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Experimental studies on seed production of tropical grasses in Kenya. 6. The effect of harvest date on seed yield in varieties of *Setaria sphacelata, Chloris gayana* and *Panicum coloratum*

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Summary

The effect of harvest date was investigated in seed crops of varieties of *Setaria sphacelata* (Nandi), *Chloris gayana* (Rhodes grass) and *Panicum coloratum* (Coloured Guinea) over four years from 1968-1971. Harvest date did not appear to be very critical; it could generally be spread over a period of 1 - 2 weeks. The interval between initial heading and optimum harvest date was normally 6 - 7 weeks. In most crops it was observed that considerable shedding of spikelets could be tolerated before yields of PGS (Pure Germinating Seed) dropped with subsequently delayed harvest dates. As much as 30-50% shedding could be tolerated in Coloured Guinea but usually less than that in Nandi and Rhodes grass. It is suggested that most of the early shedding concerned empty spikelets.

Early heading varieties produced nearly twice as much seed as late heading ones.

Introduction

In seed crops prone to shedding, yields are often sensitive to harvest date (Evers and Sonneveld, 1956; Griffiths et al., 1967). Evans (1966) found that seed losses in ryegrass and cocksfoot were as high as 40-50% when harvesting was carried out 4 days after the optimum date. Shedding is also prevalent in tropical grasses. The picture is further complicated by the wide variety in age of heads and spikelets within heads due to lack of uniformity in heading and flowering (Boonman, 1971a).

In Kenya seed is usually harvested by hand; heads are reaped with sickles and stooked in the field to mature. After a fortnight, seed can be beaten out readily with sticks. Unlike temperate grasses and cereals, tropical grasses are invariably still green at seed harvest.

The present study was prompted by the anxiety among seed growers that the margin between under- and over-ripeness is very narrow. Poor yields are often attributed to having harvested at the wrong time. Traditionally, growers were advised to harvest at the first sign of shedding but this recommendation does not appear to have been based on critical investigation. Hence, it appears imperative to determine how critical the timing of harvesting is and how this can be recognized in the field.

The experiments described below ran concurrently with those on tillering and heading previously reported (Boonman, 1971b). The treatments consisted of different harvest dates. Of each harvest date, yield of clean seed and percentage Pure Germinating Seed (PGS) were measured to calculate the yield of PGS. Observations were also taken on 1000-grain weight of the clean seed and on the percentage of shedding at each harvest date.

Materials and methods

The experimental lay-out has been described in a previous paper (Boonman, 1971b). The varieties were *Setaria sphacelata* cv. Nandi I and Nandi III; *Chloris gayana* cv. Mbarara, Masaba and Pokot Rhodes; *Panicum coloratum* cv. Solai, usually referred to as Coloured Guinea. *Panicum maximum* and *Brachiaria ruziziensis* are of minor importance as seed crops and are not considered in this study.

The first harvest was invariably taken 3 or 4 weeks after Initial Head Emergence (IHE, 5-10 heads per m^2). Subsequent harvests followed at the intervals shown in Table 1.

The interval between harvests was shortened in 1970 and again in 1971 to define the effect of harvest date more precisely. In both years, 2 crops were allowed to develop to conform with commercial practice.

A total of 1212 plots were handled in this study. The usual hand methods of harvesting were followed. At each harvest date 25 random, fully emerged heads were rated visually for percentage shedding of spikelets. Each treatment was subjected to germination tests.

Table 1. Harvesting schedule.

Year	Interval between harvests (weeks)	Number of harvests	Period of optimum harvest dates
1968	2	5	Sept. - Oct.
1969	2	5	August
1970 early - season	1	5	June - July
1970 late - season	1	5	Oct. - Dec.
1971 early - season	½	10	July - August
1971 late - season	½	10	Nov. - Jan. 1972

Results

To simplify the presentation of the data accumulated over 6 seasons of 6 varieties, a summary of the essential data of all 36 crops is given in Table 3. In Table 2 a more detailed account is given of 6 crops, i.e. of 3 different seasons of one variety (Nandi I) and of 3 varieties in one season (early 1971). Fig. 1 presents a picture of how yield of clean seed and PGS, and percentage of PGS and shedding varied, on average, according to date of harvest. Fig. 1 is typical of what was found in nearly all crops: optimum harvest date (OHD) for yield of clean seed was reached before the OHD of PGS yield and shedding affected yield of clean seed more than yield of PGS, as will be elucidated below.

