IMPROVEMENT OF SEED YIELD OF SIRATRO (*MACROPTILIUM ATROPURPUREUM*)

1. PRODUCTION AND LOSS OF SEED IN THE CROP

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ABSTRACT

Patterns of accumulation and loss of standing and fallen seed in specialized seed crops of siratro (Macroptilium atropurpureum *cv. Siratro) were derived from the results of field experiments and measurements on commercial crops in North Queensland.*

Several (usually two) flushes of seed production can be induced annually under favourable conditions. Each is capable of producing of the order of 1,500 *kg per ha of seed, but the brief peaks of standing seed seldom exceed* 500 *kg per ha. Disappearance of fallen seed is relatively slow, with substantial carry-over from one flush or one season to the next. Consequently large quantities of good quality fallen seed accumulate, with* 500 *to* 1,000 *kg per ha being frequently recorded.*

It is concluded that far greater immediate increases in seed yield are likely to result from attempts to recover fallen seed than from improvements in growing and harvesting of the standing crop.

INTRODUCTION

Annual seed production of the perennial pasture legume cultivar "Siratro" (Barnard 1972) of the species *Macroptilium atropurpureum* currently exceeds 45,000 kg (100,000 lb) in Queensland. Almost 90% of this comes from the specialized seed producing districts of the north-east, with an estimated average annual yield between 1968 and 1971 of about 150 kg per ha (Anon. 1970 and 1971).

The price paid by the pastoralist for siratro seed is high, and frequently a barrier to its use. The chief long-term cause of high price is high production costs. Vicary (1970), dealing with specialized seed growing in north Queensland, estimated production costs at $420 per ha for an annual seed yield of 240 kg per ha, a figure which did not include property overheads and costs of ownership. About two-thirds of Vicary's costs were fixed—the inevitable costs of growing the crop, irrespective of yield or total acreages. In these circumstances there is a strong inducement to increase production per unit area.

Our approach to the problem of yield improvement has been to attempt to trace and rectify seed wastage before considering means of increasing overall crop production. This required first a study of the dynamics of reproductive development in conventional crops from which "balance sheets" of seed production and loss could be made. These, it was argued, would define sources of loss and indicate the magnitude of gain that would follow exploitation. The work done up to this point is reported here.

The results led, before their collection was complete, to a possible remedy for the loss of seed. Its development proceeded, on the initiative of local growers, in parallel with the original study. The consequences are reported in a following paper.

Crop Management Practice

Access to irrigation in a climate which combines the advantages of predictable wet and dry seasons with negligible frost risk has enabled the more favourably situated north Queensland growers to develop a comparatively intensive crop management system. This relies on the inducement of a succession of cycles of wet followed by dry conditions. Adequate soil moisture is necessary to produce a strong

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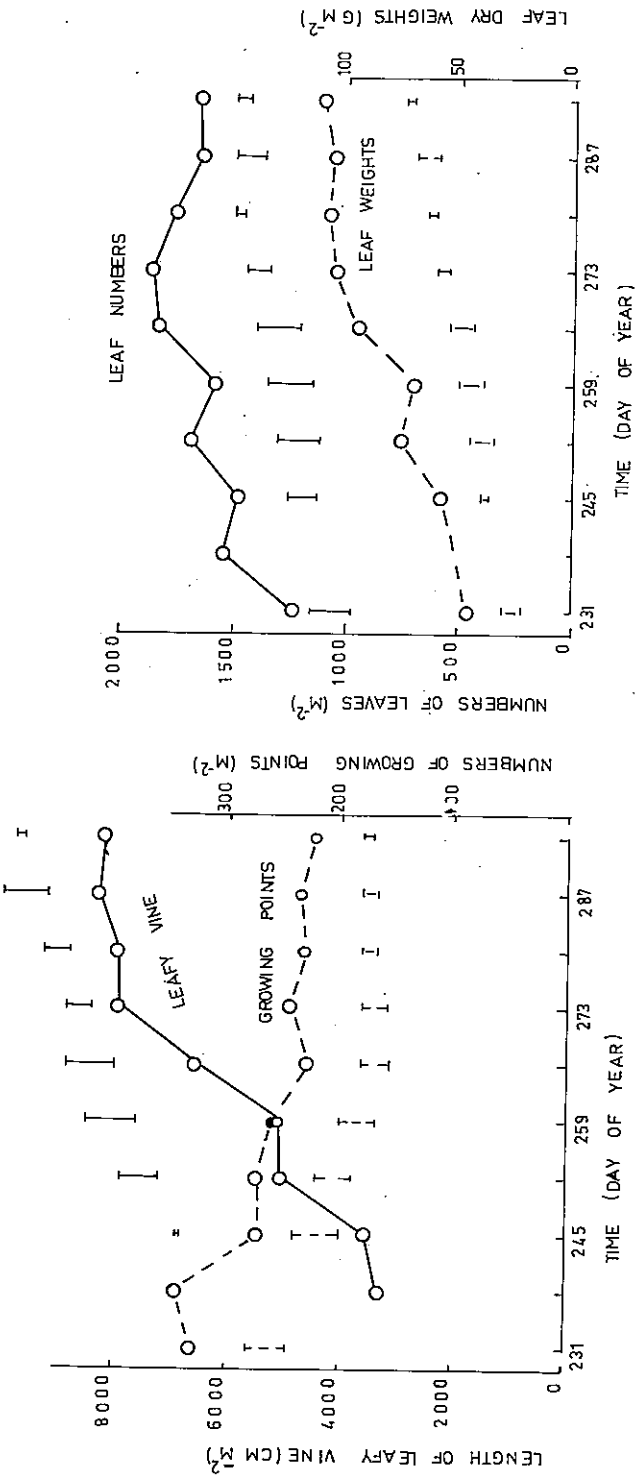

