pure germinating seed yield (g/m ²)	64.8*(16.6)	41.8*(17.0)
Initial inflorescence emergence (IIE)	Mid-August	Mid-August
Peak head density and start of seed shedding	Mid-September	Mid-September

¹Figures in parentheses are % of coefficient of variation.

²Means marked * differ significantly (P = 0.05).

Like other members of *Andropogoneae*, vetiver possesses 2 kinds of spikelets borne in pairs (diad) on the branches of panicles (Figure 1). The sessile spikelet is hermaphrodite and may produce a caryopsis while the pedicelled spikelet of the diad is staminate and sterile. The pedicelled spikelet often falls earlier than the sessile spikelet but a dispersal unit may also be a diad (diaspore). However, while stripping the panicle, diads are often separated and a sessile spikelet is usually identified due to its larger size and a stalk of pedicelled spikelet attached to it.



Figure 1. *Vetiveria zizanioides*. 1. Inflorescence; 2. Portion of a branch; 3. Sessile and pedicelled spikelet.

Figure 1. *Vetiveria zizanioides*.

Per cent seed set was determined by dehusking sessile spikelets (100 × 5). While dehusking the sessile spikelets for determining the per cent seed set (also for germination studies of caryopses), sessile spikelets were categorised into filled (caryopsis and husk) and empty (no caryopsis). Weights of 1000 caryopses and their husks, 1000 pedicelled spikelets and 1000 empty spikelets were recorded to determine the weight difference between a filled and an empty diad and contribution of various diad parts towards total diad weight (Table 2).

Two kinds of germination studies were conducted: (i) with sessile spikelets, and (ii) with caryopses obtained by dehusking sessile spikelets. While details of specific treatments are described for each experiment, standard procedures prescribed by ISTA (Ellis *et al.* 1985) were used for all germination tests. Subsamples of 4 × 100 spikelets/caryopses were germinated for 21 days at 20/30°C with light during the day cycle. Tests were carried out within 10 days of 'seed' collection and thereafter at regular intervals. The following dormancy-breaking treatments were also imposed on 2-month-old spikelets in 1995 and compared with a control: pre-chilling, moistened spikelets kept at 5–7°C for 7 days before the start of germination; and spikelets moistened with a 500 ppm solution of gibberellic acid (GA₃) and potassium nitrate (KNO₃) at the start of the experiment and subsequently with distilled water. Ten seedlings with the longest root and shoot growth were measured on the fifth day of germination.

Results

Components of spikelet yield

Growth of the sward started with the onset of the monsoon and plants were taller than 1.5 m at the time of inflorescence exertion during mid-August. Inflorescence exertion was recorded when an inflorescence was fully exerted above the flag leaf. More than 70% of the tillers carried inflorescences and measured up to 1.95 m long. Data on tiller density, diameter of flowering tillers, leaf area index (LAI), leaf:stem ratio of tillers with head, dry matter yield etc. are given in Table 1. Vetiver has a determinate habit and formation of spikelets follows the differentiation of inflorescences on the terminal apices of tillers which formerly budded off leaf initials. Anthesis started acropetally as soon as the inflorescence emerged and continued for c. 5 days on a single inflorescence. Spikelets were purple (due to cyanidin glycoside) during anthesis and gradually turned light brown at maturity. Seed setting was completed within c. 10 days of anthesis and shedding was basipetal, starting 21 ± 3.7 days after anthesis. Complete shedding of spikelets was not observed even after 45 days of anthesis as each inflorescence had c. 30% spikelets intact.

A typical panicle (Figure 1) had 10–13 whorls of branches joined to the central axis. Basal

whorls were well defined and possessed 9–12 branches measuring 7–8 cm with 8–10 diads each. Spikelets were flattened, tapering towards the apex. Sessile and pedicelled spikelets measured (length × breadth) 5.08 ± 0.05 × 1.35 ± 0.25 mm and 4.09 ± 0.63 × 1.01 ± 0.13 mm, respectively. The stalk of the pedicelled spikelet measured c. 5.0 mm and it detaches from the tip of the stalk and the pedicel remains attached with sessile spikelets. The caryopsis is wheat-like in colour, fragile, round towards the base and gradually pointed towards the apex. Caryopses measured (L × W) 3.2–3.4 × 1.0–1.2 mm and were 0.5–0.6 mm thick. Weight of 1000 diads (paired spikelets) and their parts is given in Table 2. Caryopses comprised 38–46% of total diad weight and 54–48% of sessile spikelet weight, while pedicellate spikelets contributed 15–22% towards total diad weight. Mean seed yields (sessile spikelets) per inflorescence were 902 mg and 596 mg with PGS (pure germinating seed) yields of 64.8 gm/m² and 41.8 gm/m² in 1995 and 1996, respectively (Table 1).

Table 2. Weight (g) of 1000 diads (filled) and their parts from vetiver grass.

