THE EFFECT OF NITROGEN FERTILIZER AND ROW SPACING ON SEED PRODUCTION IN SETARIA SPHACELATA

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ABSTRACT

Seed yield of two frost tolerant setaria introductions was differentially affected by nitrogen rate (42-336 kg/ha/year) and season of harvest (January or May).

Linear response to nitrogen at the January harvest was greater for CPI 33452 than for CPI 32930. In the May harvests response to nitrogen remained linear for CPI 33452 but was quadratic for CPI 32930, which was higher yielding at the lower nitrogen rates but markedly lower yielding at the highest nitrogen rate.

Consistently higher yields for the May harvests than for the January harvests at the lowest nitrogen rate for both introductions indicated lower availability of soil nitrogen early in the season.

Row spacings of 50 or 100 cm had no significant effect on seed production, and there was no consistent benefit from split versus single nitrogen application for each harvest cycle. Interactions involving introductions, nitrogen *and* spacing *were significant in some harvests, and were largely attributable to poor response of CPI 32930 at the highest rate of nitrogen.*

Clean seed yield was correlated (r = 0.85 to r = 0.90) with inflorescence number which was in turn greatly influenced by nitrogen rate. Length of seed head and seed weight were not greatly affected by nitrogen treatment.

Calculated recovery of potential seed yield was only 5% to 7% and annual seed yield ranged from 20 to 90 kg/ha. Reasons for the low seed yields are discussed.

INTRODUCTION

Setaria sphacelata has been grown commercially in Queensland and northern New South Wales since 1961 (Barnard 1967). However, seed commands a high price in comparison to pasture grass seed in temperate regions, and this could limit the acreage sown. The high price of seed is related to low yields obtained—Vicary (1970) quotes a mean figure of 29 lb per acre (33 kg per ha). In contrast yields of 300-900 kg seed per ha may be expected from temperate grasses (Evans 1954, Lewis 1962, Griffiths *et al* 1967). The poor seed yield from setaria may result from a number of causes, such as low fertility, poor recovery, irregular initiation of inflorescences and seed ripening or sub-optimal management practices. In the short term, modification of management practices is most likely to result in improved seed production. The present paper is an investigation into the effects of row spacing and nitrogen application on seed production; in addition the sequence of inflorescence emergence and recovery of seed at harvest were studied as a basis for determining their contribution to low seed yield.

MATERIALS AND METHODS

Two of the most promising frost tolerant introductions of setaria, CPI** 32930 and CPI 33452 were chosen for study. Subsequent selections from CPI 33452 have

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** Commonwealth Plant Introduction

given rise to the new cultivar Narok. Both introductions are leafier and more palatable than the commercial cultivars Nandi and Kazungula. They differ in habit, CPI 32930 having mainly basal leaves whereas in CPI 33452 more leaves are borne along the stem. Local experience with these introductions from Kenya suggests that they are day neutral, and capable of flowering at any time of the year. The experiment was planted in May 1967 on an alluvial soil at Samford, south-east Queensland. Seed was sown at a rate of 1 lb per acre (1.1 kg/ha) of pure germinating seed, using a hand operated drill. The experiment was a randomised block split plot design, with four replicates. Main plots were the row spacings, 50 cm (S_{50}) and 100 cm (S_{100}) and sub-plots were the eight combinations of four levels of nitrogen, 42(N_1), 84(N_2), 168(N_3) and 336(N_4) kg per ha per year as urea and the two introductions. Nitrogen was applied in two equal dressings followed by irrigation in September and February at the start of each growth cycle and the plots were harvested in January and in May before the occurrence of damaging frosts. Phosphorus and potassium were applied at the rate of 250 kg superphosphate and 125 kg potassium chloride per ha each spring.

Each sub-plot consisted of five or ten eight-metre rows, depending on spacing treatment. Experimental harvests were taken from the centre three or six rows, respectively. Because it is extremely difficult to determine the best date for harvesting, complete rows (or pairs of rows in the narrower spacing) were harvested at weekly intervals over a two week period, giving three independent sub-harvests from each plot. The first harvest of each sequence was judged by experience, and at this time five to ten percent of seed heads were shattering. Harvest dates were 26th January to 9th February and 8th to 22nd May 1968; 20th January to 3rd February and 19th May to 2nd June 1969; and 5th to 19th January and 6th to 20th May 1970. After harvesting the entire area was cut back to 15 cm with a forage harvester.

In the third year of the experiment alternate rows of the narrower spacing were eliminated by severe cutting and dalapon application. A further treatment—single or split nitrogen application—was then imposed such that each treatment occurred twice on plots previously with narrow spacing and twice on plots previously at a wider spacing in the four replicates. The experiment was then treated as a completely randomised block.

Seed heads were harvested with reaping hooks and were dried in calico bags in a forced air drier at 32°C (90°F). Seed was separated by rubbing and sieving and then cleaned of empty hulls in a laboratory aspirator.

