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On the seed production of tropical grasses in Kenya

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Abstract

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The small amount of viable seed that can be harvested from tropical ley grasses such as *Chloris gayana*, *Setaria sphacelata* and *Panicum spp.* is largely due to the wide range in maturity between different heads and in maturity between seeds in any head. Ripe seed is also liable to shed. Adequate and timely top dressing with nitrogen, close row width and careful choice of harvest date increased seed yield either directly or by synchronizing ripening. There was considerable variation within and between varieties in seed yield characteristics: heading date, head number and seed setting, which all displayed high heritability. Heading date and head number were closely correlated with vigour of regrowth. Varieties could well be improved simultaneously for seed and herbage productivity.

Definitions and abbreviations

Yields and fertilizer rates are expressed in kg ha^{-1} $crop^{-1}$, unless stated otherwise. Wherever necessary, references are made in this article to tables (T), figures (F) or pages (P) of the above papers, indicated by their number (I-VII).

Heading tillers: these are tillers in which heads have fully emerged, the critical feature being that the base of the head should be visibly free from the subtending leaf sheath.

Crop Index: the ratio of yield of clean seed to total herbage dry matter yield.

IHE, Initial Head Emergence: stage of initial heading when 5–10 heads per m^2 have fully emerged from the subtending leaf sheath.

PGS, Pure Germinating Seed. The relevant formula is: yield of clean seed × percentage PGS = yield of PGS.

Contents

The content of this thesis has been previously published in the following papers:

Experimental studies on seed production of tropical grasses in Kenya.

I General introduction and analysis of problems. Neth. J. agric. Sci. 19 (1971): 23-36.
II Tillering and heading in seed crops of eight grasses. Neth. J. agric. Sci. 19 (1971): 237-249.
III The effect of nitrogen and row width on seed crops of *Setaria sphacelata* cv. Nandi II. Neth. J. agric. Sci. 20 (1972): 22-34.
IV The effect of fertilizer and planting density on *Chloris gayana* cv. Mbarara. Neth. J. agric. Sci. 20 (1972): 218-224.
V The effect of time of nitrogen top dressing on seed crops of *Setaria sphacelata* cv. Nandi. Neth. J. agric. Sci. 20 (1972): 225-231.
VI The effect of harvest date on seed yield in varieties of *Setaria sphacelata, Chloris gayana* and *Panicum coloratum*. Neth. J. agric. Sci. 21 (1973): 3-11.
VII (co-author: A. J. P. van Wijk) The breeding for improved seed and herbage productivity. Neth. J. agric. Sci. 21 (1973): 12-23.

Introduction

The object of these studies was to find ways of improving the low seed yields of tropical grasses. Kenya has a well established grass seed industry and it was assumed that such studies would be of practical value.

The approach was centered on the factors affecting seed yield of species that are popular with farmers for their herbage productivity (I, T1). The most important of these are *Setaria sphacelata* cv. Nandi and *Chloris gayana* cvs Mbarara, Masaba and Pokot Rhodes.

Formerly, commercial yields rarely went above 25 kg Pure Germinating Seed (PGS) ha^{-1} $crop^{-1}$. In spite of the inevitably high seed prices (I, T3) the demand for seed has risen steadily over the past decade (I, T2).

Certain cultural practices had been adopted in the past by seed growers (I; III; IV; V; VI), although there were very few data, locally or abroad, to support these practices. There was also little information on the relative merits of the many varieties available. It was, therefore, felt necessary to adopt the following lines of approach to the problem of low seed yield:

- to analyse the mechanism of seed yield: heading, tillering and seed yield components;
- to determine the techniques of management: fertilizer, row width, seed rate and harvesting time;
- to study the effect of weather and season;
- to study and utilize the genetic variation with the aim of producing varieties with higher seed yield, without detriment to herbage productivity.

Determinants of seed yield

A schematic review of seed yield components and the important factors affecting them is given in Table 1. Figures representing absolute values are in italics, whereas non-italics are relative to 100. For comparative purposes data are included for a good seed crop in Europe of *Phleum pratense* (Timothy), a small-seeded grass with some resemblance to *Setaria sphacelata* in seed yield components. The Nandi variety of the latter species was taken as the example in Table 1, but other species and varieties were found to behave similarly.

The striking features of Table 1 are (1) the gap between the actual and potential yields and (2) the importance of management and breeding as a means to bridge this gap.

The usual yield equation for seed crops is:

yield of (clean) seed = number of heads × number of seeds per head × seed weight.

A refinement of this equation to include the PGS is needed for tropical grasses because of the low viability of the seed normally encountered:

yield of PGS = yield of clean seed × %PGS = number of heads × number of PGS per head × seed weight.

