Annals of Arid Zone 48(1): 57-62, 2009

Seed Yield and Seed Germination in Primary and Secondary Spikes in Buffel Grass

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Abstract: Seeds of four genotypes of buffel grass (*Cenchrus ciliaris* L.) were sown in July 2003 to study the effect of type of spikes and crop age on seed yield and germination. There were significant differences among the genotypes for number of spikes plant^{-1}, spike length and seed yield of both primary and secondary spikes during three years (2003-05) of crop growth. The mean values of spikes plant^{-1}, spike length, seeds spike^{-1}, test weight, seed yield plant^{-1} and seed germination were more in primary spikes than that in secondary spikes for all three years, except the number of secondary spikes plant^{-1} in the first year, and spike length and seeds spike^{-1} in third year. Seed yield plant^{-1} was maximum in the second year, of which two-third was contributed by primary spikes. Positive and significant association of number of primary spikes plant^{-1} with its seed yield and seed germination showed that increase in number of primary spikes results in more seed yield of better quality. The results revealed that the contribution of seeds due to primary spikes was significantly more than secondary spikes to the total seed yield, and maximum seed yield with highest germination was from the harvest of second year.

Key words: *Cenchrus ciliaris*, genotypes, seed yield, spikes.

Buffel grass (*Cenchrus ciliaris* L.), locally known as 'Dhaman' grass, is widely distributed in the plains of Rajasthan, Punjab and western UP extending into the foothills of Jammu to an elevation of 400 m in India (Dabadghao and Shankarnarayan, 1973). It is highly nutritive for animals as its fresh plant on a zero-moisture basis has 11.0% protein, 2.6% fat, 73.2% total carbohydrate, 31.9% fiber and 13.2% ash (Gohl, 1981). It is persistent and extremely drought tolerant species. The rhizomes of established pasture respond very well to summer as well as winter rains. Like many other tropical grasses *C. ciliaris* has a prolonged period of inflorescence production resulting in unsynchronized ripening of seed heads. To avoid seed loss due to shedding, efforts are made to collect entire seeds, but hand picking of seeds increases the production cost. Tillers, which emerge from ground, bear primary spikes and may have branches, which bear secondary spikes. Availability of limited moisture and nutrients restricts the branching. As the species is perennial, hence rainfed crop faces various kinds of stresses and aberrant climate change makes the forage and seed production uncertain. Shortage of quality pasture seed limits the rejuvenation of degraded grazing lands. In such situations production of high germinable seeds would be a better proposition for forage production from degraded grazing lands and wastelands. Effect of crop age and spikes on quantity and quality of seeds is least studied, although much work has been done on forage quality (Ruiz *et al.*, 2004), intercropping with pasture legumes (Reddy *et al.*, 2004), fertilizer requirements and row spacing (Kumar *et al.*, 2005) and seed germination (Rajora *et al.*, 2002). Hence, the present study was conducted.

Materials and Methods

Seeds of four genotypes including three from selections made at the institute (CAZRI 2221, CAZRI 75 and CAZRI 358) and a variety (IGFRI 3108) developed by IGFRI, Jhansi (India) were sown in randomized complete block design with five replications in second week of July 2003 after first shower of the summer monsoon at C. R. Farm of the Central Arid Zone Research Institute, Jodhpur. The climate of this area is typically arid, characterized by exceptionally hot dry summers, sub-humid monsoon and cold dry winters. Soil is loamy sand with a pH of 8.1 and has low level of nutrients with 0.23% organic C, 0.03% N and 0.02% P. Plot size was 3 m x 4 m with tussock-to-tussock distance of 50 cm within row and 75 cm between rows (tussock is referred as plant hereafter). The spikes were harvested manually from 2nd September to 28th October, 2nd September to 5th October, and 23rd July to 21st September for primary spikes, and from 7th September to 28th October, 2nd September to 5th

October and 4th August to 27th September for secondary spikes in 2003 (I-year), 2004 (II-year) and 2005 (III-year), respectively. Spike length, seeds spike^{-1}, 1000-seed weight (test weight) and seed yield plant^{-1} were recorded. The harvested seeds were dried at room temperature to the moisture of less than 10%. Seed germination tests using 500 seeds were conducted within 90 days of the harvest at 20-30°C (20°C for 16-h and 30°C for 8-h) using sand as medium in seed germinator. The tests lasted for four weeks. The data were subjected to analysis of variance as per standard procedures of Snedecor and Cochran (1967).