In the third year total numbers of fully emerged seed heads and seed heads more than half shattered from the N_1 and N_4 plots of CPI 33452 were recorded at weekly intervals (until the disturbance to the crop resulted in damage and loss of seed) and also at harvest. In addition the length of 50 seed heads from each of these treatments was measured and the weight of one thousand spikelets was recorded. Recovery of potential seed yield was calculated using these data and density of spikelets on the rachis assessed on nursery grown plants of the same introduction.

RESULTS

The effects of nitrogen, spacing, introductions and sub-harvest date on seed production and treatment interactions are considered separately. Data for the January 1968 harvest are not included, as residual soil nitrogen had a considerable effect on the low nitrogen plots. Rainfall and temperature data for the site are given in Table 1.

TABLE 1

Monthly rainfall (mm) for Samford for the years 1968-1970

Month	1968	1969	1970
January	433	66	152
February	86	57	88
March	73	69	197
April	36	28	57
May	60	232	11
June	5	18	19
July	34	21	13
August	49	236	15
September	21	26	38
October	10	168	200
November	61	142	125
December	85	59	468

Nitrogen

Application of nitrogen greatly increased seed yields ($P < 0.001$) at all harvests but yields were generally low (Table 2).

TABLE 2

Effect of nitrogen on seed production in setaria (kg/ha) at the different harvests

N (kg/ha/yr)	May 1968	Jan. 1969	May 1969	Jan. 1970	May 1970
42	18.74	7.65	14.20	5.57	22.75
84	18.94	9.90	17.87	7.90	27.88
168	25.12	15.87	21.26	20.93	33.89
336	27.41	18.26	18.83	34.37	38.92
L.S.D.* 5%	3.62	2.78	3.32	5.16	4.14
1%	4.81	3.70	4.40	6.82	5.49

The linear regression coefficients for the January harvests were about two to three times those calculated for the May harvests. The difference was not significant in 1969 but was highly significant ($P < 0.01$) in 1970. Intercepts were significantly lower ($P < 0.05$; $P < 0.001$) for the January harvest than for the May harvest in both years. Intercepts were similar for yearly totals, but slopes differed significantly ($P < 0.05$). This difference was attributable to the more favourable growing season in 1970 (Table 1).

The effect of applying nitrogen at the beginning of each growing cycle, or splitting the application with half at the beginning of the cycle and half after eight weeks was tested in 1970 (in the May harvest the first application was three weeks after the area was cut back). There was a slight reduction in seed yield from the split application treatment (Table 3) although this was not significant either in the January, the May harvest or for the combined harvests.

* Least significant difference

TABLE 3

Effects of single as opposed to split dressing of nitrogen on seed production in setaria (kg/ha)
(Means of four nitrogen levels and two introductions)

	Jan. 1970	May 1970	Total
N applied in one dressing	18.26	32.13	50.39
N applied as split dressing	16.13	29.59	45.72
Level of significance	N.S.	N.S.	N.S.

Spacing

No significant differences between spacing occurred at any of the harvests or for the totals of all harvests.

Introductions

In three of the five harvests, CPI 33452 yielded significantly more seed than CPI 32930 (Table 4). There was no significant difference in seed yield in May 1968 or May 1970. The greatest difference between introductions occurred in January 1970 ($P < 0.001$), but CPI 33452 was also higher yielding in January 1969 ($P < 0.001$) and May 1969 ($P < 0.05$), though these differences were small. However since there were pronounced interactions involving introductions and nitrogen, no overall conclusions can be drawn from main effects.

TABLE 4

Seed production by different introductions of setaria (kg/ha)
(Means of four nitrogen levels)

Introduction	May 1968	Jan. 1969	May 1969	Jan. 1970	May 1970
C.P.I. 32930	23.20	11.27	16.63	11.48	30.84
C.P.I. 33452	21.90	14.57	19.45	22.90	30.89
Level of significance	N.S.	***	*	***	N.S.

Date of sub-harvest

Yields differed markedly between sub-harvests ($P < 0.001$) with the exception of the January 1969 harvest but there was no consistent trend with sequence of sub-harvest (Table 5). The decrease of seed yield in May 1968 and increase in January 1970 suggested that these harvest sequences might have been too late and too early, respectively. In four of the five harvests, delay of seven days in harvesting resulted in a 40% drop in seed yield, or an increase of 40 to 50%.

