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POSSIBLE SOLUTIONS TO CONTAMINATION OF WHITE CLOVER SEED CROPS BY BURIED SEED

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Abstract. Buried hard seed from seed returned to the soil during harvesting and incorporated by cultivation, poses the greatest threat of contamination. When a different white clover *(Trifolium repens* L.) is sown, contamination will occur when hard seeds within the germinating zone soften and emerge. Harvest losses can return 40 to 210 kg/ha of hard seeds to the soil. Flowering management and efficient harvesting are necessary to minimise quantities of hard seed returned to the soil. For a buried seed load of 845/m* in the germinating zone of a cultivated seed bed at sowing in March, 8% of that seed load gave rise to establishing plants of which one-third (19/m²) were surviving in mid-October. At closing the percentage crop contamination within the sown row was directly proportional to the within-row seeding rate of the sown cultivar. At wider-than-normal row spaces, (45 cm compared with 15 cm) either inter-row cultivation or spraying for removal of contaminants was necessary at closing to reduce contaminants to a density similar to that in 15 cm spacing treatments. Physical contamination of the harvested seedline, compared with levels present at closing, had doubled for normal, but trebled for wider-than-normal spacings. Lowest percentage physical contamination of a seedline gained was 13% for a 6 kg/ha seeding at 15 cm spacings.

The results indicate that successful cultivar change on many areas will be difficult. A buried seed count is considered an essential guideline to aid choice of paddock. Future management systems now being developed, include the use of herbicides and direct drilling, and should help to minimise this problem.

Keywords: White clover, ***Trifolium repens***, seed production, contamination, cultivar change, harvest losses, hard seed, cultural practices.

REDUCING HARD SEED RETURNED TO THE SOIL

Flowering Management

To minimise the hard seed content of white clover *(Trifolium repens* L.) seed returned to the soil, crop management should promote the shortest flowering span consistent with a high harvestable seed yield potential. Mid-November closings achieve this objective for all NZ bred cultivars (Figure 1) (Clifford, 1979; 1980). However some overseas cultivars may vary in closing date requirements.

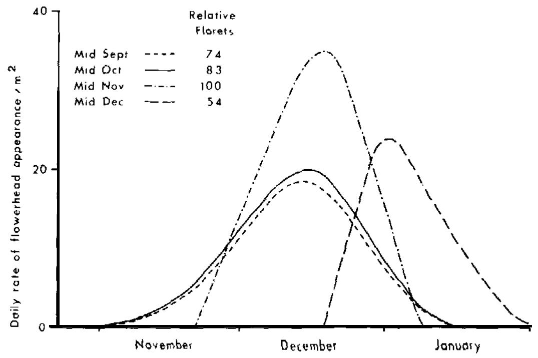

FIGURE 1. Effect of closing date on intensity of and flowering span in a white clover seed crop (from Clifford, 1980).

Harvest Time

Having optimised flowering span, harvest must occur at the earliest possible time consistent with good storage quality of the resultant seedline. Best timing of harvest is about 6 weeks from peak flowering, or where more than one worthwhile flowering has occurred, 4 weeks from the last. Even the hard seed content of seed lost from early harvesting will increase if soil moisture levels remain low after harvest. Thus, all harvesting losses must be minimised.

Harvesting Process

Apart from climate losses hard seed can be returned to the soil at three harvest stages: mowing, pick-up and header separation. Climate, mowing, and pick-up losses are common to the total crop area. Separation losses occur in the limited bands of the header offal.

A preliminary survey of on-farm losses, including pick-up but not separation losses, ranged from 12-39% of the total crop available for harvest (Clifford and McCartin, 1985). The overall mean loss was 200 kg/ha containing 130 kg/ha hard seed. A series of evaluations of mower types and crop conditions for mowing also showed wide variations in harvesting efficiency (Clifford and McCartin, 1985) (Table 1). Percentage crop losses at both mowing and harvest ranged widely, being higher than previously suspected. Notably an overall advantage of about 10% in retrieving mowing losses was obtained when a counter-rotating beater-type pickup ('Murphy') was used to deliver the cut crop to the header for threshing and separation.

