Tropical Grasslands (1993) Volume 27, 327–334

Tropical pasture establishment.
6. Treatment of Seca stylo seed to reduce hard seed content

J.M. HOPKINSON[1] AND C.J. PATON[2]
[1]*QDPI, Walkamin Research Station, Walkamin, Queensland*
[2]*QDPI, Brian Pastures Research Station, Gayndah, Queensland, Australia*

Abstract

Two approaches were investigated for the reduction in hard seed content of Seca stylo (*Stylosanthes scabra*). One was to cause strophiole-breaching through imposition of brief high temperatures by contact with a heated metal plate, and the other scarification of the testa by hammer milling.

Numerous combinations of metal temperature and duration of contact produced a range of levels of the heat dose applied (degree-seconds above 90 °C). Response curves relating heat dose to the amount of seed softening and killing were constructed. The similarity of the softening and killing curves, coupled with inconsistency in response between seed lots, explained unreliable results of treatment that were not materially improved by modifications such as prior wetting or rapid cooling after heat treatment. Two causes of inconsistency were detected: a sharp fall in the mean critical heat dose for killing as seed moisture content rose; and apparently different insulative properties of upper and lower segment seed hulls. Heat treatment, besides killing some seeds, weakened survivors and further reduced the numbers of seedlings emerging from soil. Despite its effectiveness in softening seed, it was judged to be too unreliable for practical use. Hammer milling, by comparison, was simple and effective. The extent of dehulling could be controlled at about 50%, with germination of dehulled seeds raised to over 60%, and no effect on those remaining intact. Scarification is not a complete substitute for strophiole-breaching, but currently there is no way to produce breached seed commercially other than by expensively suction-harvesting fallen, already weathered seed.

Introduction

As it enters the market, seed of Seca shrubby stylo (*Stylosanthes scabra*) is of high average vital quality but predominantly hard (Table 1). Seed sold for sowing may be required at any of a wide range of soft seed contents, to cater for the great diversity of environments into which it may be sown. Much seed therefore needs to be treated to increase soft seed content. There are two types of soft seed, scarified and strophiole-breached, each with distinct germination characteristics, offering scope for further matching of seed to seedbed conditions (Hopkinson 1993). These are obtained by different treatments which achieve the desired result, but have adverse side-effects. Treatment is thus not a simple matter, and a clear understanding of what it entails is needed for the purposeful development of suitable methods.

We have both separately investigated seed treatment methods, taking different approaches according to the perceived needs of the regions we serve. This paper attempts to bring together the two lines of investigation in order to assess the present position. As a preliminary, the background to hardseededness as it applies to Seca must be explained.

Seed characteristics

The fruit of Seca is a pod that separates on ripening into 2 segments, each consisting of a seed completely enclosed by a tough, persistent hull. The hull of the upper segment is hooked, that of the lower not (Figure 1). The seed itself is typical of wild-type papilionaceous legumes, with all the structures that control its moisture

Correspondence: J.M. Hopkinson, QDPI, Walkamin Research Station, Walkamin, Qld 4872, Australia