It can be seen from Table 1 that potential yields of *Setaria* are close to actual yields obtained with *Phleum pratense* in Europe, while seed yield components are also very similar. In contrast, actual yields in current varieties are only a few percent of the potential. The examination of seed yield components offers some explanation. Head numbers in the current variety are only half of those of the potential, while seed weights are similar, but the principal cause for the huge difference in PGS yields lies in the low seedsetting, defined here as the average number of germinating seeds (PGS) per head emerged, which amounts to only 15% of the potential. Although low seedsetting and low head number are partly genetical in origin, seed yields could still be quite adequate were it not that in tropical grasses seed yield components do not operate uniformly. Here lies the crucial weakness of the grasses studied and this appears to be the main cause of the low seedset observed. Head emergence is prolonged both within and between plants and flowering within heads can continue for weeks (I, T4). Seed maturation is, therefore, spread over a very long period. To make things worse, seeds tend to shed upon maturation. Thus, at any harvest date, seed losses are incurred due to shedding or incomplete seed formation in late emerged heads, while many heads may be still enclosed in their leaf sheaths.

Heading patterns primarily affect head numbers but as no seed can set in heads that emerge too late, seed set and seed weight are affected also. In an undisturbed crop, heading can continue for 2–4 months prior to reaching the maximum number (I, F1, T5; II, F1, F2; III, T6; VII, F2) although tiller numbers reach their maximum in a shorter period (II, F1); III, F2). In contrast, in bred varieties of temperate grasses at higher latitudes, heading is confined to a number of days whereas tillering has been going on for months since the previous autumn. The daylength effect, which causes tillers of very different ages to elongate and head within a few days in temperate conditions (II, P248), seems to be absent at Kitale where differences between maximum and minimum solar daylength are only 9 minutes (I,

Table 1. Scheme of the response of seed yield and its components (absolute values in italics, non-italics relative to 100)

	Yield			Yield components					Crop Index (%)
	dry matter at seed harvest (kg ha^{-1})	clean seed (kg ha^{-1})	PGS (kg ha^{-1})	number of heads (m^{-2})	number of harvested clean seeds per head	PGS (%)	number of pure germinating seeds (PGS) per head	1000-grain weight (mg)	
Current variety (Nandi), good crop	*10000*	*160*	*50*	*250*	*180*	*30*	*50*	*350*	*1.6*
Management:									
good crop	100	100	100	100	100	100	100	100	100
without N	25	8	5	15	50	60	30	100	30
N applied 4 weeks late	90	60	35	80	80	55	45	100	70
wide rows	100	80	65	90	90	80	70	100	80
harvested 1 week early	100	100	80	90	120	80	100	90	100
harvested 1 week late	100	70	80	110	55	110	60	120	70
Weather:									
favourable	100	100	100	100	100	100	100	100	100
average	100	60	40	90	70	60	40	100	60
unfavourable	100	40	10	80	50	30	15	100	40
Varietal:									
current Nandi	100	100	100	100	100	100	100	100	100
improved variety	110	150	280	190	80	180	140	100	130
potential variety	> 110	500	1500	200	250	300	750	100	500
Current variety of *Phleum pratense* in Europe, good crop	—	*800*	*700*	*500*	*400*	*90*	*350*	*400*	—

P31) and heading can occur throughout the year. Any tiller that reaches the required stage is able to form a head, its time and success of emergence depending upon age and the concurrent effects from other tillers. In tropical grasses only a small proportion of tillers produce a head at seed harvest (III, F1, T3, T4; IV, T2, T4; V, T2). The highest number of tillers observed in this study was in Nandi, 2800 per m^2 producing 290 heads (III, F2, T6). *Panicum coloratum* cv Solai (Coloured Guinea) had the highest head number on record, 520 per m^2 (II, F2; VII, T1).

It is now important to see how the seed yield components respond to management, weather and breeding (Table 1) before we move on to a more detailed discussion of the various factors.

In the absence of nitrogen (N), which is evidently the most critical growth factor, all yield components, except 1000-grain weight, are greatly reduced. PGS yields drop much further (to 5%) than dry matter yields (25%), which illustrates the sensitivity of seed yield to N deficiency, partly through low head number (15%) and partly through low PGS per head (30%). With all other management factors listed in Table 1, herbage yields, head numbers and 1000-grain weight are affected only to a minor degree, i.e. less than ± 20%. The principal yield component subject to variation is the number of PGS per head. This component is primarily responsible for the reduction in PGS yield with late N dressing, wide row width and unfavourable season. With late harvesting the low number of PGS per head was compensated for by an increase in head number and 1000-grain weight, so that the ultimate PGS yield was not affected seriously.