TABLE 1 Range of harvesting losses for mowing and pick-up-for-threshing and the hard seed content. (Clifford and McCartin, 1985).

Operation	Crop losses % lost	kg/ha
Total seed		
Mowing	17-59	200-540
Pick-up	5-38	60-340
Hard seed	61-71	40-210

The percentage hard seeds in pick-up losses were 61 to 71%. Hard seed returned to the soil (not picked-up) ranged from 40-210 kg/ha, a very high rate compared with the normal sowing rate of 3 kg/ha.

Lowest seed losses (5%) were recorded for a desiccated crop cut the morning of harvest with a double-reciprocating knife mower, retrieved for threshing and separation with a 'Murphy" pick-up the same afternoon. Overall losses were highest with twin-spindled rotary mowers.

TABLE 2 Effect of threshing and separation efficiency at harvest on the distributions of hard seed. (Clifford and McCartin, 1985).

Threshing Performance	Distribution pattern (kg/ha) Pick-up area	Offal trail area
Good	151	167
Poor	154	417

Separation losses, although of economic importance, should not add to the hard seed content of the soil. Scarification of seed in the threshing and separation cycle should ensure that any losses in the header offal are of immediately viable seed. However, poor threshing conditions and/or header settings can give up to a threefold increase in hard seed returned in the limited area of the offal trail (Table 2). Thus, an already serious problem can be further compounded by way of unequal distribution within the paddock.

Future Development

A current collaborative research programme between the New Zealand Institute of Agricultural Research (NZAEI) and Grasslands Division is aimed at reducing the present level of losses. Upgrading the efficiency of beater-type pick-ups and direct heading of desiccated crops to minimise losses are being assessed. The initial testing of a rotary direct-heading prototype attachment (designed by R. J. Thomson, NZAEI) has improved scarification of seed. At both pick-up and separation, seed losses from rotary, direct heading contained much less hard seed (76 and 45%) than losses from a conventional Murphy pickup (97 and 94% respectively). As such the presence of sufficient soil moisture to impede further development of hard seed post harvest is of less significance.

To date, using the best techniques as described, hard seed returned to the soil for a high yielding specialist crop would be reduced to about 70 kg/ha. Compared to other means where contamination can be introduced, harvest losses are still by far the major source of contamination. Other means are dirty equipment (drills, header, tractors, bins), sheep that have been feeding on seeding stands or feeding hay that contains clover.

ACTIVATING BURIED SEED

To date no satisfactory method has been developed to promote either a high level of germination or mortality within the buried seed load.

Fumigants, e.g. methyl bromide, do not kill buried white clover seeds. There was an increase in the rate of emergence of white clover seedlings for 18 months after treatment with methyl bromide compared to no fumigation (Popay et *al., 1983).*

Some minor effects have been measured for earthworm activity (McRill and Sagar, 1973).

The softening of buried hard seeds of clovers resulting in germination and emergence has been studied in detail for subterranean clover ***(T. subterranean)*** (Quinlivan, 1966;

Taylor, 1984), red clover (*T. pratense*) (Win Pe, 1978) and white clover (Robinson, 1960). Rates of seed softening decrease with increasing depth of burial, apparently because soil insulates seeds from high soil surface temperatures and from fluctuating temperatures. For buried white clover seed, peak softening and establishing occurs in spring (Robinson, 1960; Popay et *al.*, 1983), and to reduce contamination, autumn sowings are preferred to spring sowings.

Buried seed rates of white and suckling clovers were measured before and after 4 years cropping at a Marton site (Suckling and Charlton, 1978). Levels were reduced a great deal but significant levels still remained.

In a study on subterranean clover Taylor (1985) reports that after 4 years residual buried seed loads in the O-6 cm were 20, 240 and 330 seeds/m² for no-tillage, minimum tillage and conventional tillage systems. These results can be explained in terms of seed burial by cultivation. Most of the seed on the surface in no-tillage plots germinated in the first two years and rapidly depleted seed reserves in the soil.

Farmer establishment practices

On the intensive clover cropping farms of Canterbury (96% of the total NZ area in crop), white clover seed is frequently sown and harvested every third year. Therefore breakdown in buried seed levels would be lower than in the two previously described cases.