It is evident from Table 2 that harvest date had a profound effect on all yield aspects under investigation. The most important of these is the yield of PGS (yield of clean seed $\times$ % PGS = yield of PGS). Yields reached a maximum at a certain date, the optimum harvest date (OHD), but statistical analysis revealed that nearby harvest dates were often not significantly lower in yield than OHD. For instance, in the Nandi I crop of 1969

Table 2. The effect of harvest date on aspects of seed yield.

	Harvest date (weeks after IHE)																			LSD	
	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	$P < 0.05$	$P < 0.01$
Nandi I, 1969																					
Yield of clean seed (kg/ha)			88				108				80				69				54		
PGS (%)			4				9				14				17				13		
Yield of PGS (kg/ha)			3				10a				11a				12a				7a	5	7
1000-grain weight (mg)			520				570				550				600				630		
Nandi I, late 1970																					
Yield of clean seed (kg/ha)			173		123		83		55		23										
PGS (%)			5		15		13		12		21										
Yield of PGS (kg/ha)			9		18		11		7		5									4	6
1000-grain weight (mg)			260		290		350		350		370										
Shed spikelets (%)			0		10		40		70		90										
Nandi I, early 1971																					
Yield of clean seed (kg/ha)		29	39	44	132	105	125	144	129	130	128										
PGS (%)		0	3	11	10	42	40	53	53	58	48										
Yield of PGS (kg/ha)		0	1	5	13	44	50	76b	68b	75b	61									12	16
1000-grain weight (mg)		270	290	320	320	500	480	520	520	490	490										
Shed spikelets (%)		0	0	0	0	10	30	40	40	50	40										
Mbarara Rhodes, early 1971																					
Yield of clean seed (kg/ha)		93	48	50	77	104	143	109	73	88	71										
PGS (%)		3	9	13	32	39	32	45	46	51	54										
Yield of PGS (kg/ha)		3	4	7	25	41c	46c	49c	34c	45c	38c									17	24
1000-grain weight (mg)		240	220	240	260	270	260	270	270	250	260										
Shed spikelets (%)		0	0	0	0	10	30	20	70	50	60										
Coloured Guinea, early 1971																					
Yield of clean seed (kg/ha)		107	111	149	162	142	209	137	120	111	107										
PGS (%)		0	2	7	9	20	12	28	52	44	40										
Yield of PGS (kg/ha)		0	2	10	15	28	25	38	62d	49d	43d									20	28
1000-grain weight (mg)		330	330	370	380	500	410	530	560	560	600										
Shed spikelets (%)		0	0	0	0	10	30	40	50	75	75										

PGS-yields followed by the same letter do not differ significantly at $P < 0.05$.

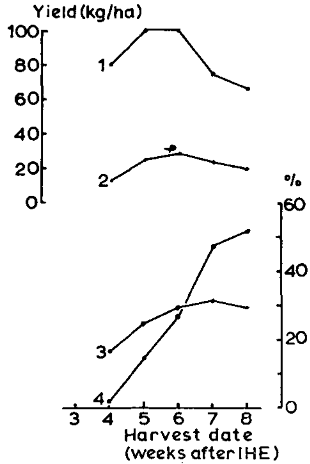

Fig. 1. The average effect of harvest date on yield and shedding. 1 = yield of clean seed; 2 = yield of PGS; 3 = % PGS; 4 = % shedding.

yields were highest at the 10th week (W_{10}) but those at W_6, W_8 and W_{12} were not significantly lower at $P < 0.05$. Consequently, any harvest date from 6 - 12 weeks after IHE was appropriate to achieve maximum yield. In other words, harvesting could be carried out over a safety range or margin of 6 weeks. In contrast, the Nandi I crop of late 1970 had no such margin. It showed a critical OHD at W_5, with significantly lower yields at W_4 and W_6. Of the early 1971 crops, Nandi I, Mbarara Rhodes and Coloured Guinea gave harvest margins of 1 week ($W_{6\frac{1}{2}}$ - $W_{7\frac{1}{2}}$), $2\frac{1}{2}$ weeks ($W_{5\frac{1}{2}}$ - W_8) and 1 week (W_7 - W_8), respectively. Obviously, these safety ranges were even wider at $P < 0.01$.

The OHD and harvest margins of all 36 crops, together with the corresponding data on PGS yields, 1000-grain weights and shedding are presented in Table 3. Yield of PGS (a) and 1000-grain weight (d) are given for the optimum harvest date (b) only, while (c) indicates the range, if any, of harvest dates on which PGS yields were not significantly lower than at (b). Under (e) the percentage of spikelet shedding is given for the last date of (c) or, where no range was present, for OHD.