It is further evident from Table 1 that considerable improvement in raising the number of PGS per head and, consequently, PGS yield per ha is achieved through breeding. Massive scope for further improvement still exists before yields approach anywhere near their potential.

From the above it is evident that attempts to increase seed yield should be two-pronged: (a) to maximize seed yield components and (b) to synchronize the action of each component. The effect various factors have on this will be discussed now.

Fertilizer and plant density

Nitrogen application and row width are of paramount importance as farmer's tools to increase yield. They are here dealt with together because of their frequent interaction.

As regards other fertilizers, phosphate was found to have no direct effect on PGS yields, its action being confined to promoting rapid establishment after sowing (III, IV). No deficiences of sulphur, potassium or other elements were noticed during these studies, even though some of them involved the annual removal of up to 20 tons of herbage dry matter over four to five years (III, T5, IV). Likewise seed rates even when varied from 0.2 to 1.8 kg PGS per ha (III; IV, T1) had no significant effect on PGS yield in the establishment crop or thereafter.

Nitrogen fertilizer and row width are important tools to manipulate heading and subsequent seed setting. It was found that any given crop produces more seed under conditions of close tiller density and appropriate N dressing. Tiller density should be such as to allow a high number of heads to emerge in a short time while suppressing the development and heading of late tillers (III). Stoloniferous species such as Rhodes grass achieve an optimum density of their own to some extent (IV, T1, T2), but row width is critical in non-stoloniferous species, such as setaria. It was found in Nandi that many tillers were produced at a narrow row width (III, F2) while N ensured that a high percentage of them produced a head (III, T4). At 130 kg N per ha, PGS yields were one third higher in narrow rows of 30 cm than in wide rows of 90 cm. However, increases in PGS yield due to narrow row width were often not accompanied by parallel increases in head number and 1000-grain weight and heads were invariably shorter, even in Rhodes grass (III, T3, T4; IV, T2). Thus, higher PGS yields were brought about by a better seedset, i.e. more PGS per head. One possible explanation is that seed maturation was more even at narrow row width because heading was noted to begin later (III, T3, T6, F1; IV, T2). Secondly, in short heads less competition may occur between spikelets so that more seeds mature fully per head.

PGS yields were increased sixfold to sevenfold by the application of 100 kg N per ha which appeared to be the general optimum in post-establishment crops. Levels above 100 kg gave increased PGS yields only in a few seasons with very high yields, e.g. late 1970 and 1971 (III, T2; IV, T3). In general, however, rates above 100 kg increased head numbers further, but either reduced the percentage PGS (e.g. Mbarara Rhodes (IV, T2, T3)), or percentage and yield of PGS (e.g. Nandi (III, T2, T4, F1)). Of the various possible causes (III, P32), the most likely one is that seed set is reduced in the long heads produced at high N. Though heads often look darker at high N, there appears to be more shedding in them (IV, P223).

Without N, PGS yields dropped rapidly after the establishment crop (Table 1; III, T2; IV, T3; V, T3). With low N, PGS yields were usually higher at wide row width. Conversely, wide row widths responded little to N (III, T2, T4, F1). This interaction points to the necessity of combining narrow row width and adequate N fertilizer.

Although N level is of great importance, its effect is greatly reduced when applied late in relation to the growing season and growth stage of the crop (V). N had most effect when applied to young grass early at the onset of the rains. A delay of 4 weeks decreased PGS yield by more than 60% in Nandi (V). The main seed yield component to be adversely affected by late N was the number of PGS per head (Table 1), though head numbers did decline, but not nearly as much. The 1000-grain weight was not affected if N was applied late in relation to growth stage. It, however, increased when cleaning cut as well as top dressing were delayed (V, T2). Late applied N seems to encourage late tillering and heading, probably at the expense of seed setting in early heads, without compensating for the latter (V, T5, T1). However, the date of IHE in the early-season crop was not affected by date of N application, so that heading and flowering occurred under the same weather conditions whether N had been applied early or not.

Time of harvest

Unexpectedly, Kitale grasses were found to be less sensitive to harvest date than their proneness to shedding would lead one to believe. In fact, it was found that shedding could amount to more than 30% without impairing PGS yield (VI, T3, F2). The most likely explanation for this unusual phenomenon is that it is empty spikelets that are shed early, while compensatory gains result from the late developing spikelets. The period over which harvesting can be carried out safely was on average 1–2 weeks for varieties of Nandi, Rhodes grass and Coloured Guinea, all investigated over a period of 4 years. The interval between IHE and optimum harvest date was normally 6–7 weeks.

Up until now, it seems that growers have had the habit of harvesting too early as they naturally become alarmed once shedding sets in. Although it is difficult to reproduce growers' practice, it can be assumed that some 20% of the crop potential was lost by this early harvesting (Table 1).