FIGURE 1
1970 Experiment. Criteria of vegetative development. Vertical bars indicate standard errors of means.

vegetative framework, but then a check to vegetative growth (most conveniently achieved through water stress) is believed to be required to induce a clear and vigorous flush of flowering.

The transition from wet to dry season completes the first cycle, the first crop being harvested between May and July. Subsequent cycles are controlled (with only occasional interference from rain) through the irrigation schedule until the next wet season intervenes. From one to four crops may be harvested annually, two being the commonest number. Under this system almost all crops have been direct headed with conventional combine harvesters.

Crop Morphology

An established stand of siratro consists of a mat of intertwined branches, the apical shoots of which remain permanently vegetative. The primary axillary shoots may be either vegetative or reproductive, but outside the wet season they appear to be predominantly reproductive. Far more inflorescence buds are initiated than ever develop, and a strong bud dormancy mechanism appears to operate. Two secondary axillary vegetative buds at the base of each inflorescence provide a reservoir of new vegetative shoots.

The individual inflorescence consists of a single compound raceme, each secondary branch of which produces a strongly compressed succession of triads. A triad is a group of three flower buds formed successively on a single but very compressed tertiary axis. Each triad appears as a row of three flower buds of about the same age. The central primordium of each triad aborts, leaving a pair of flowers to develop. Development of successive triads occurs apparently in response to failure of the last, so that more than one pair of open flowers is not found at a time on one secondary branch, though a single raceme may bear several pairs of flowers or pods at any time. The origin, structure, and development of triads appears to be very similar to that described for the french bean (Ojehomon and Morgan, 1969).

EXPERIMENTAL WORK

Sequence of Events

In late 1970 a detailed study of regrowth, reproductive development, and seed production and loss was made on a commercial seed crop. The results required confirmation, and they also drew attention to the need for more detailed information on the fate of fallen seed. To these ends an experimental plot of siratro was established on Walkamin Research Station for use in 1971–1972. In addition, sampling of farm crops at harvest to estimate crop production and losses was carried out as opportunities arose.

1970 *Experiment*

Methods

A section of a commercial seed crop in its third year since establishment on the property of Mr. C. P. Vicary near Mareeba (lat. 17°S, long. 145°E; altitude c.400 m; average annual rainfall c.900 mm; red basalt clay loam) was selected for uniformity and freedom from weeds. At the time the experiment began (19.viii.1970) the crop was beginning to regrow after a seed harvest in June 1970. The whole 1.8 ha paddock, including the experimental area, received uniform treatment from the grower, being sprayed with insecticide on a regular schedule, irrigated as judged necessary (Figure 2), and finally harvested by a conventional self-propelled combine harvester. Heavy rain on 9.viii.1970 made initial irrigation unnecessary.

The experimental area was divided into five blocks, and sampling positions were allocated at random within each block. On each sampling occasion before harvest a single 0.4 m^2 quadrat cut was taken from each block. The cut material