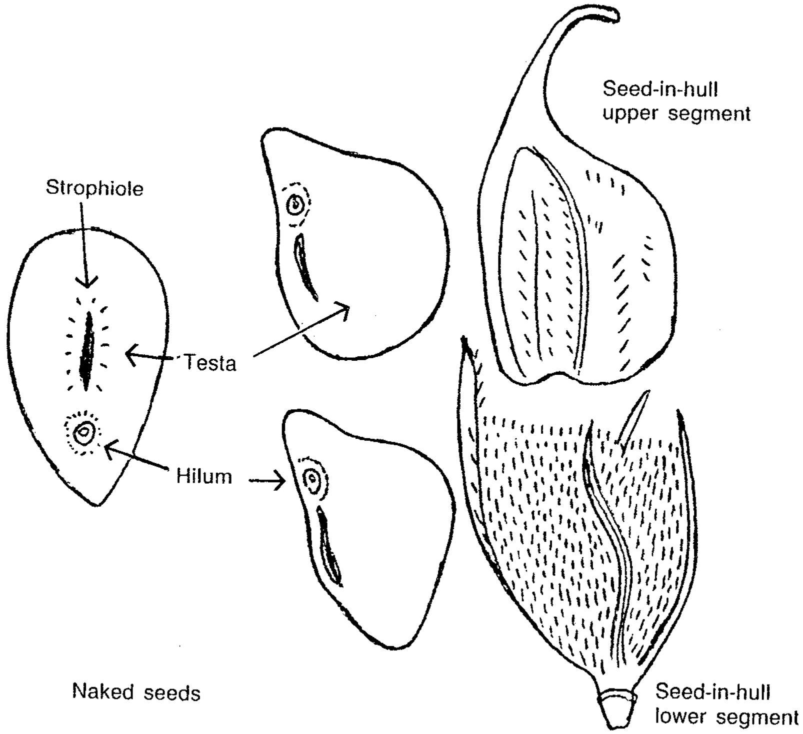

Figure 1. Seca stylo seed. The two pod segments are initially joined, but part on ripening. While still joined, they are aligned as shown. The lower segment hull is variable in appearance; the bracteoles may or may not persist; the shape may be from conical to egg-shaped; the density of hair varies. The pair of naked seeds alongside is drawn as they are aligned in their hulls. The single seed is turned through 90° to show the strophiole and hilum (stalk scar) along the main ridge.

status fully developed. The hilum serves as a one-way hygroscopic valve, allowing the seed to dry out thoroughly, which in turn permits the testa to develop complete impermeability (c.f. Argel and Humphreys 1983). The strophiole is normally intact, and remains so for very long periods of storage. The hull is highly protective, preventing the incidental scarification and strophiole-rupture that often accompany threshing and processing of legume seeds that are shed naked. Most seed crops are direct-headed upon ripening, which removes any opportunity for seeds to soften through weathering (Gardener 1975). Usually, therefore, the only permeable seeds in an untreated sample are those that were immature at harvest and thus have imperfectly developed testas. They are of little significance, because they are few, lack vigour and have short life expectancy. Most untreated seed lots with high laboratory germination values are from suction-harvested crops in which the seeds have had the opportunity to weather on the soil surface. The seed with the maximum germination value of 63% quoted in Table 1 was from a suction-harvested crop.

Seed can be softened (i.e. made permeable to water) either by fracture of the testa with scarification or by strophiole-breaching. Scarification requires prior dehulling because of the protective properties of the hull. The strophiole is apt to rupture only when the tensile stresses that act on the testa are suddenly increased, providing a route for water entry. Sudden temperature changes are most commonly used to achieve this, either through heat treatment or exposure to intermittent bright sunlight (Gardener 1975; Mott 1979; Mott and McKeon 1979;Gilbert and Shaw 1979). Seed is comparatively easy to treat on a small scale, the problems mainly arising with attempts to adapt methods to the commercial need for cheap, rapid throughputs of big tonnages.

Table 1. Summary of results of 86 different official tests carried out on submitted samples of Seca seed at the Mareeba Seed Testing Laboratory between August 1988–May 1990 and representing most seed harvested in Queensland in 1988 and 1989. The records exclude seed known to have been treated to reduce hard seed content.

	Average (%)	SD (%)	Maximum (%)	Minimum (%)
Germination	12.9	±8.3	63	0
Hard seed	75.3	±10.7	92	25
Live imbibed seed	1.8		12	0
Abnormals	0.4		2	0
Dead seeds	9.5		31	2

Approaches to seed treatment

Central Queensland. Unpublished work by D. Gramshaw showed clear advantages in establishment of strophiole-breached over scarified seed of Fitzroy stylo (*S. scabra*) in the Biloela area. A continuous-flow method of heat treatment of Verano stylo by passage through a heated, rotating cylinder developed in the Northern Territory (Mott 1979), was found to soften finestem stylo (*S. guianensis* var. *intermedia*) successfully at Gayndah (Paton 1993). This led to a series of experiments at Gayndah designed to formulate suitable levels and durations of high temperature for cylinder-treatment of Seca.