Weather

It was suggested that seed setting, the major variable determining PGS yield, was greatly affected by weather conditions in the pre-heading period (V). The available evidence suggests that rainfall is of critical importance. It can be seen from Fig. 1 that June is a relatively dry month and so are September and October. This may explain why early N application is crucial. It can also be seen from Fig. 1 that solar radiation and maximum temperatures drop steadily until July when they begin to rise again.

Large variations in PGS yields not only occurred within season but also between seasons and years, especially in Nandi (III, T2; V; VI, T3), though to a lesser extent in Rhodes grass (IV, T3, T4; VI, T3) and Coloured Guinea (VI, T3). In contrast, yields of dry matter were relatively constant (III, T5; IV, T4). Variation in head number was also limited, bearing no significant relation to PGS yield in a particular season (Mbarara Rhodes $r_5 = +0.51$, Nandi $r_3 = -0.61$). Consequently, head number cannot be used to predict PGS yield. There was also variation in 1000-grain weight from season to season, but heavy weights occurred in both good and bad seasons (VI, T3). These considerations point again to the overriding importance of seed setting as the principal determinant of PGS yield per season and, in turn, to the effect of weather.

The weather and yield data over the 5 years, i.e. 10 seed harvests, of this study, 1967–1971, show a definite relationship. In Table 2 a comparison is made between weather data for 5 harvests with above-average yields, 5 harvests with below-average yields and the long-term seasonal averages. Seasons with good yields had more rain which was better distributed

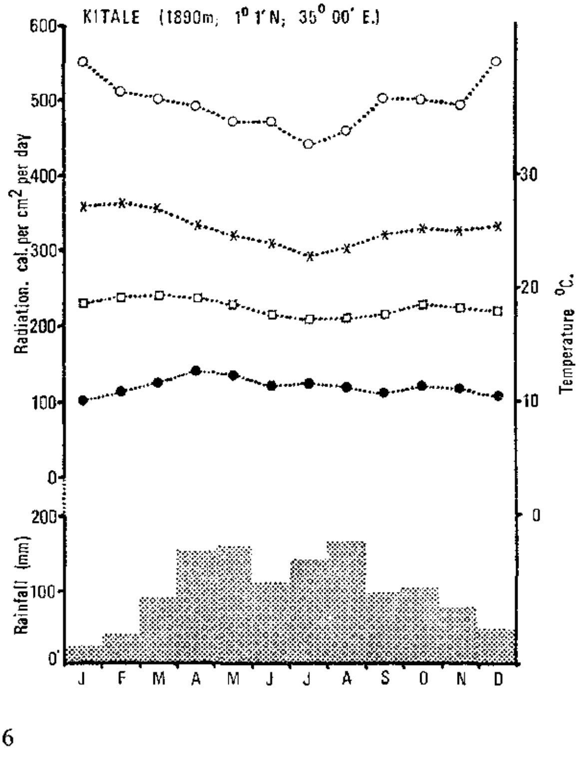

Fig. 1. Seasonal variation in energy imput, temperature and rainfall; ○......○ incoming solar radiation; ×......× mean maximum temperature; ●......● mean minimum temperature; □......□ mean temperature.

Table 2. A climatic comparison of growing seasons (April–June; July–September) over 1967–1971, at Kitale

	Number of seasons	Rainfall (mm)	Days with more than 1 mm rain	Periods with less than 5 mm rain		*Mean daily temperatures* (°C)			Daily hours of sunshine (Campbell-Stokes)	Solar radiation (Gunn-Bellani) cals cm^{-2} day^{-1}
				10-days	5-days	Max.	Min.	Mean		
Seasons with good yields	5	473	54	0.0	3.2	23.5	11.5	17.5	6.4	460
Seasons with bad yields	5	372	38	1.8	6.4	24.4	11.8	18.1	7.1	490
Average seasons	long-term	408	47	0.8	5.1	24.1	11.7	17.9	7.0	470
Coefficient of correlation with PGS yield (r_s)		+0.44	+0.80**	−0.91**	−0.55	−0.41	−0.25	−0.34	−0.54	−0.52