Year	Diad (filled)	Sessile spikelet		Pedicellate spikelet	Empty sessile spikelets
		caryopsis	husk		
1995	1.753	0.8152 (46.5) ¹	0.6733 (38.4)	0.2645 (15.0)	0.7351
1996	1.6185	0.6165 (38.0)	0.6500 (40.1)	0.3520 (21.7)	0.783

¹ Figures in parentheses indicate % of diad weight.

Table 3. Mean weekly temperatures and relative humidity from mid-August to mid-September.

SMW ¹	Temperature (°C)				Relative humidity (%)			
	Maximum		Minimum		Period I ²		Period II	
	95	96	95	96	95	96	95	96
33	32.0	31.6	24.5	24.5	92	95	69	73
34	30.6	29.2	23.7	23.6	98	97	83	84
35	32.8	32.1	24.7	24.4	97	98	74	81
36	30.5	31.1	22.6	23.8	93	97	80	78
37	31.5	32.2	22.6	24.3	96	95	61	67

¹ SMW = Standard meteorological week.

² Period I = morning; Period II = afternoon.

Freshly collected spikelets showed dormancy but removal of the hull gave 26% germination (Table 4). Germination % increased with storage, reaching a maximum after 3 months (51.3% and 90.3% germination in spikelets and seeds, respectively). However, per cent germination started to decline after 9 months, and 25% and 44.5% germination were recorded in spikelets and seeds, respectively, after 20 months in storage. There was no significant change in per cent germination between 3 and 6 months in storage. Dormancy of 2-month-old spikelets could be reduced by KNO_3 and GA_3 (Table 5).

Table 4. Effect of storage period and removal of husk on per cent germination (1995).

	Storage period (months)					
	0	2	3	9	15	20
Spikelets	—	18.5a ¹	51.25b	38.5c	29.0d	25.75d
Caryopses	26.0a	88.5b	90.25b	65.75c	44.25d	44.5d

¹ Within rows, values sharing the same letter do not differ significantly ($P > 0.05$).

Table 5. Effect of dormancy-breaking treatments on % germination of spikelets and root and shoot growth (seed collected in 1995).

Treatments	% germination	Root length (mm)	Shoot length (mm)
Control	18.5a ¹	19.4a	27.9a
Pre-chilling	26.0a	16.3a	28.5a
KNO_3	53.5b	19.2a	35.7b
GA_3	47.5b	15.5a	39.1b

¹ Within columns values sharing the same letter do not differ significantly ($P > 0.05$).

² Potassium nitrate.

³ Gibberellic acid.

Discussion

Unlike many other tropical grasses (Crowder and Chheda 1982; Humphreys and Riveros 1986), vetiver did not have a prolonged period of inflorescence production, uneven ripening of seeds on an individual head and early shattering of mature seeds. Within 10–12 days of HIE, more than 70% of the tillers had produced an inflorescence and, unlike other tropical grasses (Humphreys and Riveros 1986), no axillary (aerial) tillers were recorded. However, a typical

flowering tiller produced one or two more apical inflorescences from the base of the flag leaf by mid-October. The size of these subsequent panicles was reduced, the number of diads produced by second and third panicles being about 30% and 20% of that for the first panicle with <15% seed set. Inflorescence density is low compared with other tropical grasses (Boonman 1993), but PGS yield is higher because of the high mean sessile spikelet yield per head. The harvest index of 5–8% in vetiver is therefore higher than for other tropical grasses, though low in comparison with temperate grasses (Boonman 1980).

Harvesting of 'seeds' by a single harvest after c. 10 weeks growth is desirable. Synchrony in flowering may be attributed to fertiliser application and also to the genotype. Seed set (55–65%) is lower than in other native grasses flowering during late October or early November when night temperatures are lower. Biological seed production potential in grasses is site specific and determined by the climate of the geographic region. It appears that prevailing climatic conditions were not unfavorable for 'seed' yield. Regions with good potential for grass seed production are characterised by moderate climate, maximum and minimum temperatures not exceeding 30°C and 9°C, respectively, and relatively calm and still weather with little or no precipitation during anthesis and seed ripening (Crowder and Chheda 1982).

Fresh spikelets showed dormancy and required an after-ripening period of c. 3 months. Hull-imposed dormancy is evident as dehulling facilitates germination of seeds as in other grasses (Simpson 1990). The reduction of spikelet dormancy by GA_3 and KNO_3 is also common in other grasses. Spikelets required up to 16 days to germinate (though the experiment continued for 21 days) while caryopses germinated within 5 days of sowing, suggesting that the hull perhaps imposes some kind of mechanical restraint or may restrict the availability of oxygen to the embryo (Simpson 1990). A decline in germination was observed after 9 months in storage, although >25% of spikelets still germinated after 20 months under ordinary storage conditions. 'Seed' of vetiver can be stored safely for about 9 months, in ordinary storage under north Indian conditions till the advent of the rainy season in July, when it could be used for sowing with little loss of viability.

Higher rainfall with a greater number of rainy days during inflorescence exertion and anthesis in the second half of August (1996) possibly reduced the seed yield as well as quality.

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