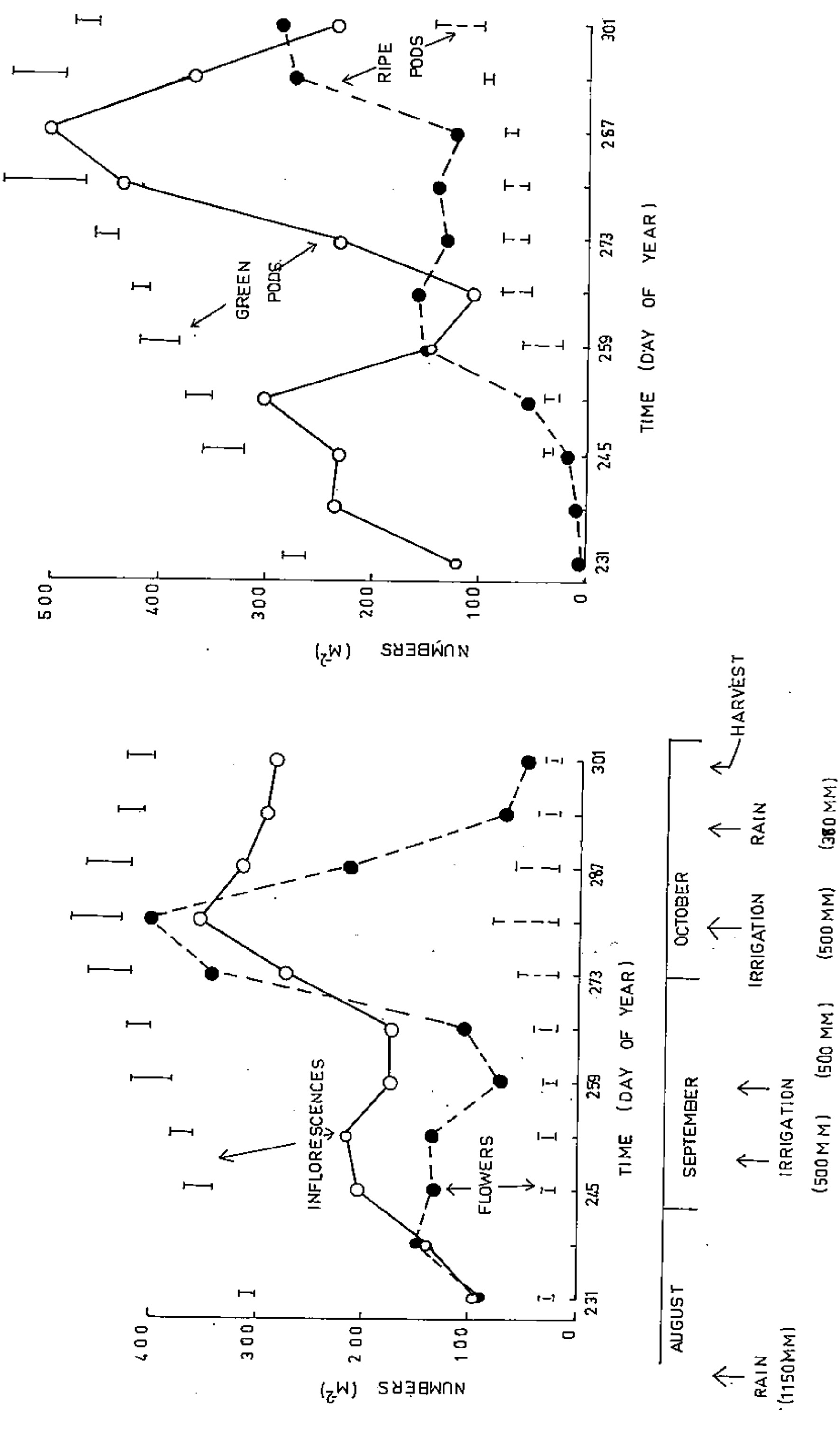

FIGURE 2

1970 Experiment. Criteria of reproductive development and record of water received. Vertical bars indicate standard errors of means.

was sorted and the following measurements made as an indication of the course of development:

Length of leafy vine. Attempts to measure the total vine length per unit area of the entire tangled mass were abandoned as impracticable, and only lengths of vine between the oldest attached leaf and the growing point were measured. Changes from one time to another would thus give an under-estimate of the total shoot extension, since no account was taken of leaf senescence.

Numbers of growing points. A vegetative growing point was counted as such if it bore at least one unfolded new leaf. Dormant or undeveloped axillary shoots were thus not included.

Number of leaves. A leaf was counted if it was attached, not senescent, but old enough to be visibly separate from the bud and to have an area exceeding about 1 cm^2.

Leaf dry weights. Only leaves as counted above were included.

Inflorescences. An inflorescence was counted if it bore one or more open flowers (as defined below) or seed pods containing seed.

Flowers. A flower was counted if the corolla was exserted, but if pod development had visibly begun it was placed in the *green pod* category. The distinction between *green* and *ripe* pods was arbitrary, and shattered pods were put in a separate category (not recorded here).

Seed was regarded as such if, after air drying and threshing it would pass a 3.2 mm but not a 2.0 mm round-hole screen. *Standing seed* was that collected within the canopy of leafy material; *fallen seed* that lodged either in the litter below the canopy or on the surface of the ground (but not embedded in it).

Samples of standing material were cut at weekly intervals until harvest, and on two occasions the ground was swept clean of litter below the canopy and all seed extracted from the sweepings. On the morning before harvest ten quadrats were cut at random from the remainder of the paddock outside the experimental area, and both standing and fallen seed extracted. The yield of combine harvested seed was recorded.

Samples of seed from every source were subsequently subjected to routine purity and germination analyses at the Queensland Department of Primary Industries Seed Testing Laboratory.

Results

(i) *Vegetative development*

Regrowth began with the early August rain and was under way by the time measurements began (Figure 1). A rough equilibrium, probably corresponding to full closure of the canopy, was reached during the latter half of the period of measurement. Before this time the apparent decline in numbers of growing points, the sharp rise in length of leafy vine, the only slight increase in leaf numbers, and the approximate doubling of mean leaf dry weight all reflect the progressive thickening of a canopy whose essential framework was established very early in regrowth.