For Canterbury clover farms, observations on establishments from buried seed, in relation to time of cultivation and companion-crop competition, allow a better understanding of the likely success of present clover sowing alternatives in combating contamination of a cultivar-change crop. Spring contaminant establishments under cereal crops tend to be low; presumably a competition effect. By contrast contamination resulting from later-spring cultivations for peas is usually high. For autumn sowings with ryegrass seed crops the establishments of clover crop contaminants are low; again a competition effect. Non-competitive autumn pure-clover sowing also allows contaminants to establish, moreso if associated with cultivation and irrigation. However, for autumn pure-clover sowings compared to spring establishments under peas, contaminant survival beyond initial establishment tends to be much lower. These observations suggest that the lower contamination levels for companion sowings with either cereals or ryegrass may be negated through an equally poor establishment of the sown cultivar. Current successful establishments of autumn-direct-drilled-pure crops appear to have only low levels of contamination. However, the timespan this practice has been in use does not allow meaningful observation. Thus, for our seed-production environment, a greater knowledge of the duration harvest losses must be retained on the soil surface to render them ineffectual is essential.

Until then, many of our traditional seed production areas will contain high buried-seed loads (Lancashire et *al.*, 1985). Many growers in these areas wonder what degree of success they are likely to have in changing from seed production of Huia to that of an alternative cultivar within the rules for cultivar change introduced by Ministry of Agriculture. and Fisheries (MAF).

CHANGING CULTIVARS

Rules for Change of Cultivar

For certified seed the new rules require that no white clover must have been grown in the previous five harvest seasons, coupled with annual cultivation of the site (Anon., 1984). For second generation seed these requirements are reduced to the standard OECD minimum of 3 years. Nucleus, Breeders and Basic sown seed must be sown in 30 cm row spacings, at a recommended sowing rate of 3.0 kg/ha. The crop is inspected on four occasions by MAF. Contamination level allowed is none for Breeders and Basic, 1/100 m² for 1st Generation and 1/10 m² for 2nd Generation seed.

For Grasslands cultivars final paddock selection for Breeders seed of all clover cultivars is on a basis of buried legume seed counts before allocation of seed. Sites with O-3 seeds per 50 core samples taken to a depth of 5 cm, equivalent to O-120 seeds/m², are preferred. The average buried seed rate of paddocks applying for Breeders seed has been of the order of 800/m² (Lancashire *et al.*, 1985).

Experimental Results

At Lincoln for the 1977-78 season Grasslands Division evaluated the potential to grow an alternative cultivar on a site with a buried seed rate similar to the average obtained in tests. The paddock was harvested for Huia clover seed in January 1976, grazed until late winter, deep ploughed then surface worked and sown in spring 1976 to process peas, Establishment of volunteer clover under the peas was more than adequate to have used the paddock for a 'volunteer' seed crop.

After the peas were harvested it was assumed that the remaining buried seed was 'hard seed'. An area of this stand was surface worked to remove volunteers then sown in mid March 1977. Feathermark white clover, which is agronomically similar to Huia but has a red midrib leaf mark controlled by a simple dominant gene (Corkill, 1963), was precision drilled. There were 6 replicates in a randomised design. Treatments were as follows: 3 kg/ha at 15 cm spacings (standard),, 6 kg/ha at 15 cm spacings (high row density), 2 kg/ha at 45 cm spacings (high row density), with inter-row treatments of nil or either inter-row spraying or cultivation for contaminant control before closing to flower in mid October 1977.

The initial buried seed rate was $845/m^2$ in the germination zone, and after cultivation for sowing, this was reduced by 14% (Table 3). By mid June, 8% of the seed load was present in the form of establishing plants ($60/m^2$), contaminating the sown cultivar. However, by mid October two-thirds of these contaminations had perished, leaving 19 contaminants/m^2 (Table 3). In late January

TABLE 3 Effect of ground preparation on buried seed load (O-5 cm) and establishment from buried seed.