It can be seen from Table 3 that OHD varied according to season and, to a lesser extent, according to variety. In more than 70% of all 36 crops, OHD occurred at W_5, W_6 or W_7, with an overall average of 6.6 weeks after IHE. The crops of 1969 and late 1971 were clear exceptions, with intervals between IHE and OHD of, on average, 8.8 and 4.8 weeks, respectively. This was most likely due to climatic reasons. The early-season crops normally mature in June or July and the late-season crops in October or November. Table 4 presents the long-term climatic data for these periods. The crops of 1969 and late 1971 were harvested in unusual months (Table 1), with different weather in the period of heading and maturation (Table 4). The 1969 crop matured in weather with more rain and fewer hours of sunshine than normal, whereas the crop of late 1971 had less rain and more hours of sunshine than the usual harvest months. This would suggest that the interval between IHE and OHD is reduced in bright, dry weather. However, more data on unusual harvest periods are needed to verify this theory, since the above trend was not consistent in all seasons of this study.

Varieties differed little in OHD, largely irrespective of whether they were early or late heading. The only consistent difference observed was that the late heading Pokot Rhodes (Boonman, 1971b) was never later in OHD than Masaba Rhodes.

Table 3. The effect of harvest date on:
(a) yield of pure Germinating Seed (kg/ha) at (b);
(b) optimum harvest date (weeks after Initial Head Emergence);
(c) range of weeks of harvests with yields not significantly lower than at (b);
(d) 1000-grain weight (mg) at (b);
(e) percentage of spikelets shedding at last date of (c), or at (b).

Variety		Year/season						
		1968	1969	early 1970	late 1970	early 1971	late 1971	Mean
	Interval between harvests (weeks)	2	2	1	1	½	½	
Nandi I	(a)	24	12	9	18	76	50	32
	(b)	6	10	5	5	6	4½	6.1
	(c)	6-6	6-12	4-5	5-5	6-7	4-4½	1.4*
	(d)	330	600	290	290	520	500	420
	(e)	10	NR	10	10	60	10	20
Nandi III	(a)	5	12	4	12	35	19	15
	(b)	7	8	6	6	6	6	6.5
	(c)	5-9	8-8	3-9	5-6	4½-6	4-7	2.6
	(d)	330	570	280	330	490	500	420
	(e)	10	NR	60	20	20	30	30
Mbarara Rhodes	(a)	56	15	32	40	49	73	44
	(b)	8	11	5	6	6	4	6.7
	(c)	6-8	5-11	5-5	6-9	5-7½	3½-6	2.7
	(d)	340	270	240	260	270	290	280
	(e)	20	NR	10	60	50	50	40
Masaba Rhodes	(a)	68	10	12	84	32	36	40
	(b)	6	10	8	7	7½	5½	7.3
	(c)	6-6	4-10	8-8	6-8	5-7½	4-6	2.1
	(d)	320	280	200	270	240	270	260
	(e)	0	NR	40	60	30	10	30
Pokot Rhodes	(a)	53	6	11	48	12	13	24
	(b)	6	6	7	6½	7½	3	6.0
	(c)	6-6	4-10	7-7	5-7	6-8½	3-4	1.9
	(d)	370	320	250	330	290	310	310
	(e)	30	NR	30	40	60	NR	40
Coloured Guinea	(a)	46	46	78	30	62	51	52
	(b)	8	8	6	7	6½	5½	6.8
	(c)	8-12	8-10	6-6	6-7	6½-7½	4½-6	1.6
	(d)	390	380	500	420	560	530	460
	(e)	30	NR	50	40	70	50	50
Mean	(b)	6.8	8.8	6.2	6.3	6.6	4.8	6.6
	(c)	1.7	4.3	1.2	1.5	1.8	1.8	2.1*
	(e)	20	NR	30	40	50	30	30

* Means denote average length of range in weeks.
NR = not recorded.

Table 4. A climatic comparison of seed maturation periods.

	Monthly rainfall (mm)	Days with more than 1 mm rain	Daily hours of sunshine	Mean daily temperature (°C)
July - August 1969	139	18	6.7	17.3
June - July (long-term)	123	16	6.9	17.5
November - December 1971	58	8	7.5	17.5
October - November (long-term)	89	13	6.9	18.1

Table 3 also indicates that the safety margin of harvest dates was fairly wide in most crops. About 50% of all 36 crops had a margin of 2 weeks or more, 75% had 1 week or more, and in only 25% of the crops OHD was critical. On average, a margin of 2.1 weeks was observed, calculated on the basis of $P < 0.05$; at $P < 0.01$ this was increased to even 2.4 weeks (data not presented). The 1969 crops were again exceptional. The margin amounted to as much as 6 weeks in 4 of the 6 varieties. Compared with other seasons, this could not be attributed to weather, yield level, harvest interval or experimental error. Seasons and varieties alike, there were no significant correlations between PGS yield at OHD, interval between IHE and OHD, and harvest margin, so that all varied independently.