(ii) *Reproductive development*

Two clear flushes of reproductive activity occurred (Figures 2 and 3). Each produced successive peaks in the number of flowers, inflorescences, pods and seed. The earlier peak of each was much the smaller probably because the vegetative canopy was incomplete. Although measurements did not continue beyond harvest day, the prior records of flower and green pod numbers indicate that the second flush most probably did reach a peak of seed production at about harvest.

The grower, experienced in the management of siratro, predicted the two flushes, and chose to irrigate at the height of the first rather than to harvest, in justified anticipation of a higher yield.

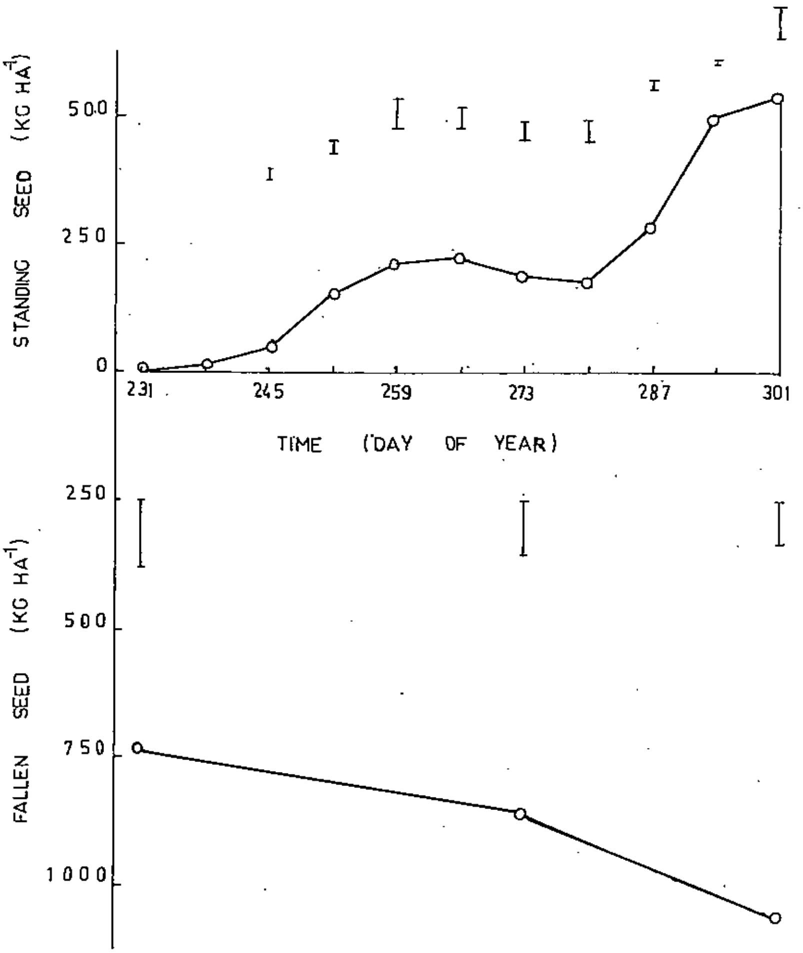

FIGURE 3
1970 Experiment. Record of accumulation of standing and fallen seed. Vertical bars indicate standard errors of means.

(iii) *Seed gained and lost up to harvest*

Extraction of fallen seed indicated the accumulation of a very large quantity of seed on the ground (Figure 3). Much of it must have been derived from previous crops, though whether of the same or of previous years was not known.

The large pool of fallen seed increased the standard errors of the means and tended to obscure the loss of seed to the ground from the current standing crop, and the net gain to the pool of fallen seed of about 300 kg per ha over the period of measurement is not statistically convincing. Nevertheless a gain of this order is quite realistic, slightly exceeding the quantity carried at the first peak of standing seed.

The exact chronology of the life of individual flowers and pods is impossible to state categorically, since the later stages of ripening and shattering are highly dependent on the weather. However, contemporary measurement of tagged inflorescences on an adjacent area showed that on average, individual flowers and pods lasted about 4 and 25 days respectively, pods being ripe for about the last 7 days before shattering.

It is most likely, therefore, that the whole of the first flush and the earlier formed seed of the second would have been shed by harvest time. A necessarily rough calculation of the total production potential of the two flushes suggests that the equivalent of about 1,600 kg per ha of seed might have been formed. Of this about 540 was standing ripe seed at harvest, and perhaps a further 450 would still be unripe at harvest. This leaves a balance of about 600 kg per ha of seed presumed to be shed to the ground. If account is taken of both the net gain of 300 kg per ha to the pool of fallen seed and the calculated loss due to disappearance of fallen seed at an arbitrary rate (borrowed from subsequent figures) of about 1% per day, the figure of 600 kg per ha appears, if anything, to be an under estimate.

(iv) *Harvest gains and losses*

The overall productivity of the whole paddock, on which harvest estimates were made, was substantially lower than that of the carefully chosen experimental area (Table 1).