Results and Discussion

Number of rainy days ranged from 16 to 26, the maximum being in 2003. In the year of establishment, the rainfall was 420 mm and it was about 30% more than the average rainfall of the area. It was 220 mm in second year and 283 mm in the third year. In 2003 more than 60% of the rains was received during July. July-August experienced 74-79% of the rains of individual years and it was more in July during 2003 and 2005. Mean highest maximum RH were recorded in August and these were 91% in 2003, 86% in 2004 and 78% in 2005. Highest mean maximum temperatures were 41.0°C in May 2003, 40.9°C in April 2004 and 41.5°C in June 2005.

There were significant differences among the genotypes for spikes plant^{-1}, spike length, seed yield plant^{-1}and seed germination of primary spikes during all the three years. Differences were non-significant for seed spike^{-1} and test weight, except test weight during 2004. For secondary spikes, differences were significant for all the traits in all the years, except seeds spike^{-1}, test weight and seed germination in second year (Table 1).

Seed yield and seed germination of primary and secondary spikes of different genotypes is given in Table 2. In the first year total seed yield plant^{-1} was maximum (17.4 g) for CAZRI 358 of which 43% was contributed by the primary spikes. The seed yields of other genotypes were less than half

Table 1. ANOVA for seed yield, its components and seed germination in C. ciliaris

Source	d.f.	Spikes plant^{-1}	Spike length	Seeds spike^{-1}	Test weight	Seed yield plant^{-1}	Seed germination
			Primary spikes				
I-year (2003)							
Block	4	108.0	0.84	756.7	0.18	13.6	58.9
Genotype	3	460.2*	7.16**	1123.6	0.17	25.2*	908.9**
Residual	12	81.8	0.81	453.0	0.21	6.6	53.2
II-year (2004)							
Block	4	80.9	1.14	158.6	0.81*	4.8	122.1
Genotype	3	957.2**	5.92**	535.7	1.93**	91.2**	1531.1**
Residual	12	30.6	0.52	385.6	0.19	1.7	177.3
III-year (2005)							
Block	4	17.1	0.58	112.7	0.04	1.3	27.8
Genotype	3	2247.3**	4.54*	300.3	0.51	112.5**	1172.4**
Residual	12	48.4	0.88	287.3	0.22	2.5	116.6
			Secondary spikes				
I-year (2003)							
Genotype	3	5290.9**	11.91**	3122.6**	0.590**	87.2**	781.0**
Residual	16	348.9	1.02	466.8	0.099	10.5	72.8
II-year (2004)							
Genotype	2	3581.9**	11.95*	440.5	0.317	134.3**	356.6
Residual	11	240.7	1.94	1066.0	0.303	7.1	345.6
III-year (2005)							
Genotype	2	3042.0**	5.56**	1018.3*	0.978*	83.0**	1215.2**
Residual	12	32.6	0.55	198.1	0.184	2.2	131.1

*P<0.05, **P<0.01.

Table 2. Mean performance of different genotypes for seed yield and seed germination in C. ciliaris

Genotype	Primary spikes		Secondary spikes	
	Seed yield $plant^{-1}$ (g)	Seed germination (%)	Seed yield $plant^{-1}$ (g)	Seed germination (%)
I-year (2003)				
CAZRI 2221	4.5	51.6	3.9	42.0
CAZRI 75	3.6	23.8	2.3	23.8
CAZRI 358	7.5	42.4	9.9	42.8
IGFRI 3108	2.2	25.4	0.2	18.4
CD (5%)	3.5	10.1	4.3	11.4
II-year (2004)				
CAZRI 2221	10.0	76.6	1.5	58.4
CAZRI 75	7.8	38.8	0.6	40.8
CAZRI 358	13.2	60.2	10.2	48.0
IGFRI 3108	3.0	42.2	-	-
CD (5%)	1.8	18.3	3.9	NS
III-year (2005)				
CAZRI 2221	4.9	57.8	1.1	46.4
CAZRI 75	7.8	33.2	2.0	19.2
CAZRI 358	12.9	48.6	8.5	19.6
IGFRI 3108	1.7	23.6	–	–
CD (5%)	2.2	14.9	2.0	15.8

of CAZRI 358. The minimum seed yield was 2.4 g $plant^{-1}$ (IGFRI 3108) and it was mainly contributed by the primary spikes. In the second and third years also CAZRI 358 showed maximum seed yield and in second year it was about 34% more than the seed yield of first year. From second year onwards, there was no secondary spike in IGFRI 3108, so the genotype was excluded from analysis of variance.

For seed of all the years, mean germination was more with primary spikes. CAZRI 2221 had maximum seed germination for both the types of spikes during all the three years. For primary spikes, it ranged from 51.6% to 76.6%, the highest being in the second year. Same trend was observed for secondary spikes, i.e. 42.0% in first year and 58.4% in the second year (Table 2). Similarly, significant effect of position of fruits on seed germination has been reported in okra (Krishnakumary and Mini, 2003; Yadav and Dhankhar, 2001). After second year, seed germination of both types of spikes decreased with age of the plants.