North Queensland. At Walkamin Research Station, B.H. English (personal communication) modified a hammer mill to extract seed from incompletely threshed, dried heads of various stylos. The method also proved suitable for partial dehulling and accompanying scarification of Seca seed-in-hull, and having a high throughput (up to 2 t/h) it became widely used. Seed treated by this method acquired a reputation locally for good establishment from late (i.e. December) sowings. To check and explain this success, experiments were done to characterise the effects of milling and evaluate heat-treated seed.

Together the two approaches provided some useful insights on the consequences of treatments. Below we summarise the experiments that followed their adoption, extracting only those results that are relevant to the main assessment.

Methods

Heat treatment

Heated, rotating cylinders rely on brief heat transfer from metal to seed as the seed tumbles along the inclined cylinder. The controllable variables are metal temperature and duration of contact. The approach taken with Seca at Gayndah was to subject seed-in-hull from a range of commercial lines to numerous combinations of the 2 variables (overall range 100–200 °C for 5–40 seconds), with seed sampled for routine germination testing before and after treatment. It was impracticable to use the cylinder for multiple runs on small samples, and instead imitative treatments were devised that involved agitating small seed samples in a pre-heated iron pan. Groups of heat treatments were also combined with secondary treatments designed to alter temperature gradients during heating and cooling, such as prior wetting and subsequent rapid cooling. In all, 5 separate experiments incorporating different seed sources, ranges of heat treatments and forms of secondary treatment were carried out.

Hammer milling

Samples were taken during the milling of 6 commercial seed lots, as it is impossible to mill small, isolated quantities realistically. Five were milled at Walkamin, one privately. The Walkamin R.S. mill had a one-eighth inch (3.2 mm) round-hole perforated metal screen brazed on to the original three-eighths inch (9.5 mm) round-hole concave, which served to prolong retention in the milling chamber. The mill was driven at about 1 500 rpm (hammer tip speed 117 km/h) and treatment severity controlled by variation in the feed rate. It was intended to dehull about 50% of seeds, and the range was in fact 50–65%. The private mill dehulled 25%.

Combined evaluation

Samples of seed from the same sources as used for milling were heat-treated at Brian Pastures, Gayndah, at a temperature and duration of treatment judged from earlier experiments to be most likely to reduce hard seed content effectively, i.e. 160 °C for 20 seconds. The heat-treated seed, comparable hammer-milled seed and untreated seed were then subjected to laboratory germination and shadehouse soil emergence tests at Walkamin.

Germination tests were done on 3 replicate samples of 100 seeds from each lot in standard conditions at 35/20 °C. Soil emergence tests were done in trays in a shadehouse over 93 days with 4 cycles of alternating watered and dry conditions at an average air temperature of 26 °C. Five replicates of 100 seeds from each lot were sown at an average depth of 2.5mm. Emerging seedlings were recorded until emergence ceased, after which surviving hard seeds were exhumed.

Results

Heat treatment

The initial heat treatment experiments generated a great body of results about changes in viability, germination and hardness in relation to treatment. Only those of immediate relevance are presented here. The main effects, i.e. softening and killing, are expressed independently of each other and in terms of the number of seeds affected as a percentage of the number available to be affected. Thus, the number of seeds killed by a particular treatment is recorded as a percentage of the number of living seeds present before treatment, irrespective of their hard seed status. The number softened is the reduction in number of hard seeds as a percentage of the original number of hard seeds, regardless of whether or not any died. These values are then plotted against the heat dose received, measured as the cumulative degree-seconds above 90 °C of contact.