The machine harvest of standing seed recovered an estimated 79% of the seed available to the harvester, though a mere 19% of the total present. Over the next 23 days fallen seed disappeared at an estimated rate (assuming a constant rate per unit of seed present) of about 1.1% per day. Germination of good seed, decay of damaged, loss down cracks, etc., all probably accounted for the disappearance.

(v) *Seed quality*

The overall percentage of live seed in the samples taken was consistently high, with the exception of the machine harvested standing seed (Table 1). Damage to soft, unripened seed in the threshing cylinder probably caused this reduction.

In the samples of hand-harvested seed taken before the machine harvest, the percentage of hard seed was high, with that of the standing seed consistently higher than that of the fallen, perhaps due to the greater average age of the latter. Machine harvesting obviously reduced hard seededness, presumably through scarification.

The mean weight of seed derived from the ground was invariably greater than that of standing seed. This is presumably due to the fact that all ground seed has come from shattered pods and is therefore fully mature.

1971 *Experiment*

Methods

An area of about 0.1 ha of clean ground on Walkamin Research Station (latitude 17°S, longitude 145°E; altitude c.580 m; average annual rainfall c.900 mm; red basalt clay loam) was sown to siratro in December 1970. It established strongly and a first combine harvest was taken from it on 12.vii.1971. The area was divided into five randomized blocks, which were sampled in the same way as in the 1970 experiment.

Apart from samples of standing and fallen seed being collected immediately before the July harvest, activity was concentrated into two periods. Weekly samples of both standing and fallen seed were taken over the period of development of the second crop (September–October). Then, after a second combine harvest on 19.x.1971, ground samples were taken at approximately fortnightly and later monthly intervals until 8.v.1972, in order to record the course of disappearance of seed from one season to the next. The canopy was occasionally lightly mown to prevent the development of new seed pods.

Results

The first crop was deliberately harvested early to reduce the accumulation of seed on the ground to a minimum. It yielded about 110 kg per ha of cleaned seed. When growth of the second crop began there was a negligible amount of fallen seed present.

TABLE 1
Seed data from 1970 *Experiment*

Occasion	Experimental Area				Whole Paddock			
	First Seed Peak	Mid Growth	Final Seed Peak and Harvest		Harvest			After Harvest
Day (of year) of recovery	266	273	301		301			324
Origin of seed	Standing	Fallen	Standing	Fallen	Standing	Fallen	Standing	Fallen
Method of harvest	Hand	Hand	Hand	Hand	Hand	Hand	Machine	Hand
*Pure seed yield (kg ha^{-1})	226 ± 38	854 ± 102	540 ± 65	1,055 ± 84	261 ± 50	830 ± 90	206	680 ± 57
Germinating seed (%)	12	21	6	25	6	24	33	31
Hard seed (%)	80	72	91	69	89	74	49	59
Total live seed (%)	92	93	97	94	95	98	82	90
Mean single seed weight (mg)	11.9	13.2	11.9	13.1	11.7	13.2	12.0	13.1

* Including standard error of mean.