TABLE 5

Seed production at different sub-harvests at 7 day intervals (kg/ha)
(Means of four nitrogen rates and two introductions)

	May 1968	Jan 1969	May 1969	Jan. 1970	May 1970
Sub-harvest 1	31.80	12.83	16.43	10.44	35.57
2	18.31	12.87	23.27	16.22	37.35
3	17.54	13.06	14.42	24.91	19.66
L.S.D. 5%	3.14	2.41	2.88	4.47	3.60
1%	4.15	3.20	3.81	5.92	4.77

Interactions

Significant interactions involving *spacing* occurred only in May 1969. At high levels of nitrogen there was a reduction in seed yield from the wider spacing, especially in the case of CPI 32930. This resulted in significant *spacing* × *nitrogen* ($P < 0.01$) and *spacing* × *introduction* × *nitrogen* ($P < 0.05$) interactions (Fig 1). The latter interaction approached significance in May 1968 but not in January 1969. These interactions could have resulted from shelf shading at high levels of nitrogen and close spacing with CPI 32930.

Split application of nitrogen had no major effect on seed yield, but did interact ($P < 0.05$) with *nitrogen* level in the May 1970 harvest when the highest seed yields obtained in the experiment were achieved. Seed yields were higher from the split nitrogen treatment at N_4, but lower at N_1, N_2 and N_3 (Fig. 2). Fig. 4 shows that this was due not to increased number of seed heads, but to increased weight of seed per head.

Significant interactions ($P < 0.001$) involving *introduction* and *nitrogen* occurred in May 1969 and January and May 1970 (Fig. 3). These resulted from an entirely different response pattern in the two varieties. Fitted linear regressions were significant or approached significance for both introductions for all January harvests, except January 1969, when moisture stress probably limited response in CPI 33452. Conversely, in May harvests there was a quadratic response of CPI 32930, although CPI 33452 was still linear. This quadratic response of CPI 32930 was associated with higher yields at low nitrogen levels, but markedly, reduced yields at the highest nitrogen level. This did not result from lodging in this introduction.

Introduction and *sub-harvests* interacted in May 1968 ($P < 0.01$) and January 1970 ($P < 0.05$). This would be expected as a result of even small differences between introductions in flowering time. There was an interaction between *nitrogen* and *sub-harvests* in May 1970 ($P < 0.001$) which may be interpreted as earlier maturity in the plots which received higher levels of nitrogen (e.g. see Fig. 4). This was particularly evident in CPI 32930, and resulted in an associated second order interaction of *introduction* × *nitrogen* × *sub-harvest* ($P < 0.01$). *Split application* × *nitrogen* × *sub-harvest* was also significant ($P < 0.05$); a delay in maximum seed yield resulted from split applications at the higher but not at the lower N rates.

Development of inflorescences

The earliest seed heads emerged three to four weeks after topping of the area and continued over a prolonged period up to both the January and May harvests of 1970 (Fig. 4). With the N_4 treatment harvested in January there was a linear increase between week 8 and week 17 (sub-harvest 3) after cutting back, which was unaffected by splitting the application of N. Seed heads more than half shattered followed a parallel trend with a lag period of five to six weeks indicating a five to six week period from head emergence to shattering. In the May harvest the trend was similar but a peak in total seed head number was obtained 15 weeks after cutting back. The decline in total seed heads with the final counting in week 17 was probably due to removal of some of the ripe heads by mice.

In both harvests total seed head number was greatly affected by the level of nitrogen fertilizer. Numbers at the N_4 level were increased five fold in the January harvest and nearly three fold in the May harvest compared with the values for N_1. It is also evident that in the January harvest the highest rate of nitrogen resulted in earlier production of seed heads. This was not apparent at the May harvest.

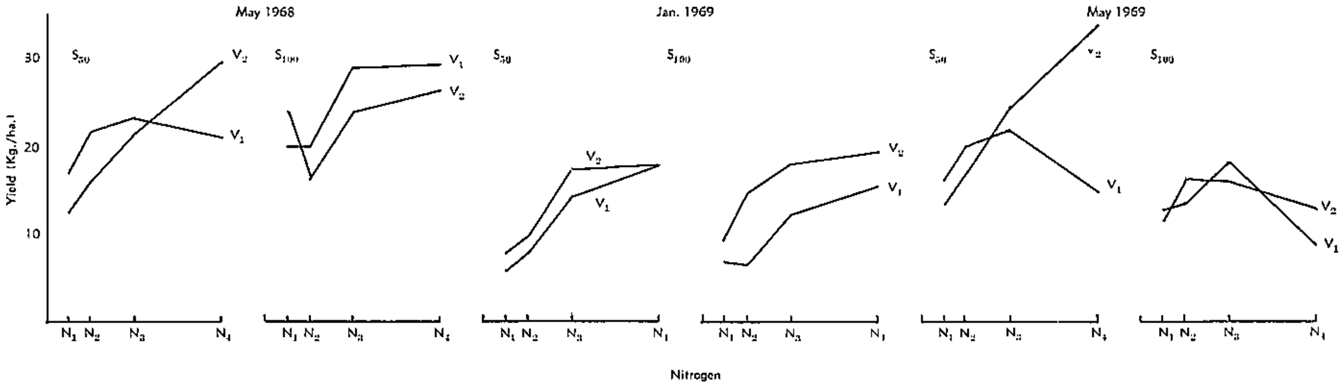

FIGURE 1

Interaction of nitrogen (N), introduction (V) and spacing (S) on seed production in setaria. ($N_{1,2,}$ $_4$ = 42,84,168 and 336 kg N per hectare per year; V_1 = CPI 32930. V_2 = CPI 33452: S_{50} and S_{100} = row spacings of 50 and 100 cm. respectively).