For any seed lot, with other conditions held constant, relationships between heat treatment and effect on seed followed a sigmoid curve (Figure 2). This is provisionally interpreted according to the following model: any seed has a critical heat dose at or above which an effect is obtained; the critical dose differs between individual seeds of the population; and a population of critical doses is distributed about a mean that corresponds to an effect on 50% of seeds (referred to as the D_{50}). With a convenient choice of scale for the x axis, in this case log heat dose, an approximately normal distribution can be obtained. This allows the D_{50} to be calculated from the linear regression of probit-transformed percentages on log heat dose. It serves as a single value to characterise the entire response and to summarise all contributory records. This is particularly useful because the results of any single treatment are highly variable, and the summation of a large number of records is needed before a reliable value is obtained. The D_{50} values of Figure 2 derive from records of the behaviour of more than 8 000 individual

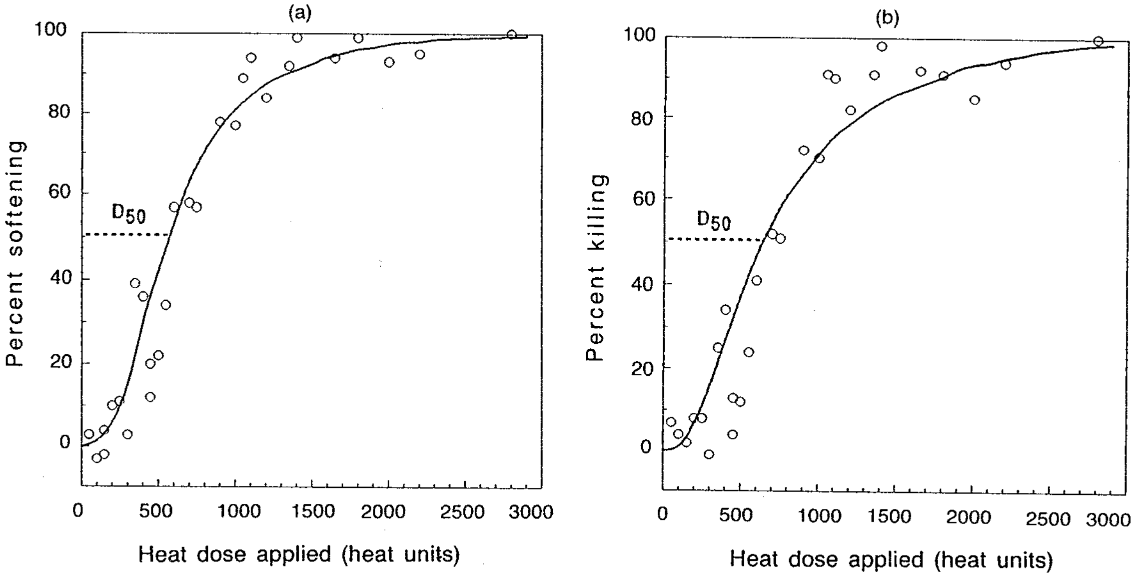

Figure 2. Relationship between heat dose and (a) percent softening and (b) percent killing of Seca seed. The fitted curve is derived from the straight line of best fit of probits on log heat dose. Values for r^2 are 0.89 and 0.78 for softening and killing, respectively.

seeds. The D_{50} may be taken as a measure of the effectiveness of heat in bringing about a particular result, either softening or killing. It is specific to the seed lot from which the samples were drawn, and can be used across lines to compare properties such as tolerance to heat or ease of softening.

Of the two effects, softening is the desired objective and killing the unwanted accompaniment. To be reliable and effective, treatment should produce widely divergent response curves with low D_{50} values for softening and high for killing, and do so consistently for all seed lots. However, this was not the case.