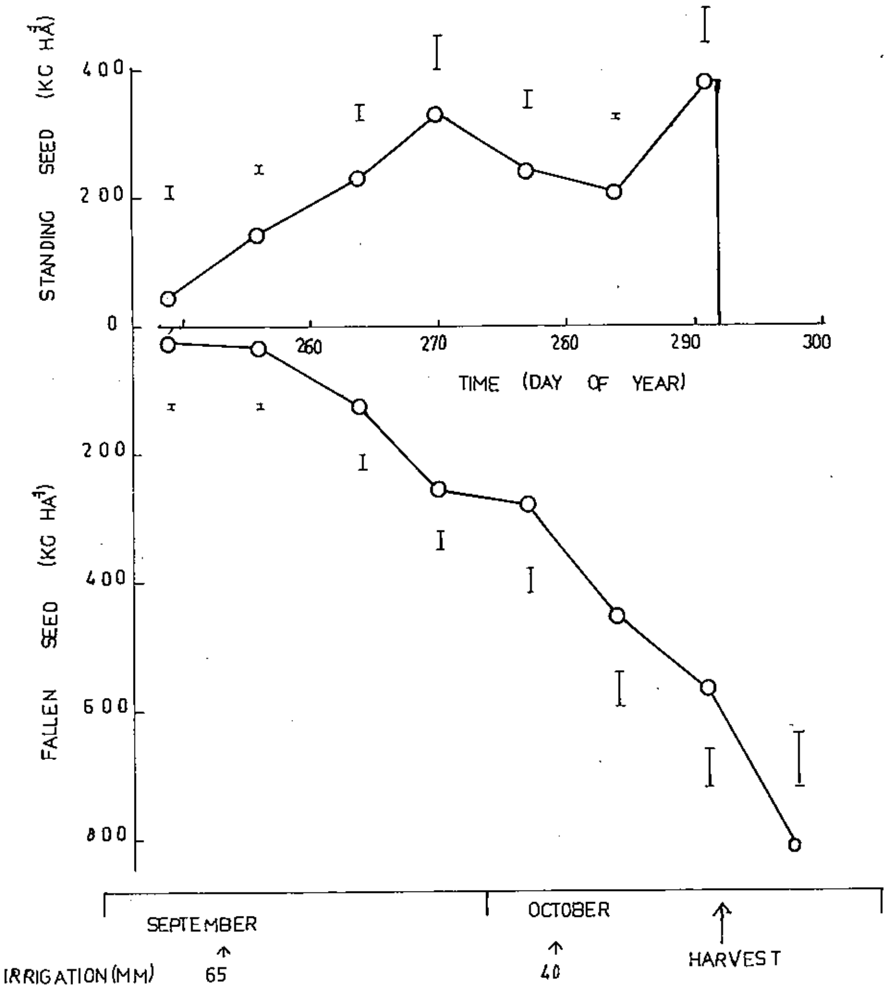

FIGURE 4
1971 Experiment. Record of accumulation of standing and fallen seed. Vertical bars indicate standard errors of means.

The course of development of the second crop followed much the same course as that of the 1970 crop measured. Two substantial waterings induced two peaks of inflorescence density (not illustrated), followed by two peaks of standing seed yield (Figure 4).

Meanwhile seed accumulated progressively on the ground to reach almost 600 kg per ha on the morning before harvest. As a consequence of the harvest operation (and no doubt of an exceptionally violent wind storm preceding it), approximately a further 200 kg per ha was deposited.

Summing standing and fallen seed at day 292, assuming disappearance of fallen seed at rates similar to those subsequently recorded, and adding an arbitrary figure for unripened seed (derived by comparison with the 1970 data), one can calculate a rough estimate of total seed production for the crop of about 1,500 kg per ha.

During the course of disappearance of fallen seed that followed harvest, two stages are recognizable—an earlier one lasting 50 to 100 days during which seed

TABLE 2

Quantities of seed measured (kg ha^{-1}) (with standard errors of means) on crops at time of harvest

Reference	Location	Harvest Date	Seed present before harvest		Seed present after harvest	Crop History
			Standing	Fallen	Fallen	
A	Walkamin	19.vii.71	455 ± 82	126 ± 22	103 ± 24	Crop in 8th year. Burnt every year since 1966.
B	Cooktown	4.vii.71	496 ± 100	64 ± 13	71 ± 36	Crop in 2nd year. Burnt and disced in 1970.
C	Mareeba	21. vi.71	—	—	736 ± 88	Crop in 4th year. Undisturbed.
D	Walkamin	12.vii.71	331 ± 26	575 ± 141	713 ± 145	Crop in 4th year. Undisturbed.
E	Walkamin	vii.71	—	—	696 ± 66	Crop in 3rd year. Undisturbed.
F	Walkamin	12.vii.71	189 ± 44	5 ± 2	20	Crop in 1st year. (Experimental).
G	Walkamin	19. x.71	380 ± 56	565 ± 60	810 ± 82	Crop in 1st year. (Experimental).
H	Mareeba	22. vi.72	439 ± 103	319 ± 30	—	Crop in 1st year.
I	Mareeba	x.72	595 ± 106	563 ± 98	—	Crop in 1st year. No pre-winter harvest owing to late establishment.

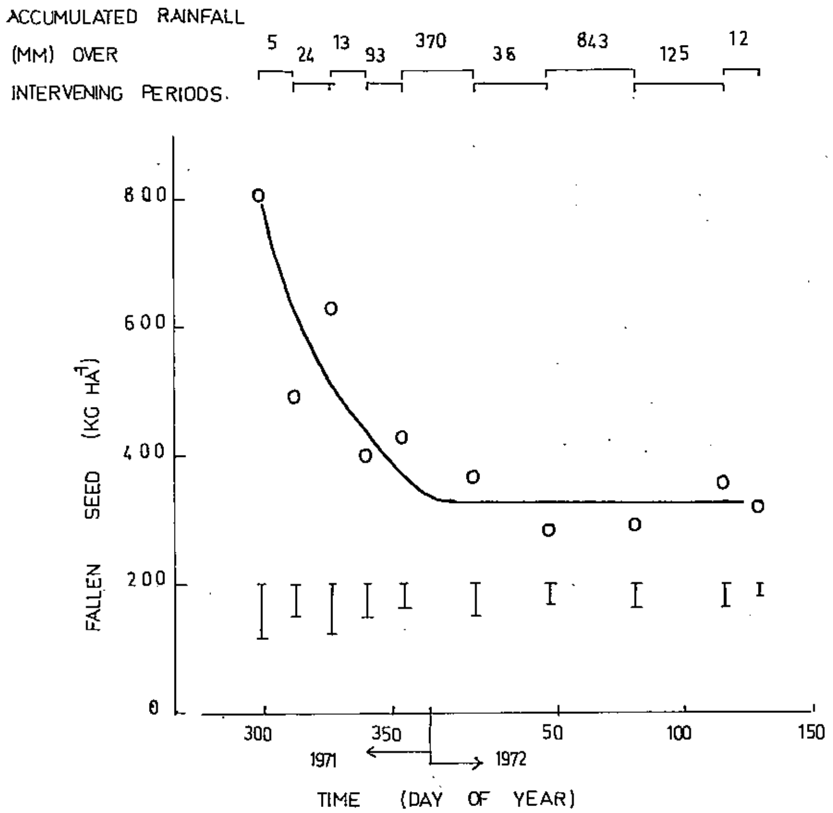

FIGURE 5
1971 Experiment. Record of disappearance of fallen seed following harvest. Vertical bars indicate standard errors of means.

disappeared at the rate of about 1% per day; and a later one of indefinite duration during which the quantity remained more or less constant.