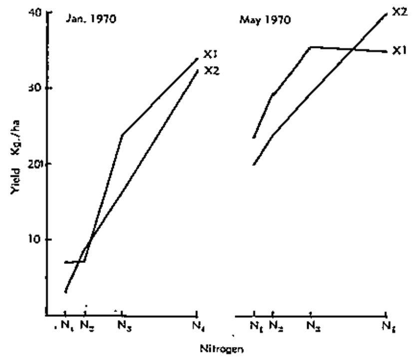

FIGURE 2

Interaction of nitrogen level and split (X2) as opposed to single (X1) dressing on seed yield in setaria.

Effect of nitrogen on seed head length and seed weight

Neither the level of nitrogen nor splitting the application affected seed head length. Values for the $N_{1(1)}$, $N_{1(2)}$, $N_{4(1)}$, $N_{4(2)}$ treatments were 20.70, 20.57, 20.85 and 21.89 cm respectively, with a mean of 21.0 $\pm$ 0.19 cm. The seed weight of cleaned seed was very similar for the N_1 and N_4 treatments and averaged 1200 $\pm$ 38 seeds/g.

Seed recovery

Cleaned seed yields were positively correlated ($P < 0.001$) with seed head number for both the January and May harvests of 1970, but the slopes of the regression lines differed (Fig. 5). The intercepts did not differ significantly from zero. Thus in January 1 g of seed was recovered from 23 seed heads and in May from 16 seed heads. Spikelet density on the rachis was obtained from nursery grown plants of the same introduction and averaged 53 $\pm$ 8.6 spikelets per cm. From the mean inflorescence length of 21.0 cm, the density of 53 spikelets per cm length and the mean seed weight of 1200 seeds per g the potential seed yield from 23 and 16 seed heads was calculated. Values were 21.3 g and 14.8 g respectively, and since only 1 g was recovered this represents a recovery of only 4.7% and 6.8% for the January and May harvests. From Figure 4 it can be seen that total seed head number at N_4 increased at a uniform rate of approximately 12 seed heads/m^2/week over the 9 week period preceding the January 1970 harvest and at 11/m^2/week over the 8 week period preceding the May harvest. It is very unlikely that ripe seed could be set in less than two weeks after emergence of the seed head and this could well extend to three weeks. So at any particular time approximately 24-36 seed heads/m^2 will fail to yield seed. This constant number of newly emerged seed heads will form a lower percentage of the total seed heads as the total number increases. However, beyond a period of 6-7 weeks the number of shattered seed heads will increase. Theoretically the yield should stabilize over a period when the number of shed seed heads equals the number of those recently ripened and there would be more likelihood of low yields through harvesting too early than too late. However, the yield data only show such a plateau at one harvest (Table 5).