Comparing to CAZRI 2221 and CAZRI 358, variety IGFRI 3108 had very low seed germination, even less than the limit of Indian Minimum Seed Certification Standards, which is 30% for this species (Tunwar and Singh, 1988). Genotypes CAZRI 2221 and CAZRI 358 were collected from the hot and dry climate of western Rajasthan and hence had better adaptation in arid climate. Wide range of germination (17.0-86.8%) has been reported earlier also in this species (Rajora and Singh, 2005). Genotypes collected from arid areas including Rajasthan performed better for dry matter when evaluated under similar situations in Australia (Hacker *et al.*, 1995).

The mean values of various traits of primary spikes were more than of secondary spikes, but the significant differences were only for spike length, seeds $spike^{-1}$ and test weight during first and second years and seed yield $plant^{-1}$ in second year (Table 3). During third year, the trend was almost same as in previous years, except spike length and seeds $spike^{-1}$, where the values of secondary spikes were higher than those of primary spikes. During third year seed yield and seed germination of primary spikes were significantly more than of secondary spikes.

During first year there were 50.7 total spikes $plant^{-1}$ of which about 40% were primary spikes with 52.3% contribution to the total seed yield.

Table 3. Mean, range and SD for primary and secondary spikes related traits and 't' values in C. ciliaris

Trait	Primary spikes			Secondary spikes			't' value
	Mean	Range	SD	Mean	Range	SD	
I-year (2003)							
Spikes plant^{-1}	20.0	8.6-54.8	12.13	30.7	0.4-126.4	33.60	1.34
SL (cm)	10.8	8.2-13.3	1.35	8.8	5.0-11.0	1.65	4.30**
Seeds spike^{-1}	121.1	63.4-164.2	25.96	103.0	49.8-151.0	29.77	2.09*
Test wt (g)	2.86	1.85-3.53	0.44	2.03	1.20-2.68	0.42	3.05**
SY plant^{-1} (g)	4.5	1.3-15.9	3.32	4.1	0.02-19.7	4.76	0.31
SG (%)	35.8	15.0-58.0	13.77	31.8	12.0-57.0	13.59	0.94
II-year (2004)							
Spikes plant^{-1}	23.5	4.8-50.2	13.69	14.2	0.0-81.6	24.50	1.48
SL (cm)	12.6	10.1-14.6	1.23	10.5	6.0-13.1	1.87	4.06**
Seeds spike^{-1}	187.7	156.8-231.2	19.01	138.9	77.6-193.8	31.14	5.68**
Test wt (g)	3.91	2.51-5.25	0.77	2.75	1.44-3.54	0.55	4.83**
SY plant^{-1} (g)	8.5	2.0-15.4	4.06	4.4	0.1-15.3	5.16	2.61*
SG (%)	54.5	21.0-85.0	19.48	49.6	0.0-77.0	18.64	0.72
III-year (2005)							
Spikes plant^{-1}	29.1	5.4-65.8	19.72	15.9	0.0-57.6	20.72	2.06*
SL (cm)	9.1	7.3-11.7	1.18	9.8	7.8-11.4	1.13	1.54
Seeds spike^{-1}	85.3	63.6-125.0	15.89	107.2	83.4-144.8	17.76	3.84**
Test wt (g)	2.47	1.80-3.23	0.48	2.46	1.45-3.30	0.55	0.05
SY plant^{-1} (g)	6.8	1.1-14.0	4.43	3.9	0.7-11.8	3.71	2.10*
SG (%)	40.8	11.0-68.0	16.27	28.4	8.0-65.0	16.91	2.19*

Note: SL= Spike length, Test wt= Test weight, SY= Seed yield and SG= Seed germination; *P<0.05, **P<0.01.

Mean number of primary spikes plant^{-1} was minimum (20.0) in first year and it increased to 23.5 in second and 29.1 in third year. Number of secondary spikes plant^{-1} was maximum (30.7) in the first year and decreased to 14.2 in second year and there was not much change in third year. Spike length varied from 8.8 cm for secondary spikes in first year to 12.6 cm for primary spikes in second year. Primary spike length changed significantly from year-to-year for all the three years and for secondary spike length the significant change was between of first and second years only (Table 3 and 4). Number of seeds per primary spike was 121.1 in the first year and it increased to 187.7 and then it decreased to 85.3 in the third year and the differences were significant for all the three comparisons. Similarly for secondary spikes, the seed number increased significantly from 103 (I-year) to 139 (II-year) and decreased significantly to 107 in third year. Seeds spike^{-1} were maximum for both types of spikes during second year.