Treatment	Populations /m^2	kg/ha
Buried seed load		
Before cultivation	845	5.5
At mid June	663	4.1
Contaminants		
At mid June	60	0.4

1978 plots were individually harvested and 200 seeds were grown to determine the percentage physical contamination for each plot. Contamination within the row was directly proportional to the within-row seeding rate of the sown cultivar (Table 3). A similar result was obtained in a trial at Palmerston North in 1980. Before inter-row treatment, differences in percentage contamination, because of sown cultivar density, were present only for the 15 cm spaced comparison (12 cf. 7%). Once treatments of both inter-row spraying and inter-row cultivation had been applied, the advantage of high density sowing to reduce potential seed crop contamination became evident at wider than normal spacings for these practices also (Table 3).

Contamination levels of the harvested seed lines were higher than estimates made on vegetative components before flowering. However, they were in accord with those for flowerhead contamination at harvest (Table 4).

TABLE 4 Effect of cultural practice on physical contamination of the resultant seedline.

Contamination	Control	Row spacing (cm) 15	15	45	45	45	LSD 5% or s.e.
Seed rate (kg/ha)	Nil	3	6	2	2	2	
Mechanical Control	Nil	Nil	Nil	Nil	Cult.	Spray	
Pre inter-row treatment (early October)							
Contaminants/m'	21	19	20	14	20	22	±2.8
% Contamination within the row		11	4	5	6	6	4.6
% Crop contamination		12	7	13	9	10	± 2.1
Post inter-row treatment							
At mid-October closing (%)		12	7	13	4	5	6.7
Prior to harvest							
% contaminant flowerheads		25	12	37	22	16	10.1
At harvest							
% physical contamination of the seedline		26	13	35	21	16	12.2

The increase in percentage contamination of the seed line, for 45 cm rows compared with 15 cm spacings, was attributed to contaminants within the untreatable 7.5 cm zone either side of the wide spaced rows being able to better exploit the wider inter-row area, Thus, at wider-than-normal spacings minimising the untreated zone either side of each row is paramount. Genetic differences in the ability of the two cultivars to produce seed were of no consequence.

However plants derived from the buried seed load appear to be predominantly smaller leaved than the cultivar from which they were derived (Lancashire *et al.*, **1985**), and thereby predisposed towards a greater seed yielding potential (Clifford, 1985). Thus leaf-size differences as well as competitive advantage were a probable contributor to the large increase from percentage vegetative contamination to that found in the harvested seedline (Table 4).

Genetic differences amongst certain cultivars, particularly in leaf size, can have the potential to produce major effects and should not always be discounted (Clifford, 1985). Where small-leaved contaminants are found in a large-leaved crop, their per-plant contribution to the seedline will be higher than that from one of similar leaf size. This feature highlights the need for establishment inspections; a time when maximum genetic expression is evident. Once leaf-size-reducing practices to maximise yield have been imposed (Clifford, 1985), the effectiveness of later inspections may be impaired.

Sowing Management

Crops should be autumn sown to reduce contamination from hard seed which has a peak emergence in spring. To ensure adequate vegetative development necessary for a high yielding seed crop, sowing should be no later than mid February. To achieve this on a well prepared cultivated seedbed, sowings can only follow ryegrass, early pea crops, or a fallow. Sowings after cereals frequently fail because of poor seedbed preparation and/or delay in sowing. Irrigation will be essential in most years.

Overseas results already discussed (Taylor, 1985) suggest that autumn direct-drillings of paddocks that are in excess of the MAF 3 or 5 year-annual-cultivation requirement will give the best results.

Cultivar Change — Is it possible?

The likely degree of success, based on available information, is predicted in Table 5. Without roguing, none of these crops meet any of the inspection requirements for physical purity as laid down by MAF. The least contaminated crop (60 cm spacings) may be rogued to a level satisfactory for 2nd generation New Zealand Certified Tahora seed. At best, costs of cultivar change will be high. Further, should the initial crop not meet certification standards it will be out of clover seed production for up to another 5 years. For many farmers who include peas in their rotation, this is an unacceptable situation because of disease problems.

TABLE 5 Empirical effect of row spacing on contamination and resultant seed yield.