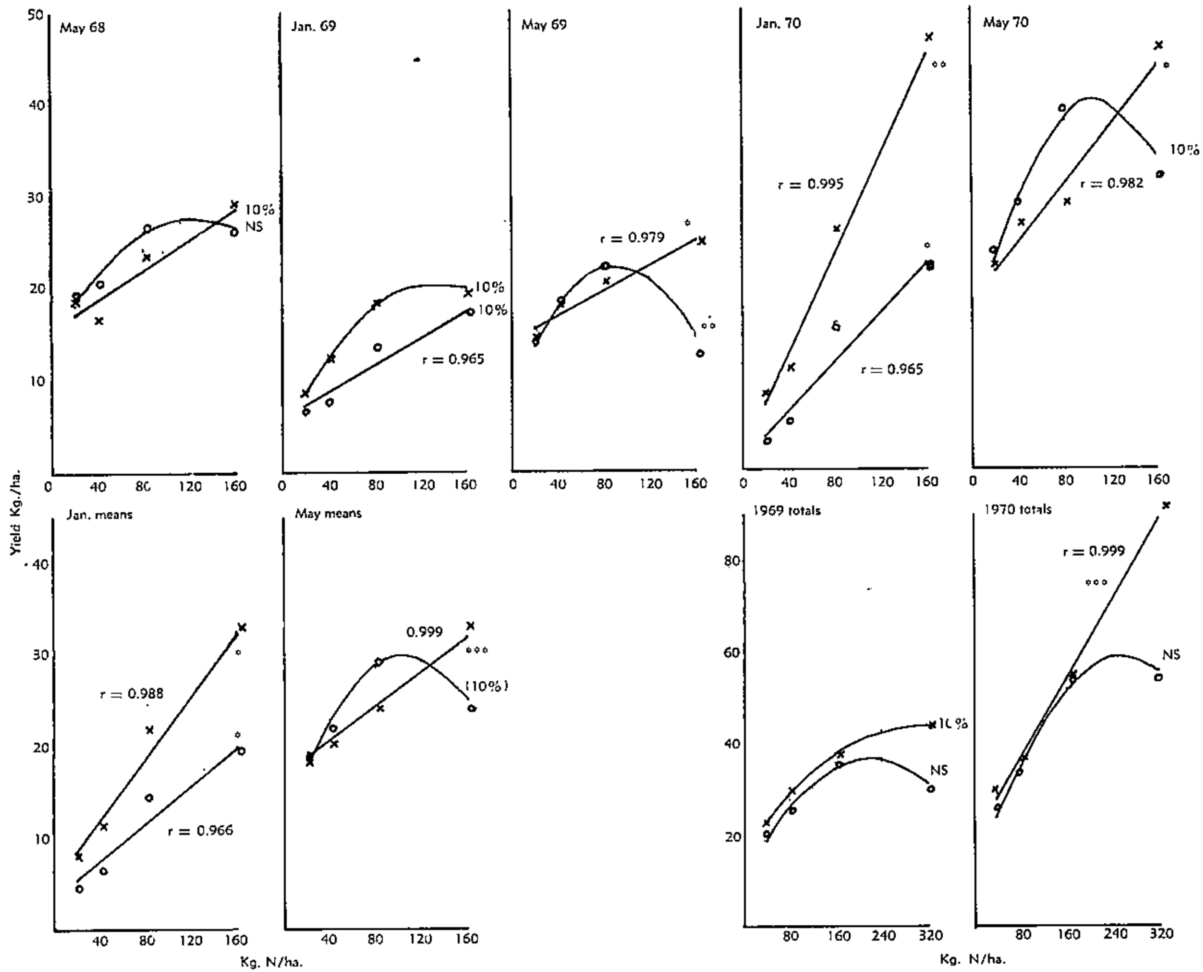

FIGURE 3

Fitted regressions and actual seed yields for the response of seed yield to nitrogen fertilizer rate for two introductions of setaria for each harvest and harvest combinations. Asterisks indicate significance levels of the fitted regressions and the correlation coefficients for the significant linear regressions are indicated on the graphs. (o - CPI 32930; x - CPI 33452).