Despite isolated increases in germination of 40–50% from single treatments, pairs of general response curves were only slightly displaced from one another, as in Figure 2, and different seed lots produced widely differing D_{50} values. Consequently the *net* effect, increase in germination, was very inconsistent. No single heat treatment could be guaranteed to soften seeds of an unknown lot without also killing many. Of the secondary treatments, prior wetting of seed and repetition of heat treatment only displaced both curves more or less equally, and thus offered no advantage. Rapid cooling after treatment produced no large or consistent additional benefits.

Inconsistency between lots was the most discouraging feature of the results, and investigation revealed two contributing factors.

One was an effect of moisture content of seed. Reliable D_{50} values were obtained for 11 lines of seed, for which moisture contents were determined gravimetrically, by oven-drying ground naked seed at 125 °C for 1.5h. The critical heat dose for killing fell rapidly as moisture content rose, while that for softening changed little (Figure 3). In other words, susceptibility to heat damage increased with seed moisture content without any worthwhile compensatory advantage.

The other effect was detected when seeds of upper and lower pod segments were separated for testing after heat treatment, and it was found that seeds of lower pod segments suffered fewer deaths (Table 2), possibly because of better

Table 2. Differences between upper and lower seed segments in effects of a single heat treatment (average of 6 lines of seed; heat dose = 1 400 units). No statistical difference between upper and lower segments in softening was detectable. The difference in killing was consistent across lines, and, on a simple paired t-test of the reduction in probit-transformed viability with treatment, proved significant at $P<0.01$.

Seed segment	Upper	Lower
% softening	96	93
% killing	85	61
% germination increase	− 13	+ 6

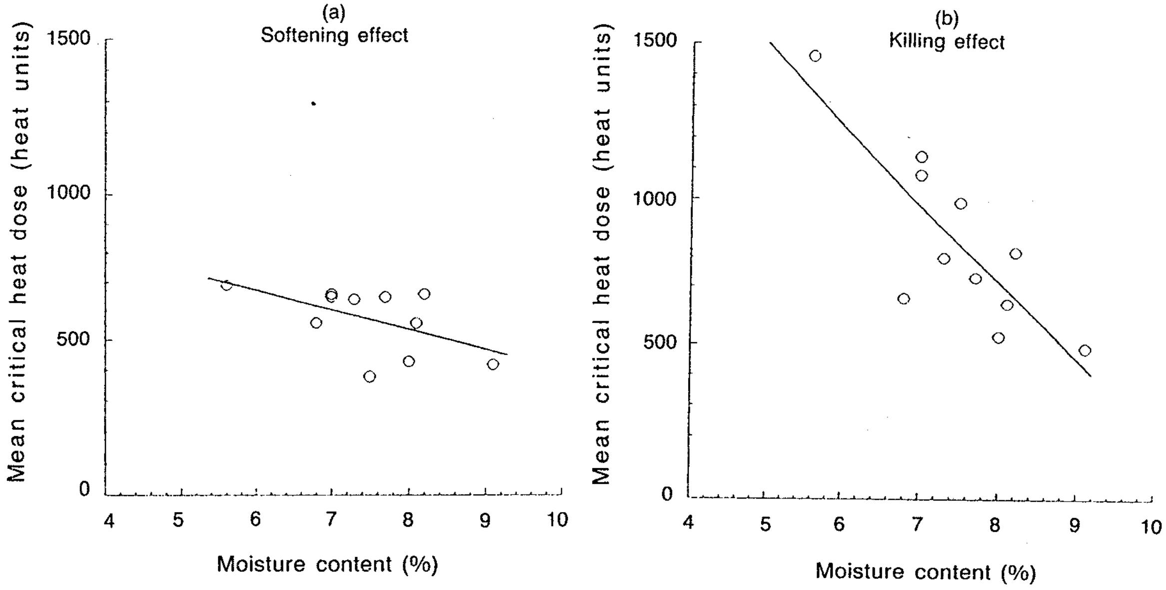

Figure 3. Influence of seed moisture content on mean critical heat dose for softening (r^2 = 0.29) and killing (r^2 = 0.67).