At each harvest date, 25 randomly collected heads were rated visually on a 1-5 scale and percentage of shedding of spikelets was calculated. Fig. 1 and Table 2 show that the percentage of shedding increased rapidly as harvest was delayed, normally starting 4-5 weeks after IHE. The shedding characteristics of all crops are given in Table 3. To indicate how much shedding can be tolerated before PGS yields drop with further delayed harvesting, shedding percentages are given only for the last date of the safe harvest range or for OHD where no range occurred. At these dates, most crops tolerated considerable shedding which seemed to vary according to species. Coloured Guinea tolerated more shedding than Rhodes grass and Nandi.

As the percentage of shedding increased yield of clean seed reached its maximum soon in contrast with the percentage of PGS which continued to increase for a longer period (Fig. 1, Table 2). It was not until 40-50% shedding occurred that the percentage of PGS reached a maximum. Fig. 2 shows the relation between shedding and PGS yield as derived from Fig. 1. Yield of PGS increased until some 25% of the spikelets had shed and decreased beyond that point.

The relationship between OHD for yield of clean seed and OHD for percentage PGS

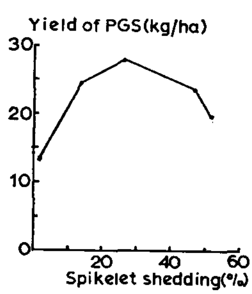

Fig. 2. The effect of shedding on the yield of PGS.

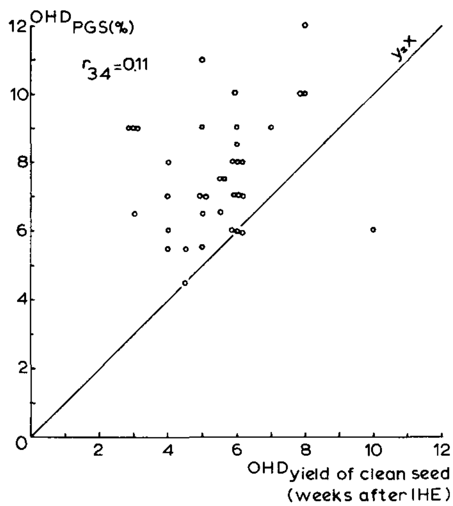

Fig. 3. The relation between optimum harvest date (OHD) for yield of clean seed and percentage PGS.

of all crops is borne out in Fig. 3. The maximum percentage PGS was clearly reached at a later date than maximum yield of clean seed, the difference being on average some 2 weeks. Only one crop was situated below the 45° line. In a generalized sense, the following chronological sequence prevailed:

$$\mathrm{OHD}_{\text{Yield of clean seed}} \xrightarrow[\text{1 week}]{} \mathrm{OHD}_{\text{Yield of PGS}} \xrightarrow[\text{1 week}]{} \mathrm{OHD}_{\text{PGS (\%)}}$$

It is evident that seed maturation was better at more advanced harvest dates. The data on 1000-grain weight lend support to this contention (Table 2, Fig. 4). Except in Rhodes grass, 1000-grain weight increased markedly with delayed harvest date.

The 1000-grain weight also varied according to season and variety (Table 3). In Coloured

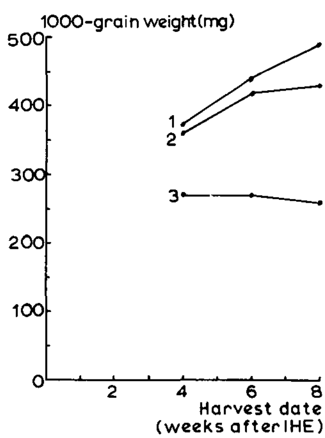

Fig. 4. The average effect of harvest date on 1000-grain weight. 1 = Coloured Guinea; 2 = Nandi I; 3 = Mbarara Rhodes.

Guinea and both Nandi varieties, weights were highest in 1969 and 1971, years with low and high yields, respectively. In Rhodes grass weights were highest in 1968, the establishment year. Coloured Guinea tended to produce the heaviest seed of all varieties, followed by Nandi and, finally, Rhodes grass. At the varietal level, Pokot produced heavier seed than Mbarara and Masaba Rhodes.