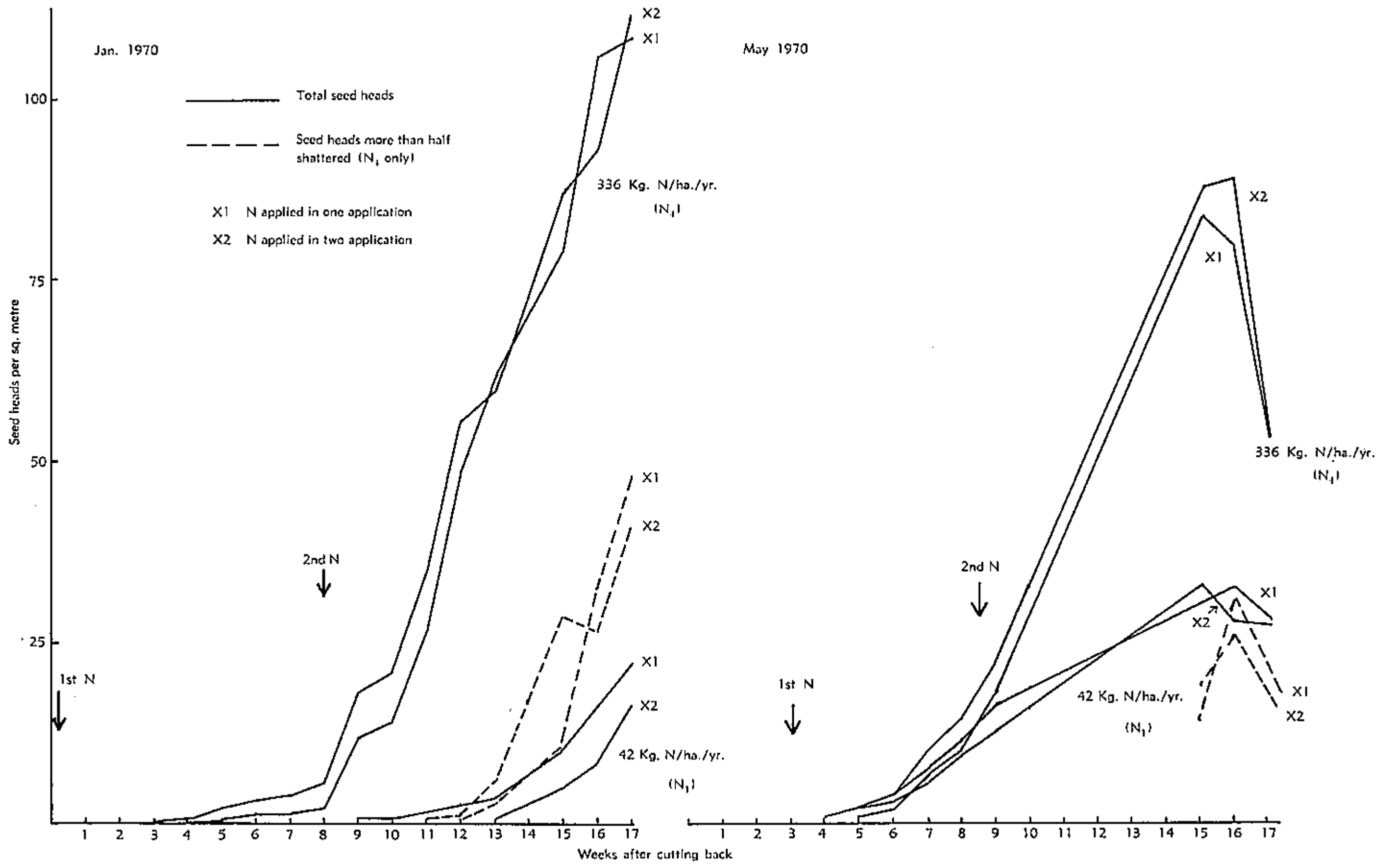

FIGURE 4

Numbers of inflorescences at successive weeks as affected by nitrogen level (42 or 336 kg N per ha. per year) and split (X2) or single (X1) application. (CPI 33452).

If we assume seed head density of 96 seed heads/m^2 corresponding to a cleaned seed yield of about 5 g/m^2 (Fig. 5) and since production of seed heads is linear over this period (Fig. 4) these can be considered as 8 batches of 12 developed over an 8 week period. Of these at least two batches will be too young to produce ripe seed and two will be sufficiently old to have shattered. Thus at least 50% of the potential seed yield will be impossible to recover by direct harvesting. This still leaves a large amount of potential yield unaccounted for. We can postulate low seed set and the development of seeds which were too small to be recovered after the cleaning process.

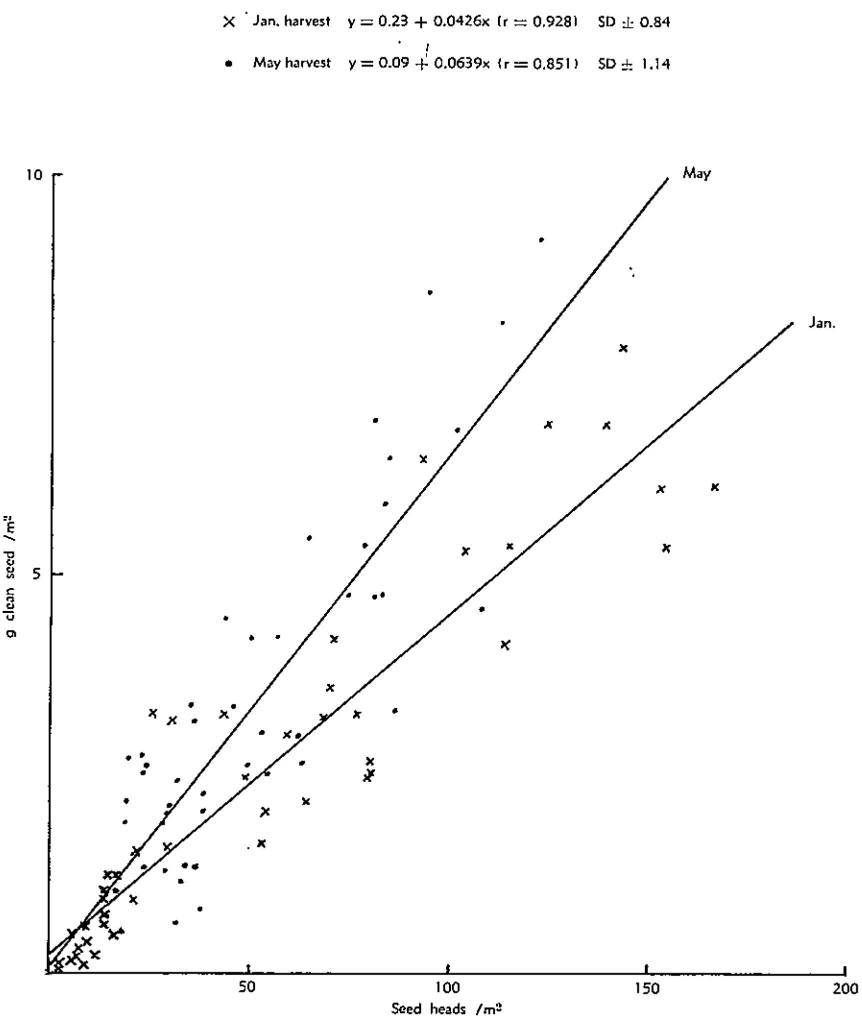

FIGURE 5

The relation between total number of inflorescences and the yield of clean seed per square metre from setaria CPI 33452 at the January and May harvests 1970.