** $P < 0.01$.

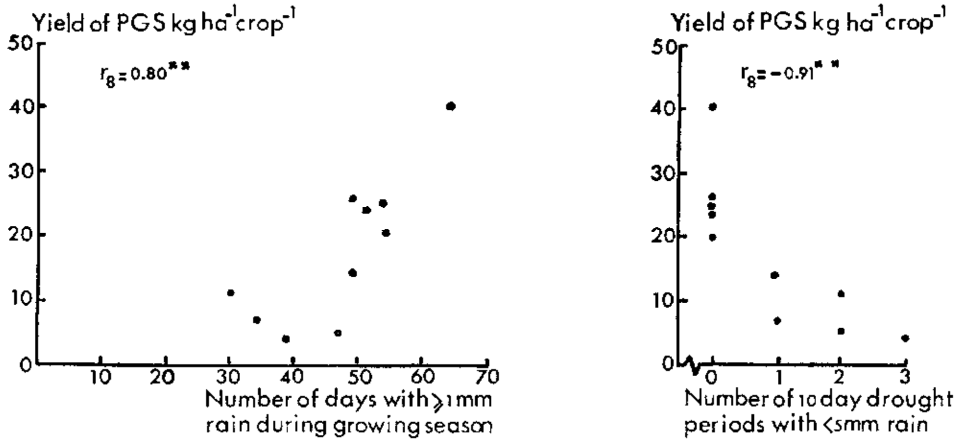

Fig. 2. The effect of rainfall distribution on PGS yield of Nandi in various seasons.

without prolonged droughts. They were also cooler with less solar radiation and fewer hours of sunshine. Considering however the correlation coefficients of Table 2 it appears that a good distribution of rainfall is the major prerequisite to achieving high PGS yield. This is further illustrated in Fig. 2. It seems that good yields are achieved if rain falls on more than half of the days of the growing season and if no drought periods occur lasting more than 10 days.

The grower can manage the crop so that early heading coincides with periods likely to have good rain. Alternatively, he may divert the crop for fodder purposes if the weather has been too unfavourable to justify waiting for the seed harvest.

The effect of weather needs further investigation, in particular to verify if rainfall in the pre-heading and, possibly, other periods is indeed of critical importance. If so, supplementary irrigation may well prove to be an economic proposition.

On the breeding side, it may be important to search for genotypes with a seed setting potential that is less dependent on weather conditions.

Genetic variation

Even though species and varieties behaved similarly in response to agronomic measures (II; III; IV; VI), they varied markedly in seed yielding potential (VI, T3; VII, T1). At the species level, *Panicum coloratum*, an early species, yielded very well, in contrast with *Panicum maximum*, cv. Makueni, although the latter is among the earliest of all Kitale varieties to come into head (II, T2). At the varietal level, the early heading varieties such as Nandi I and Mbarara Rhodes produced about twice as much as the late heading Nandi III and Pokot Rhodes, respectively. However, the medium-early Masaba Rhodes yielded almost as well as Mbarara Rhodes (VII, T1).

In the early Sixties, Nandi II and Nandi III were selected out of the original Nandi ecotype, subsequently renamed Nandi I, with the aim of developing late-heading varieties with supposedly better nutritive value. Only later did it become apparent that these late heading varieties and also those of Rhodes grass were in fact inferior not only in seed but also in total herbage production (VII).

The parental material of the above varieties had not been maintained so that each variety evolved further from one seed generation to the next. This inevitably led to genetic shift (I, T6) and a programme of re-selection was initiated in 1968, based on spaced plants collected from multiplication fields.

It was subsequently observed that these varietal populations were extremely heterogeneous in heading time, growth habit, plant vigour and head number. There was a period of 4–6 weeks between the dates of the first 5% and the last 5% of the plants to come into head (I, T5; VII, F2). Early heading groups of plants consisted largely of tall and vigorous plants with many heads. Conversely, poor plants with fewer heads made up the majority of late heading groups (VII, T2, T3, F1). Some plants produced no heads at all (VII).

In 18 clones of Nandi, grouped together on the basis of early and uniform heading, good vigour and high head number, great variation was observed as regards yield of PGS per plant, head number per plant and seed setting per head (VII, T6). Three outstanding clones had average PGS yields three times the average of all 18 clones. These three clones represent the improved variety of Table 1. Of major importance was the finding that PGS yield and its components displayed high heritability.

The high heritability and genetic gain observed for seed setting is of particular importance since this component was mentioned earlier as very sensitive to agronomic measures and weather. Seed setting is best determined by means of germination tests, however laborious they are. Weighing the clean seed is clearly not enough, because it was found (VII) that high yields of clean seed were not associated with good germination percentages ($r_{76} = -0.04$). Improved seedsetting may be genetical in origin or it may result from more even heading and flowering; it is worth noting that the best yielding clones had short heads. The production of many germinating seeds per head must be accompanied by a large number of heads, emerging over a short period. To this end, basis clones must have a uniform heading date, as well as the potential of forming numerous heads in seed production.

The close correlation between vigour, earliness and seed yield observed in this study makes it possible to combine improved seed and herbage productivity. A more vigorous variety, even if early heading and potentially high in head number, would provide more quality grazings per year. Vigorous, late heading plants do occur in small numbers (VII, F1) and varieties could be based on them. They are, however, unlikely to have the same seed yield potential as early heading varieties. Work is in progress to examine the relationships between vigour, yield and nutritive value in more detail with due respect to physiological and morphological characteristics.