Carry-over of seed from the end of one season to the start of the next thus amounted to between 300 and 400 kg per ha, or about 40% of the amount present immediately after harvest. A germination test carried out on the final sample to be collected showed that 99.8% of the seed was viable and 95.1% of it hard.

The negligible disappearance of seed in the later stages can partly be explained in terms of the prior elimination of all but hard seed. Perhaps also the re-growth of a new canopy and deposition of further litter provides a protective environment for hard seeds.

Sampling of commercial crops

Commercial crops were sampled as the opportunity arose. At least five quadrat cuts were made on such occasions, with the same methods used as in the experiments. Standing crops were sampled while harvesting was actually in progress, samples being taken along the line of the harvest cut so that pairs of adjacent quadrat cuts, one taken before and one after harvest, could be made at each position.

Growers' estimates of crop yields varied between 100 and 300 kg per ha. They are not presented individually because sampling was generally only representative of sections of a crop, and to invite individual comparisons would be misleading.

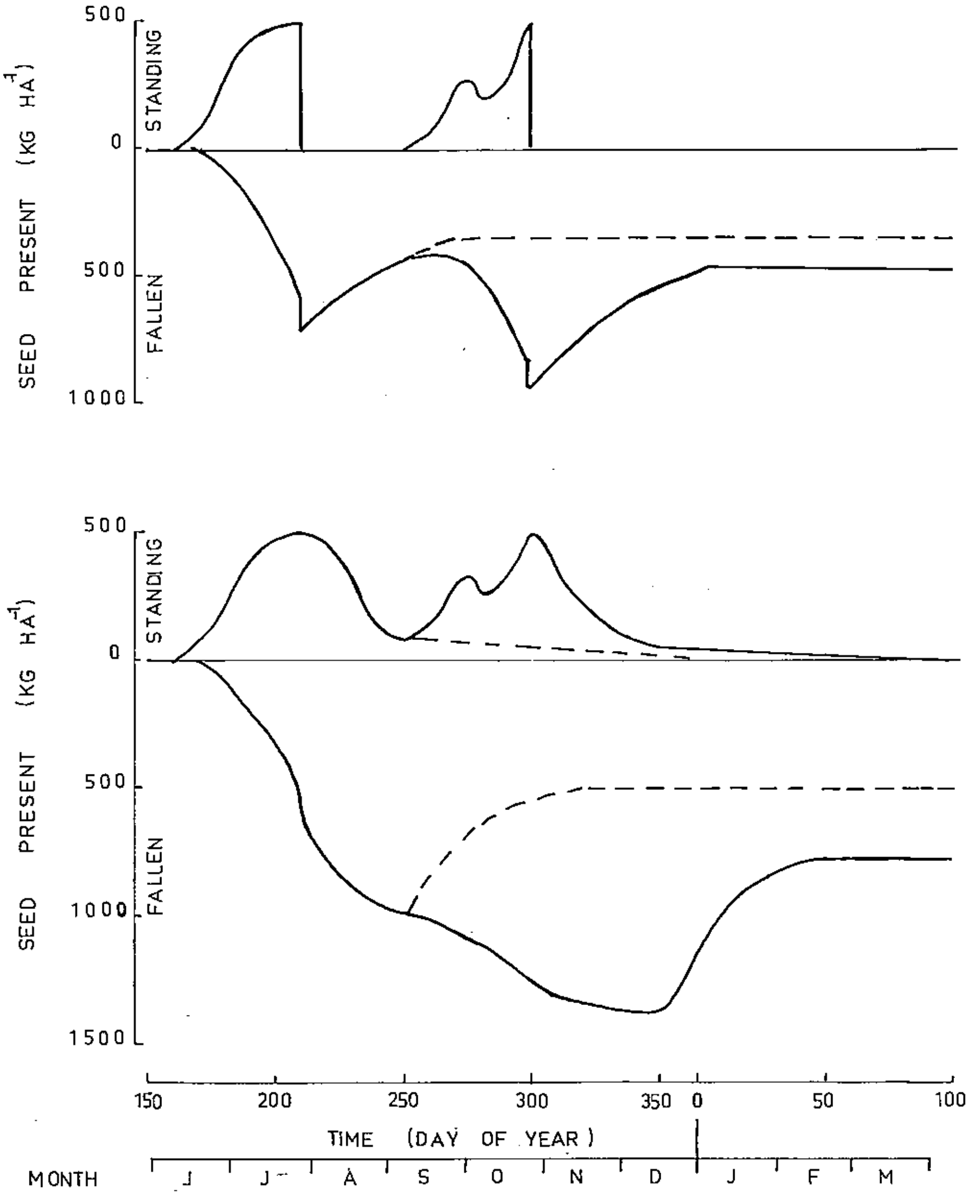

FIGURE 6

Reconstruction of expected distribution of seed in crops under various management systems, (a) with two harvested crops in the season, and (b) with two unharvested crops. Dotted lines indicate the expected situation with no second crop grown.