DISCUSSION

The use of nitrogen fertilizer, providing other nutrients are not limiting, is the most direct method that the seed grower has of increasing seed production of this tropical grass. Similar results have been obtained with other tropical species (Haggar 1966, Strickland 1971, Cameron and Mullaly 1969, Grof 1969, Chadhokar and Humphreys 1970). In this experiment annual yields of seed from CPI 33452, from which the commercial cultivar Narok was derived, were still increasing at the highest level of nitrogen (336 kg/ha/year). Higher levels than this may be necessary if maximum yield is to be obtained, providing lodging does not become a problem.

The significant *nitrogen* × *split application* interaction in May 1970 may have resulted from inefficient use of the small dressings of nitrogen applied at each split for the lower levels of nitrogen. At the highest rate each split application was much larger and sufficient to bring about a response.

The response to nitrogen resulted largely from a dramatic increase in numbers of seed heads produced (Fig. 4). The lower yields at low nitrogen levels for the January harvests compared with the May harvests, strongly suggest that nitrogen supply from the soil in spring is lower than that experienced in summer. The linear response to N at the January harvest compared with the quadratic response at the May harvest for CPI 32930 and the steeper slope of the regression line in January as compared to May for CPI 33452 would also support this contention (Fig. 3). This suggests that of the total annual nitrogen dressing more should be applied for the summer than for the autumn harvest.

No data are available which might explain the poor response of CPI 32930 to high levels of nitrogen, since plants were well grown and not lodged. However, reduced seed head production at high N levels is reported for timothy (Evans 1954). In the light of these findings care should be taken in extrapolating from results derived from one variety to other varieties, or from responses obtained at one time of the year to other harvest times.

Compared with temperate grasses, the maximum seed head density of 166/m^2 obtained in this experiment is very low, as may be seen in Table 6

TABLE 6

Comparison of components of seed yield for some temperate and tropical grasses

Species	Fertile tillers/m^2	Seed Weight/ inflorescence	Yield Range	Reference
		(mg)	(kg/ha)	
Festuca pratensis	732–990*	54–90*	490–900*	Lewis 1962
Dactylis glomerata	215–290	195–298	410–840	Lewis 1962
Phleum pratense	368–517	71–104	330–410	Evans 1954
Lolium perenne	1006–1241	42–56	390–695	Evans 1954
Lolium multiflorum	2413	36	890	Griffiths *et al.* 1967
Andropogon gayanus	10–41	—	21–86†	Haggar 1966
Setaria sphacelata	5–166	45–65	6–39	Present work

*The ranges reported are due to increased nitrogen rates or times of nitrogen application.
†Unthreshed seed yields.

Seed weight per seed head is comparable with the larger seeded ryegrass (1200 versus 460 seeds per g); cocksfoot, with seed similar in size to that of setaria, yields four times the weight of seed per inflorescence. It is thus clear that low seed yields of setaria compared with temperate grasses is due primarily to the low density of seed heads per unit area. Although density of seed heads may be increased by heavy nitrogen applications, it is unlikely to reach the levels achieved by temperate grasses.

Unlike the results reported for timothy (Stoddart 1961) and *Andropogon gayanus* (Haggar 1966), nitrogen fertilizer did not increase seed head length in the setarias studied and the linear relation between seed head number and seed yield would indicate that the clean seed weight per seed head was little changed by the use of nitrogen fertilizer. These findings need to be confirmed by more detailed studies since in most temperate species there is an increase in seed weight per seed head with nitrogen fertilizer (Evans 1954, Lewis 1962, Lambert 1963, 1964, Griffiths *et al.* 1967).

