

Determination of Harvest Date in *Lotus corniculatus* by Pod Colour

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ABSTRACT

Lotus corniculatus seed development at a series of harvest dates and its relationship to pod colour was examined. Changes in the population of pods in different colour categories were investigated. The effect of drying seed in pods after harvest and before threshing was also examined. Seeds from purple and green pods did not germinate after drying but viability developed rapidly as pods reached the yellow-brown stage. Most viable seeds were categorised as hard seeds. Later harvests showed deteriorating seed quality due to fungal infection of the pods. Pod dehiscence was low, probably due to the high relative humidity which prevailed during the experiment. It is proposed that the optimum harvest time can be determined by observation of the proportion of purple pods.

Additional index words: *Lotus corniculatus*, seed quality, pod colour, harvest timing, seed drying.

INTRODUCTION

Lotus corniculatus L. is a low-growing herbaceous legume native to Europe but widely used for forage throughout temperate regions (Rhykerd, Hawkins and Mott, 1979; Formoso, 1983; Paim, 1988). It is an important species on poor soils where clovers and lucerne do not perform well (Barnes, 1989; Li and Hill, 1989; Belesky and Wright, 1990).

As with other indeterminate flowering plants, deciding the best time to harvest may be difficult and knowledge of the development of maturity in the seed population is essential to establish a practical technique for recognising the optimum time. Anderson (1955) measured the weight of seeds from flowering to maturity and related this parameter to changes in pod colour. Seed maturity was associated with a change of colour in the pods from light green to light brown.

Winch and Macdonald (1961) identified three distinct physiological stages. In the first stage, when pods were dark green to dark purple, pods reached their maximum length but seeds were immature and did not germinate after drying. This stage was little affected by weather conditions. In the second stage, when pods were light green, seeds with viable embryos were still small and shrivelled after drying. The duration of this stage was profoundly affected by weather conditions. Seeds reached maximum viability and weight in the third stage when pods had turned golden brown. The length of this stage was also little affected by environmental conditions.

Li and Hill (1989) found normal germination developed from 26 days after flowering and peaked at 30 days. After 34 days production of normal seedlings decreased and the amount of hard seed increased.

Pod dehiscence and associated seed losses have been identified by many authors as a major problem of seed production in *L. corniculatus* (Anderson, 1955; Seaney and Henson, 1970; Marten, 1985). Metcalfe, Johnson and Show (1957) found that very small differences in relative humidity caused mature pods to dehisce in sunny weather. They concluded that seed

production would be more successful in areas where humidity did not fall below 40%. Anderson (1955) reported that only 2% of pods dehisced, even though 93% were light brown to black in colour, in a season when relative humidity remained above 50%.

Problems of dehiscence suggest that harvesting shortly after the maximum number of pods have reached maturity would maximise both quality and yield of seed harvested. Several authors point to a light brown colour as an indication of maturity and recommend harvesting when the majority of pods are at this stage, but the proportion of pods which should be in this colour category remains unclear (Anderson, 1955; Metcalfe *et al.*, 1957; Winch and Macdonald, 1961; Li and Hill, 1989).

The objective of this study was to produce a practical guide for timing of harvest by examining the relationship between pod colour in a crop population and the development of seed quality.

MATERIALS AND METHODS

Experiments were carried out at Terrington St. Clement, Norfolk, UK (52°N) in July 1992. The site was located on a silt loam soil. Climatological data were obtained from the Ministry of Agriculture, Fisheries and Food, (Terrington St. Clement Station). A local ecotype of *Lotus corniculatus* L. collected in Nottinghamshire was used, representing a wild population with a large amount of variation. The experimental plots were part of a commercial seed crop grown for "wild flower" mixtures, sown in September 1989 at a rate of 2.5 kg ha⁻¹, the plants being spaced at 10 cm intervals in rows 48 cm apart.