Table 4. 't' values for various spike traits in C. ciliaris for comparison between different years

Trait	Primary spikes			Secondary spikes		
	I-year vs. II-year	I-year vs. III-year	II-year vs. III-year	I-year vs. II-year	I-year vs. III-year	II-year vs. III-year
Spikes plant^{-1}	0.853	1.752	1.039	1.770	1.676	0.231
Spike length	4.363**	4.233**	9.127**	2.767**	1.940	1.265
Seeds spike^{-1}	9.485**	18.475**	5.416**	3.398**	0.492	3.393**
Test weight	5.294**	2.662*	7.089**	4.294**	2.624*	1.412
Seed yield plant^{-1}	3.434**	1.900	1.247	0.177	0.140	0.307
Seed germination	3.497**	1.049	2.405*	3.243**	0.650	3.218**

*P<0.05, **P<0.01.

Table 5. Correlation matrix of different spike traits in C. ciliaris over three different years

Trait	Spikes plant^{-1}	Spike length	Seeds spike^{-1}	Test weight	Seed yield plant^{-1}	Seed germination
I-year (2003) (n=20)						
Spikes plant^{-1}		0.462*	0.182	0.115	0.941**	0.462*
Spike length	0.518*		0.671**	0.471*	0.618**	-0.094
Seeds spike^{-1}	0.241	0.779**		0.224	0.290	-0.250
Test weight	0.179	0.755**	0.763**		0.301	-0.107
Seed yield plant^{-1}	0.973**	0.568**	0.378	0.235		0.266
Seed germination	0.589**	0.255	-0.063	0.108	0.468*	
II-year (2004) (n=20 for primary spikes, n=14 for secondary spikes)						
Spikes plant^{-1}		0.523*	-0.281	0.592**	0.978**	0.462*
Spike length	0.550*		0.089	0.664**	0.643**	0.172
Seeds spike^{-1}	0.224	0.635*		0.340	-0.249	-0.070
Test weight	0.494	0.634*	0.559*		0.663**	0.286
Seed yield plant^{-1}	0.993**	0.579*	0.261	0.499		0.457*
Seed germination	-0.133	-0.107	0.208	0.396	-0.085	
III-year (2005) (n=20 for primary spikes, n=15 for seccondary spikes)						
Spikes plant^{-1}		0.423	0.012	0.435	0.955**	0.538*
Spike length	0.232		0.741**	0.597**	0.496*	-0.006
Seeds spike^{-1}	-0.397	0.417		0.402	0.115	-0.203
Test weight	0.253	0.680**	0.094		0.505*	-0.004
Seed yield plant^{-1}	0.972**	0.272	-0.354	0.358		0.396
Seed germination	-0.351	-0.610*	-0.274	-0.282	-0.348	

Values of primary spikes are above diagonal and values of secondary spikes are below diagonal; *P<005, **P<0.01.

Test weight of primary spikes was maximum 3.91 g for second year and it was significantly higher than of other years. Almost same trend was observed for seed weight of secondary spikes. Total seed yield plant^{-1} was minimum (8.6 g) in the first year and maximum (12.9 g) in the second year. In first year, both types of spikes contributed equally to total seed yield plant^{-1}, whereas in the second year about two-third of the seed yield was contributed by primary spikes and same trend was observed during third year also. So contribution of primary spikes to the total seed yield is stabilized with the age of the plants. Though total rainfall in the second year was less, but the benefit of established crop and more rains of August (139 mm) significantly enhanced spike length, seeds spike^{-1}, test weight and seed germination for both types of spikes.

During first year, seed yield of primary spikes had positive and significant relationship with spikes plant^{-1} and spike length (Table 5). Spikes plant^{-1} also had significant positive association with spike length and seed germination. Other positive and significant correlations were between spike length and seeds spike^{-1}, and between spike length and test weight for primary spikes. Similar significant associations were for secondary spikes. During second year, the relationship trend was same for spikes plant^{-1} with spike length and seed yield. For all the three years of growth, for primary and secondary spikes, only number of spikes plant^{-1} had positive and significant relation with seed yield. Number of primary spikes had significant association with seed germination irrespective of years. The association analysis showed that more seed yield is expected by selecting primary spikes without compromising the seed quality.

Seed yield and germination were maximum in the second year of establishment. Primary spikes plant^{-1}, contributing significantly to total seed yield, also had positive and significant association with its seed yield and seed germination. Secondary spikes contributed about one-third of the seed yield (of which about one-third was germinable) and its germination meets the requirements of Indian Minimum Seed Certification Standards. So, the collection of seeds from secondary spikes cannot be neglected. But overall primary spikes with better seed germination fulfill main requirement of seeds. The genetic variation present in the material can be exploited for more seeds from primary spikes.

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