Tropical grasses have the reputation of being very stemmy and this property is often used to explain the reportedly low nutritive value of these grasses. Admittedly, in old, unfertilized pastures, culms can be seen throughout the year giving the pasture a stemmy appearance but the actual numbers rarely exceed 10 heads per m². Abundant heading only occurs under good N dressing and does not take place until a minimum of herbage has developed, independent of daylength (VII). Even then heading is gradual, unlike the temperate grasses, and it takes at least 6 weeks after IHE before the weight of heading tillers makes up 50% of the total dry matter (II, F1; III, P27).

General conclusion

In this study, average PGS yields obtained over 4 years, 1968–1971, were over 40 kg ha^{-1} $crop^{-1}$ for Mbarara Rhodes (IV, T2; VI, T3) and 32 kg for Nandi I (VI, T3; VII, T1). The late heading varieties in these species, e.g. Pokot Rhodes and Nandi III, only produced about half as much. The best yielding variety was Coloured Guinea with an average yield of 52 kg ha^{-1} $crop^{-1}$. On an annual basis with 2 crops per year, PGS yields were highest in 1971 amounting to 110–130 kg in Nandi I, Mbarara Rhodes and Coloured Guinea.

In absolute sense and in terms of Crop Index, such yields are still low compared with temperate grasses where yields of 500–1000 kg are quite common in small-seeded species. On the basis of yields of clean seed, Crop Index was normally only 1–2% (III, T3, T4, F1; IV, T2, T4). However, a more favourable picture arises if account is taken of the low seed rates needed for the establishment of pastures of tropical grasses (1 kg PGS) in Kenya and the long productive life of seed fields (4 years or more). If these are considered, the tropical grasses compare more favourably with temperate grasses as regards the multiplication index. In good seasons this can amount to 50 per crop.

The main conclusion from the available data is that the PGS yield can be increased substantially.

In the short run this is brought about by adopting the right husbandry techniques of adequate (+100%; III, IV) and timely (+100%; V) top dressing with N, fairly narrow row width in tufted grasses (+30%; III) and correct choice of harvesting time (+20%; VI); the increases in yield over the traditional practices are indicated by the percentages between brackets. Phosphate and seed rate were of little importance.

N is no doubt the most crucial agronomic factor. It displayed a strong interaction with row width in Nandi. High yields can only be achieved with a combination of narrow row width and high nitrogen, applied early. The present seed/nitrogen price ratio enables the grower to adopt this practice readily. One kg PGS pays for 20 kg N. Analysis of seed yield components revealed that this combination promoted rapid tillering and, subsequently, more abundant as well as more concentrated heading. The principal effect of N is to increase the percentage of heading tillers and consequently the number of heads, while narrow row width promotes the seed setting within heads. Greatly reduced seedsetting per head resulted from late N application and unfavourable weather.

It was remarkable that none of the factors, except perhaps late harvesting, had much effect on 1000-grain weight of the harvested seed. Likewise, genotypic differences, though present, were not great. Hence, improvements in seed yield must come from increases in head number and seed setting.

Although improved agronomic techniques are instrumental in raising the seed yield of a given variety, a large gap still remains in relation to potential yields which can only be overcome to any appreciable extent by breeding. With the present data at hand it is tempting to suggest that a real break-through may be achieved by selecting plants with closely matched heading date, high head number and good seedsetting, all of which displayed a high heritability.

Concern that increased head number would necessarily diminish the nutritive value does not seem justified, in view of the evidence available (VII). To the contrary, as head number and earliness of heading date are closely and positively correlated with plant vigour, more vigorous varieties would permit the farmer to graze more frequently at a high level of nutritive value. Fears that increasing the percentage of heading tillers will lower the persistence were proven unfounded by the observation that, of the present Kitale varieties, Nandi I and Mbarara Rhodes were more persistent than their late and sparsely heading counterparts.

From the genetical point of view little can be done about the prolonged intra-plant heading patterns of tropical grasses. In the tropics, even heading is found in cereal crops, which are annuals and only produce a few tillers per seedling: the plants die after reproduction. A perennial grass perennates through tillering. Thus the perennial habit and prolonged heading patterns are closely tied up with each other. Unless, of course, one succeeds in developing varieties that are sensitive to the small variations in daylength occurring near the Equator. Even if this were feasible, it may be disadvantageous in other respects.