Table 3. Summary of effect of hammer milling in comparison with those of a heat treatment of 1 400 units. All figures are in percentages and are the mean values for 6 separate lines of seed. Dehulled seed constituted an average of 52% of milled seeds. The statistical analyses are too complicated to summarise simply. The chief source of variation was differences between lines, and in that respect standard errors may be taken as approximately 15% of quoted individual means (except for single digit values where such standard errors are invalid).

	Untreated	Milled		Heat treated
		Intact	Dehulled	
Germination tests				
Readily germinable	24	25	64	18
Hard	60	52	24	4
Dead	16	23	12	78
Soil emergence tests				
Total emerging seedlings	24	25	43	11
Surviving hard seed	45	35	11	1
Presumed dead or died	31	40	46	88
Emerged seedlings, Day 6 or after 1st watering	1	1	17	0
Deaths as % of viable seeds sown	17	21	39	52

insulative properties of the hull. Since the proportions of either hull type in seed lots vary widely with the details of harvest method, this difference must be assumed to cause substantial variation between lots in response to treatment.

In the combined evaluation, heat treatment of seed proved unduly severe (Table 3), as the dose was chosen before much of the foregoing information was available. Seed that survived heat treatment had poor prospects in soil, in terms of either producing seedlings or remaining as hard seed. From this we conclude that, even where it did not kill outright, heat treatment caused damage. The rate of emergence of heat-treated seed over the first watering period did not differ measurably from that of untreated, even though strophiole-rupture occurred on a grand scale. Presumably, the damage caused by treatment delayed germination, cancelling out the effect of the earlier water uptake.

Hammer milling

Milling abraded hooks and thus improved seed flow properties. On average, it dehulled 52% of seeds, with a slight tendency to dehull proportionally more mature than immature seed, and more lower than upper segment seed. When light material was aspirated off, it reduced bulk weight by about 20%.

A proportion of dehulled seed was scarified by passage through the mill, which increased and advanced germination in both laboratory and soil tests (Table 3). Dehulling appeared to reduce survival rates of live seed in soil, which seemed to be due to damping-off, as if exposure of the embryo through damage to the testa, and perhaps to the underlying cotyledon, had increased vulnerability to pathogen invasion. Dehulling also resulted in a smaller reservoir of surviving hard seed in soil. There was no evidence that milling affected seeds that retained their hulls, differences recorded being attributable to the slight selectivity of the operation in tending not to dehull the poorer quality, shrivelled seed.

Discussion

Heat treatment

The main effects of heat treatment, i.e. softening and killing, have been recorded whenever high temperatures have been used on stylos (see McKeon and Mott 1984 for review). The view that softening is due to strophiole-rupture as a result of tensile stresses set up by sudden temperature changes is well founded, and there is no reason to doubt its present applicability. The response to heat dose (Figure 2a) is probably a response to differences in maximum temperature and heat flux in the seed itself. Mott's (1979) measurements of internal seed temperatures in relation to time of exposure to a heat source give some indication of the temperatures and rates of change that would apply. The virtual absence of a relationship between temperature and seed moisture content with respect to softening (Figure

3a) is consistent with expectation, as there is no reason to think that differences in moisture content over the relevant range would have much effect on either heat flux or tensions in the testa.

- The adverse effects of heat treatment, i.e. damage to surviving seed and death, are similar to those of aging deterioration, but are intensified beyond their normally measured limits by high temperature. The response to heat dose (Figure 2b) is similar to the response to cumulative aging at the lower temperatures at which stored seeds are kept (Roberts 1986). The relationship between heat dose and seed moisture content with respect to killing (Figure 3b) is also consistent with the aging analogy, as aging deterioration also accelerates markedly with increase in moisture content (Ellis and Roberts 1981). To extend the comparison, it is inferred that seeds that survive heat treatment must have been materially aged by it and therefore had their life expectancy and vigour reduced. The low rate of survival of viable heat-treated seed sown in soil (Table 3) can be interpreted as indicative of this. It can be argued that such effects are a sometimes hidden but inevitable consequence of the use of heat, and a fundamental shortcoming of this approach.