Quantities of standing seed measured (Table 2) were always high compared with the harvest yields from the crops. In some situations an increase in fallen seed after harvest indicated inefficient recovery by the harvester (e.g. crops D and G) but in others this was obviously not so (crops A and B; also 1970 experiment, Table 1). The discrepancy must be at least partly due to damage to soft seed during threshing and its subsequent rejection in cleaning.

The accumulation of large quantities of seed on the ground, either before or after harvest, is clearly commonplace. Three crops sampled in their first year (G, H, I) had substantial quantities of fallen seed present, a further indication that accumulation through carryover from previous years is not necessary to produce large quantities. Crops H and I also substantiate the conclusion from the experiments (assuming again the occurrence of unripe seed and the progressive disappearance of fallen seed) that single crops can produce well in excess of 1,000 kg per ha of seed.

The two commercial crops with only small amounts of fallen seed present (A and B) had both been burnt, and one (B) disced, the previous year. Casual observations on other similarly treated crops have suggested that fire drastically reduces carry-over. These crops, moreover, were sampled before the opportunity for much seed shedding had occurred. The first crop of the year, harvested in June or July, is usually both better synchronized in seed ripening and less prone to pod shattering (owing to the commoner occurrence of cool cloudy weather) than are subsequent crops.

DISCUSSION

The accumulated data are consistent and complete enough to permit rough but adequate modelling of the patterns of seed accumulation likely to occur under various systems of crop management. Four such patterns are illustrated in Figure 6. They represent situations in which either one or two good crops are grown annually, each being either combine harvested at the peak of standing seed accumulation or left to shed all its seed. We made use of the following figures:

1. Each crop reaches a peak of standing seed of 500 kg per ha over a 50 day period; meanwhile a net gain of 600 kg per ha of fallen seed occurs; if the standing seed remains unharvested, a further net gain of 400 kg per ha to the pool of fallen seed occurs.
2. The first crop, grown on stored soil moisture from the wet season, reaches a single broad peak; the second, brought on in stages by irrigation, has sharp minor and major peaks.
3. The decline from a peak is more or less symmetrical with the final rise (a result not experimentally measured but inferred from the data of Figure 2).
4. Loss of 20% of seed to the ground occurs during harvest of a standing crop.
5. Fallen seed disappears at 1% per day (negative exponential relationship between quantity and time) for the first 70 days after a peak, the quantity thereafter remaining constant.

Whatever the crop management system, it seems that greater quantities of seed are likely to be found on the ground than in the standing crop for most of the lifetime of a stand of siratro. Indeed, it is only during the period before the first standing seed peaks in a newly established or recently disturbed crop that substantial quantities of fallen seed are not to be expected. Moreover, the absolute amount present is often very great compared with any yield of standing seed, and the persistence of large quantities far less transient. This situation probably applies to all well-grown specialized seed crops of siratro, but not to pastures that are catch-cropped for seed. In these conditions (prevalent in south-east rather than northern Queensland) overall production and yield of seed is much lower, and therefore most probably also the accumulation of fallen seed.

Combine harvesting of siratro has served as the standard method of seed retrieval since commercial seed production of the cultivar began more than ten years ago. The results of this investigation indicate, however, that it is inevitably a most inefficient means of recovery. At best, the operation recovers about 20% of the seed capable of being produced; on average, it recovers probably less than 10%.

Moreover, with present practices, no single destructive harvest of the standing crop could be expected to improve beyond about 30%. Although it is possible that greater peaks of standing seed could be achieved, either through improved synchronization of ripening—Edey and Byth (1970) demonstrated one such possibility, though under conditions that did not in the first place favour a marked peak—or through reduced shattering, the most immediately obvious remedy for such immense losses is to recover the seed from the ground.

The potential for the harvest of fallen seed was recognized by Mr. Vicary as soon as the 1970 experimental results began to accumulate, and subsequently by other seed growers. It led to the purchase of suction harvesters and the development of a technique for their use in siratro, the details of which are reported in a following paper.

ACKNOWLEDGEMENTS

We acknowledge the financial support of the Australian Meat Research Committee; technical assistance from Mr. B. H. English, the help of Mr. R. L. Harty and the staff of the Queensland Department of Primary Industries Seed Testing Laboratory; the help of the farm staff of Walkamin Research Station and the co-operation of the many local farmers who gave us access to their crops and the benefits of their experience.

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[Accepted for publication July 24, 1973]