Doubling the head number may lead to doubled seed yields but the principal gains in seed yield will come from the breeding for better seedsetting. Selection for seed retention is another important undertaking but the issue is as yet somewhat obscure. There was evidence that much of the early shedding in a seed crop consists of empty spikelets (VI). On the other hand, selection for genuine seed retention can only be based on selected plants uniform in heading date and, possibly, flowering.

An interesting finding was that the present Kitale species and varieties responded similarly towards agronomic techniques and breeding, differences being largely of a quantitative nature. This makes it justifiable, though with due caution, to extrapolate from one situation to the other.

Summary

In Kenya, successful varieties have been developed from grass species such as *Chloris gayana* (Rhodes grass), *Setaria sphacelata* (setaria) and *Panicum spp.* (Guinea grasses). However, the low seed yields and consequently high seed prices are the main barrier to a more widespread use of these varieties. Nevertheless, there has been a steady increase in the area under certified seed production from 100 ha in 1961 to 1400 ha in 1970.

The maximum yield recorded in this study amounted to 127 kg PGS (Pure Germinating Seed) ha^{-1} year^{-1} obtained over 2 consecutive crops in *Setaria sphacelata* cv. Nandi I. Potential yields, calculated on the basis of seed yield components, approach those of temperate grasses, but actual commercial yields are only 5% of these. The main reason is that the seed yield components do not operate simultaneously. Within plants, heading continues for some 3 months and flowering within heads takes weeks to be completed. At seed harvest shedding and flowering often occur simultaneously within heads. Consequently, only a fraction of potentially productive heads and spikelets contributes to the PGS yield. Additionally, head numbers, seed set per head and 1000-grain weight are genetically low.

In the present varieties PGS yields can be increased substantially over former practice by:

- increasing the rate of nitrogen fertilizer to 100 kg N ha^{-1} crop^{-1} (100% increase in yield over the 60 kg N used in commercial practice);
- applying N as soon as possible after the onset of the rains (100% increase over a delay of 4 weeks);
- narrowing row width to 30–50 cm for tufted grasses such as Nandi (30% increase in yield over the traditional 90 cm row width);
- delaying harvest until 10–30% of the spikelets have shed.

It was found that species and varieties responded in a markedly similar way to agronomic measures. Nitrogen rate increased the number of heading tillers. Narrow row width occasionally did the same, albeit to a lesser extent, but the principal effect of narrow row width was to increase the seed setting per head. It is thought that this was brought about by the more concentrated head emergence observed at narrow row width and better seed maturation in the short heads invariably found at narrow row width, also in Rhodes grass. Seed setting was also the principal seed yield component enhanced by early applied nitrogen. The importance of seed setting is further emphasized by the finding that PGS yields varied greatly from season to season, independently of variation in head number, while herbage yields varied little. Although seed harvesting should be delayed until at least 10–30% of the spikelets have shed, harvesting time was not found to be very critical. It could generally be spread over 1–2 weeks without reduction in seed yield. Phosphate and seed rate were observed to exert only minor effects. In contrast with PGS yields, yields of herbage dry matter at seed harvest were very high. In Nandi, 10 tons of dry matter per ha were often achieved and an average response of 65 kg dry matter was obtained per kg nitrogen applied.

Although a substantial increase in PGS yield can be achieved through agronomic techniques, considerable inter-varietal and intra-varietal variation was noticed as regards PGS

yield. Early heading varieties yielded almost twice as much as late heading varieties of the same species. In spaced-plant populations of these varieties, wide variation was noted in heading date, plant vigour and habit, and head number. There was a period of at least 4 weeks between dates of the first 5% and the last 5% of the plants to come into head. Early heading plants consisted largely of very vigorous plants with many heads. Plants of poor vigour headed late and produced few heads. In a number of selected clones, three were found to produce PGS yields on average three times as high as the group average. High heritability was observed for week of heading, PGS yield and its components. By seeking a combination of even heading date, potentially high head number, good seed-setting and high vigour, it is possible to produce varieties with improved seed and herbage productivity.

Samenvatting (Over de zaadteelt van tropische grassen in Kenya)

Kenya beschikt over een aantal goede grasvariëteiten ontwikkeld uit soorten zoals *Chloris gayana* (Rhodes gras), *Setaria sphacelata* (setaria) en *Panicum spp.* (Guinea gras), maar de zaadopbrengst is laag. Zaadprijzen zijn dientengevolge hoog en dit belemmert de inzaai op grote schaal van deze grassen. Toch was er een toename in areaal van gekeurd graszaad van 100 ha in 1961 tot 1400 ha in 1970.