Although seed yield per head was comparable with that reported for ryegrass, it was calculated that less than 7% of spikelets formed produced harvested seed. The remaining 93% were lost either through failure of seed set, immaturity or abscission of fully ripe seed. Fertility was not studied in this experiment, but fertility values of 18.3 to 29.1% are reported for other varieties of setaria (Gildenhuys 1951). Immaturity and abscission are likely to be more important as a source of loss in setaria than in the temperate grasses. This is because temperate grasses tend to produce their seed heads over a restricted period (Wilson 1959) whereas setaria produces seed heads over a very long period (Fig. 4). This also makes it very difficult to ascertain the correct date for harvesting. Methods which could harvest seed as it ripens would yield more seed, but these have not been developed. The only method currently available for cutting down losses due to immaturity is to stook the crop after cutting with a reaper binder. This method has doubled seed yields of setaria over those obtained by direct heading (R. Roe and R. J. Jones, unpublished). Seed shattering is common to all pasture grasses, but setaria and other tropical grasses differ from temperate grasses in that the "seed" abscisses below rather than above the glumes. Hence, breeding for a more dense inflorescence in setaria would be unlikely to result in improved seed retention as was the case in *Phalaris,* where the compact heads and ensheathing glumes retain the seed. (McWilliam and Schroeder 1965).

For CPI 33452 we have calculated that the additional 294 kg/ha/year (N_4-N_1) gave 40 kg/ha/year more seed. With nitrogen at $A 0.176/kg ($0.08 per lb) this is a cost of $1.28/kg or $0·58/lb for fertilizer nitrogen only. Obviously seed prices will remain high if these low yields and low responses to N fertilizer continue.

In conclusion, seed yield of setaria may be increased greatly by applying nitrogen, largely through increasing the number of seed heads per unit area. There seems little possibility of raising seed yields to those encountered in temperate grasses, although some improvement could be expected by breeding for increased numbers of seed heads per unit area or a greater uniformity of ripening. However, a greater density of seed heads per unit area will obviously result in a more stemmy sward, and consequently in lower quality herbage at more mature growth stages. Finally, there is considerable scope for developing harvesting methods to reduce some of the large losses discussed in this paper.

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REFERENCES

BARNARD, C. (1967)—*Australian Herbage Plant Register*, C.S.I.R.O. Division of Plant Industry, Canberra, 1967.

CAMERON, D. G., and MULLALY, J. D. (1969)—Effect of nitrogen fertilization and limited irrigation on seed production of Molopo buffel grass. *Queensland Journal of Agricultural and Animal Sciences* **26**:41-7.

CHADHOKAR, P. A., and HUMPHREYS, L. R. (1970)—Effect of time of nitrogen deficiency on seed production of *Paspalum plicatulum* Michx. *Proceedings of the XI International Grassland Congress*, Australia, 315-9.

EVANS, T. A. (1954)—The effect of nitrogen application at different dates on the seed yield of pedigree grasses. *Journal of the British Grassland Society* **9**: 53-60.

GILDENHUYS, P. J. (1951)—Fertility studies in *Setaria sphacelata* (Schum) Stapf and Hubbard. Science Bulletin No. 314, Department of Agriculture, Union of South Africa.

GRIFFITHS, D. J., ROBERTS, H. M., LEWIS, J., STODDART, J. L., and BEAN, E. W. (1967)—Principles of herbage seed production. Technical Bulletin 1, Welsh Plant Breeding Station, Aberystwyth.

GROF, B. (1969)—Viability of para grass (*Brachiaria mutica*) seed and the effect of fertilizer nitrogen on seed yield. *Queensland Journal of Agricultural and Animal Sciences* **26**: 271-6.

HAGGAR, R. J. (1966)—The production of seed from *Andropogon gayanus*. *Proceedings of the International Seed Testing Association*, **31**: 251-9.

LAMBERT, D. A. (1963)—The influence of density and nitrogen in seed production stands of S37 cocksfoot (*Dactylis glomerata* L.) *Journal of Agricultural Science* (Cambridge) **61**: 361-73.

LAMBERT, D. A. (1964)—The influence of density and nitrogen in seed production stands of S48 timothy (*Phleum pratense* L.) and S215 meadow fescue (*Festuca pratensis* L.) *Journal of Agricultural Science* (Cambridge) **63**: 35-42.

LEWIS, J. (1962)—Seed production studies with S53 meadow fescue. *Report of the Welsh Plant Breeding Station Aberystwyth for* 1961, 129-36.

MCWILLIAM, J. R., and SCHROEDER, H. E. (1965)—Seedmaster: a new cultivar of phalaris with high seed retention. *Journal of the Institute of Agricultural Science* **31**: 314-5.

STODDART, J. L. (1961)—The effect of the timing of ammonium nitrate dressings on the heading of S48 timothy (*Phleum pratense* L.). *Journal of the British Grassland Society* **16**: 141-5.

STRICKLAND, R. W. (1971)—Seed production and testing problems in tropical and sub-tropical pasture species. *Proceedings of the International Seed Testing Association, New Zealand*, **36**, 189-99.

VICARY, C. P. (1970)—Costs and returns with tropical pasture plants. *Australian Seed Review* **1**: 27-30.

WILSON, J. R. (1959)—The influence of time of tiller origin and nitrogen level on the floral initiation and ear emergence of four pasture grasses. *New Zealand Journal of Agricultural Research* **2**: 915-32.

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