The question arises of why Seca presents so much of a problem for heat treatment when other stylos have responded satisfactorily. One reason is suggested by Paton's (1993) results with fine-stem stylo, which show almost complete softening at a heat dose as low as 150 units. Legumes clearly differ in the intransigence of their hardness, and the strophioles of Seca may be particularly difficult to rupture. Another problem with Seca is the presence of variation among seed lots in properties that affect the outcome of treatments e.g. moisture content and hull characteristics. Seca is not necessarily unique in this respect, and the use of Verano seed of a wider range of moisture contents than that available to Mott (1979), for example, might have exposed similar problems.

Inconsistency of the kind recorded with the present heat treatments is commercially unacceptable. A processor may tolerate occasionally ineffective treatments — indeed certain commercial scarification techniques of the past have been totally ineffective on Seca — but cannot afford ones that introduce even the slightest risk of killing someone else's seed. For this reason alone, brief, high-temperature treatment of Seca could not, on present experience, be recommended for commercial use.

Hammer milling

In contrast to heat treatment, hammer milling consistently increased laboratory germination and soil emergence without causing appreciable immediate death. In field conditions that allowed an early strike of seedlings to survive, this would be expected to improve establishment. It provides a reasonable and not unexpected explanation for milled seed's good reputation.

Compared with strophiole-breaching, scarification through hammer milling is a simple operation with simple consequences. Although it increases risk of death during germination, reduces long-term survival in soil, and may accelerate deterioration in the event of either prolonged storage after treatment or a long interval between sowing and rainfall, these effects, even in total, are small and easily kept within limits.

However, scarification is not a complete substitute for strophiole-breaching. Neither the ease with which scarification is done nor the difficulties of heat treatment alter the case for the value of strophiole-softened seed, argued elsewhere (Hopkinson 1993) and demonstrated in Gramshaw's earlier-mentioned experiments. The question remains, then, of what alternative ways of strophiole-breaching could be exploited.

Prospects

Hot metal contact methods would be more reliable if seed moisture content were first reduced to a uniform low level of about 5%. This is technically easy but unlikely to be adopted. It would add another expense, and would not eliminate all sources of inconsistency. Heated cylinder treatment is already slow; linked with extra drying, it may be seen as too cumbersome.

Other routes, e.g. oven heating (Gilbert and Shaw 1979; Mott and McKeon 1979), hot water treatment (Gilbert and Shaw 1979; Gramshaw (unpublished data)), use of microwaves (Ballard *et al.* 1976), exposure to direct sunlight (Gardener 1975), and percussion (Ballard and Grant-Lipp 1965) have a place in treatment of small lots, but so far are impracticable for large quantities.

A final possibility would be to use suction-harvested seed already incidentally softened by weathering. To induce growers to change from heading to suction-harvesting would require a premium to be offered for suctioned seed to compensate for the greater trouble and expense. This would first require users to be convinced of advantages arising from choice of strophiole-softened seed. These advantages need more widespread confirmation. Clearly partial scarification through hammer milling or some similar process will remain the only practicable seed treatment for Seca for some time.

Acknowledgements

The hammer mill modifications were conceived and made by B.H.English and the Walkamin Research Station farm staff. The records summarised in Table 1 were made available by Barbara McVea and were collected by the staff of the Mareeba Seed Testing Laboratory. Germination tests on all heat-treated seed except that for the combined evaluation were performed by Alan Peacock at Indooroopilly. The remaining work was done in facilities provided by Brian Pastures, Walkamin and Kairi Research Stations and was supported by the Meat Research Corporation and its predecessors.

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