De hoogste opbrengst aan PGS (kiemkrachtig zaad), die in deze studie werd behaald, bedroeg 127 kg ha^{-1} jaar^{-1}, verdeeld over twee oogsten in *Setaria sphacelata* cv. Nandi I. De potentiële opbrengst, berekend op basis van zaadopbrengstcomponenten, benadert weliswaar de opbrengst verkregen met gematigde grassen, doch de praktijkopbrengsten bedragen in vergelijking niet meer dan 5%. De voornaamste oorzaak hiervan is het feit dat de opbrengstcomponenten niet synchroon fungeren. Binnen een plant duurt het ongeveer drie maanden voor de meeste pluimen zijn doorgeschoten en de bloei binnen pluimen voltrekt zich over enkele weken. Het is niet ongewoon om op de dag van oogsten zowel uitval als bloei aan te treffen binnen dezelfde pluim. Derhalve draagt slechts een gedeelte van de potentieel productieve pluimen en bloempakjes bij tot de zaadopbrengst. Bovendien zijn de halmproduktie, zaadzetting binnen pluimen en het 1000-korrelgewicht genetisch beperkt.

De praktijkopbrengst van bestaande variëteiten kan belangrijk worden verhoogd door:

- het verhogen van de stikstofgift tot 100 kg N ha^{-1} gewas^{-1} (100% opbrengststijging vergeleken met de gebruikelijke praktijkgift van 60 kg);
- het toepassen van de stikstofbemesting zo vroeg mogelijk aan het begin van het regenseizoen (100% opbrengststijging vergeleken met een uitstel van 4 weken);
- het vernauwen van de rijafstand in polvormende grassen zoals Nandi tot 30-50 cm (30% opbrengststijging vergeleken met de aloude rijafstand van 90 cm);
- het uitstellen van de oogstdatum tot een tijdstip waarop 10-30% van de bloempakjes zijn uitgevallen.

De verschillende soorten en variëteiten vertoonden een opmerkelijke overeenkomst in hun reaktie op teeltmaatregelen. Het effect van stikstof bestond vooral in het doen toenemen van het aantal doorschietende spruiten. Nauwe rijafstand had weliswaar soms hetzelfde tot gevolg, maar verbeterde voornamelijk de zaadzetting per pluim. Dit werd vermoedelijk veroorzaakt door een meer synchroon doorschieten van pluimen bij nauwe rijafstand en de waarschijnlijk meer gelijke rijping in de belangrijk kortere pluimen voorkomend bij deze rijafstand. De positieve invloed van een vroege toepassing van stikstof werd ook voornamelijk teweeg gebracht door een verbeterde zaadzetting. Het belang van de zaadzetting wordt voorts bekrachtigd door de waarneming dat PGS opbrengsten sterk varieerden van seizoen tot seizoen, grotendeels onafhankelijk van de variatie in pluimaantal, terwijl de opbrengsten aan totale droge stof weinig varieerden. Ofschoon de datum van zaadoogst niet dient plaats te vinden voordat 10–30% van de bloempakjes zijn uitgevallen, was de oogsttijd toch niet scherp bepaald, maar kon zonder opbrengstderving worden uitgespreid over 1–2 weken. Fosfaatbemesting en zaaizaadhoeveelheid bleken slechts van gering belang te zijn.

In tegenstelling tot de lage PGS opbrengsten werden hoge opbrengsten bereikt aan totale droge stof. Deze bedroegen vaak 10 ton op het moment van de zaadoogst in Nandi, hetgeen neerkwam op een gemiddelde van 65 kg droge stof verkregen per kg stikstof.

Teeltmaatregelen leidden tot een belangrijke opbrengstverhoging, maar er was met name ook een aanzienlijke variatie in opbrengstvermogen tussen en binnen de variëteiten. Vroeg doorschietende variëteiten brachten bijna twee keer zoveel zaad op als de laat doorschietende van dezelfde soort. Binnen de variëteiten is een grote verscheidenheid aanwezig ten aanzien van schietdatum, groeikracht, plant habitus en pluimaantal. In alle onderzochte variëteiten van Rhodes gras en setaria bedroeg de periode tussen het doorschieten van de vroegste en laatste 5% van de planten tenminste 4 weken. Vroege planten bezaten als regel een goede groeikracht en vertoonden veel pluimen. Planten met slechte groeikracht daarentegen waren laat met doorschieten en brachten weinig pluimen voort. Een aantal goede klonen werd geselecteerd waarin werd waargenomen dat een drietal topklonen gemiddeld driemaal zo hoge PGS opbrengst bezat als alle klonen gemiddeld. Een hoge heritability werd gevonden voor tijdstip van doorschieten, PGS opbrengst en de opbrengstcomponenten, met name ook de zaadzetting. Door het baseren van rassen op klonen met een gelijke schietdatum, potentieel hoog pluimaantal, hoge zaadzetting en hoge groeikracht, zal het mogelijk zijn zowel de zaadopbrengst als de weideproduktiviteit te verhogen.