The PGS yields presented in Table 3 give a good comparison of the yielding ability of the different varieties, since they all refer to the optimum harvest date. Nandi I produced more than twice the amount of Nandi III; Mbarara produced nearly twice as much as Pokot Rhodes. The early species Coloured Guinea was the best overall. Consequently, the highest yields were produced by the early heading varieties. Yields varied considerably according to season and a strong variety $\times$ season interaction was apparent.

Discussion

Harvest date was critical in only a quarter of all 36 crops investigated in this study. In half of the crops, harvesting could be carried out safely over a range of dates covering 2 weeks or more. In 75% of the crops this safety margin was more than 1 week. It can therefore be concluded that harvest date is not very critical in the tropical grasses of this study. This finding is of practical importance because it means that the seed grower can confidently and conveniently determine when to harvest.

There was no indication that the rapid heading varieties, Coloured Guinea and Mbarara Rhodes (Boonman, 1971b) had narrower margins than other varieties. The data on heading for the 1970 and 1971 crops (data not presented) confirmed the earlier finding (Boonman, 1971b) that OHD was reached long before head numbers reached their maximum. After IHE, head numbers increased at an almost constant rate until a stage beyond that of OHD. This extended heading, together with the prolonged flowering within heads (Boonman, 1971a) is the explanation for the occurrence of a 1 - 2 week safety margin in harvesting. Flowering is reduced in late-emerging heads (Boonman, 1971a); otherwise, an even wider margin might have been expected. In temperate grasses Evans (1966) also found that harvest date was less critical if flowering was prolonged.

In an experiment on *Setaria sphacelata*, involving various varieties, nitrogen levels, row widths and harvest dates, Hacker and Jones (1971) also found no differences in yield of clean seed between harvest dates covering a 2-week period. This only applied, however, if yields were averaged over the 5 seasons of that study. Within seasons, yields varied significantly with harvest date but the rankings were not consistent over the seasons. This experiment differed from the one before us in that no practical harvest or ripeness indicators were used, which are needed to ensure the repeatibility of harvest dates in this type of experiments. Moreover, yield of clean seed is no adequate yield determinant because of its low correlation with percentage PGS (Fig. 1, Table 2, Fig. 3).

Date of IHE is important as base date for the timing of harvest dates in each season and can, together with the percentage of shedding, be used as a practical ripeness indicator. The interval between IHE and OHD was normally about 6 - 7 weeks (Table 3), so that IHE is a useful guide to predict the approximate date of harvest. More evidence is required to confirm the trend observed in Table 4 that the interval between IHE and OHD is affected by the weather prevailing during heading and seed maturation.

Shedding is also an important ripeness indicator. In former practice, the recommended harvest date was at the first sign of shedding but this is obviously too early. A considerable amount of shedding can be tolerated before PGS yields drop (Table 3). In Coloured Guinea, PGS yields were not affected until 30-50 or more percent of the spikelets had shed. Rhodes grass and Nandi were more sensitive to shedding than Coloured Guinea, yet their tolerance was still high.

The large amount of shedding that can apparently be tolerated without impairing PGS yields (Fig. 2), raises the question whether the early shed seed does indeed consist of properly developed spikelets. Naturally, as harvesting is delayed shedding, in absolute sense, increases and the losses incurred may be off-set by an accompanying gain of new seed in late maturing heads and spikelets. This complication was avoided in this study by determining the percentage shedding in a randomly harvested sample, containing old and newly emerged heads. Yet, percentage shedding increased rapidly as heading proceeded. Mwakha (1970) suggested that in *Entolasia imbricata* unfertilized spikelets absciss early, while fertilized ones only absciss on ripening. Circumstantial evidence suggests that most of the early shedding in the material of the present study also concerned empty spikelets:

a. OHD of yield of clean seed preceded OHD of percentage PGS and yield of PGS by on average 2 and 1 week, respectively. Consequently, yields of clean seed could well drop, through shedding, while PGS yields were still on the increase, apparently because full spikelets were retained (Fig. 1, Fig. 3).

b. The 1000-grain weight of harvested, clean seed increased with delayed harvest date in Nandi and Coloured Guinea, though not in Rhodes grass (Table 2, Fig. 4).

c. Some 3 to 4 months after IHE, shedding is normally complete even in the late emerged heads. It was shown earlier (Boonman, 1971a) that flowering is very much reduced in late-emerging heads so that seed setting is likely to be minimal. Hence, if the premature shedding in the late emerged heads is due to bad seed setting, the same principle will apply to other circumstances of bad seed setting.

Gordin-Sharir and Gelmond (1966) also concluded that cutting Rhodes grass too early resulted in a high percentage of empty spikelets.

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