	Row spacing (cm) 15	30	45	60
Seeding rate (kg/ha)	6.0	3.0	2.0	1.5
Inter-row contaminant control (% of total area)	0	50	67	75
Seed line contamination (% physical contamination)	10.0	7.5	5.6	5.0
Yield potential (kg/ha)*				
1st crop	1000	1000	800	600
2nd crop	450	600	650	750
Combined Yield	1450	1600	1450	1350
Acceptibihty of practice	out no inspection	? roguing costs	? roguing costs	? roguing costs

*from Clifford (1977, 1979, 1980) and unpublished data.

Ultimately only a buried seed count will give the grower some idea of the potential for success in changing from the growing of one cultivar to another. Although not always completely accurate, it has a far greater confidence level than paddock history. Unless on virgin soil, paddock history alone gives no definite indication of buried seed rates either present in, or more particularly through cultivation, likely to be introduced into the germination zone of the cultivar-change crop. It is of some urgency that an independent facility be set up for buried seed tests for all cultivars of white clover if the cultivar change is to run smoothly. Even at a substantial fee, buried seed counts would prove to be far cheaper than roguing costs for the production of uncertified seed coupled with a further five years out of clover crop.

THE FUTURE

Current rules to maintain the high quality of New Zealand produced seed traded on the overseas market are likely to change only as knowledge to further enhance these standards becomes available.

Carbon Banding

Activated carbon applied in bands above the seed row and followed by a non-selective herbicide (eg diuron) is a possible method of reducing contamination to acceptable levels (Rolston et *al.,* 1979). More recent experiments at Palmerston North have indicated that with this method there is a risk of substantial crop damage if heavy rain follows the treatment. Agricultural grades of activated carbon are not yet commercially available in New Zealand.

Herbicides

Direct drilling relies solely on herbicide removal of clover over the 5 year period. At Lincoln, dicamba, clyporilid (Lontrel 300) and glufosinate ammonia (Buster) have proved effective in eradicating the dense three-year-old stand. For cultivar-change sowings, glufosinate has an advantage in not requiring a withholding period from time of application to sowing, compared with dicamba (6 weeks) and clyporilid (8 weeks). Thus for glufosinate the time from cereal harvest to sowing of a new cultivar would be minimal. This is an important factor in meeting the mid-February requirement for sowing.

Cultivation versus direct drilling

Each cultivation has a potential to add more buried seed to the germinating zone. Over time, should any additional seed have a greater potential to germinate, then each cultivation may -be counter to minimising contamination. By contrast, direct drilling relies on total exhaustion of the establishment potential in a stable germinating zone over a 5-year period.

Grasslands Division Lincoln, is assessing the possibility of minimising 'the activation of buried seed' through direct drilling as an alternative to annual cultivations. The test area has had two successive clover seed crops (1980/81, 1981/82) and one year of no seeding to ensure that all immediately viable seed was exhausted.

A series of plots was sprayed in early November 1983 with dicamba to eradicate established clover. From mid-December through to sowing in early March 1984 this series was shallow cultivated (10 cm) for seedbed development. Direct-drilled plots were sprayed with herbicides (dicamba, clyporilid, glufosinate) in accordance with respective withholding periods and either sown as cultivated or direct-drilled plots. Contaminant counts at mid June and in early October were similar for cultivated and direct drilled plots. However, by mid October two-thirds 'of the contaminants had perished (1970 cf. 630/m² for June and October respectively). Surface-borne seeds on direct-drilled plots have the same potential to become viable as those more intimately incorporated in the soil through cultivation. The similar mortality (66%) from late winter through to late spring, as shown in earlier research, indicated the desirability of the range of crop inspection times now used in certification. An additional four years work, with more cultural alternatives, is required before formuiation of any positive results.

CONCLUSIONS

At present many uncertainties still remain as to the degree of success most farmers will have when changing cultivars. The timely introduction of new certification rules, to protect cultivar quality standards, has not been without problems in the formulating of desired rules. A general lack of research into many important aspects of growing pure crops of alternative cultivars was evident. It is obvious that sustained research will be required to alter the current situation. Until then the availability of an expanded counting service for buried seed is of immediate priority.

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