Within the crop 36 plots each 2 m long and approximately 2 rows wide were identified during flowering. In each plot, 15 individual pods were tagged with wool at a very early stage (purple colour) to study their development and maturity. At 3 or 4 day intervals, one pod from each plot was collected and these were bulked to form a sample. These pods were dried for 15–20 days at ambient temperature and were then

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threshed by hand. Germination and thousand seed weight were determined for each of the samples. All seed quality tests in this study were carried out according to the recommendations of the International Seed Testing Association (1985). Thousand seed weights were adjusted to 7.5% moisture content.

Additional pods were collected from the same plots at different stages of maturity, defined as purple, green, yellow-brown, brown and black. Pods showing visible signs of fungal infection were also collected and scored as a separate category. These pods were threshed immediately by hand and the seed dried at ambient temperature. Germination and one thousand seed weight were determined for each stage. Pods in the purple, green, yellow-brown and brown colour categories were also collected from these plots and left to dry in a greenhouse for four days before threshing.

To determine the proportion of pods at each development

stage, approximately 100 pods were harvested from each of 3 separate replicate plots of 3.36m² at 2-5 day intervals commencing on the 1st day of July. This was repeated with different plots for four harvest dates in July.

RESULTS

Mean pod length showed little change during the period, with a maximum value of 2.7 cm (Table 1). Thousand seed weight continued to rise through the experiment. The number of seeds which germinated normally was negligible, with the viable fraction represented almost entirely by hard seed, which increased progressively to a maximum of 66%. The major change in viable seed content of the samples occurred in the four days between the fourth and fifth harvest, when the proportion rose from 16% to 56%. The proportion of abnormal seedlings showed no clear trend, but contributed up to 13% of the total at the fourth harvest.

Table 1. Seed quality components at different harvest dates

	Date of Harvest						
	1/7	3/7	6/7	9/7	14/7	18/7	22/7
Pod Length (cm)	2.5	2.6	2.7	2.6	2.6	2.5	2.6
1000 seed weight (g)	0.358	0.415	0.471	0.668	0.905	0.901	0.985
1) Normal Seedlings (%)	0	0	0	0	1	1	0.5
2) Abnormal Seedlings (%)	0	3	7	13	6	10	8
3) Fresh Ungerminated Seeds (%)	0	1	3	5	1	3	0.5
4) Hard Seeds (%)	0	5	3	11	54	57	66
5) Dead Seeds (%)	100	91	87	70	38	29	25
6) Viable Seeds 1)+3)+4) (%)	0	6	6	16	56	61	67

Pod colour changed in sequence from purple through green to yellow-brown, brown and black. Pods infected with fungal diseases were also dark in colour. Thousand seed weight increased most rapidly between the green and yellow-brown stages, reaching a maximum in brown pods, but thousand seed

weight was lower in black pods and in diseased pods (Table 2). Seeds from purple and green pods showed almost no germination capacity. Seeds from yellow-brown pods were 93% viable but viability declined by the time the pods had turned black. The viability of seeds from diseased pods was low because 66% were dead.

Table 2. Seed quality components at successive stages of maturity indicated by pod colour.

Pod Colour	1000 seed weight (adjusted) (g)	1) normal seedlings (%)	2) abnormal seedlings (%)	3) fresh seeds (%)	4) hard seeds (%)	5) dead seeds (%)	6) viable seed 1)+3)+4) (%)
Purple	0.682	0	0	0.5	0.5	99	1
Green	0.676	0	1	1	0	98	1
Yellow-brown	1.310	3	4	3	87	4	93
Brown	1.377	2	6	0	87	5	89
Black	1.117	12	9	0	60	21	72
Diseased	0.691	1	6	0.5	26	66	27.5

Pods harvested at different dates showed a sharp decline in the purple and green categories at the second harvest date, with a corresponding rise in the proportion classified as brown or black (Table 3). At the third harvest (22nd July) there was little change in the proportions, but by the fourth harvest, the black pods represented 52.7% of the total and diseased pods

19.3%. Dehisced pods never represented more than 9.7% of the total. The data were log-transformed and the probabilities are given in Table 3. All colour categories except for the brown category showed a significant variance with date. Using data from Table 2, the relative proportions of viable seed in the pod populations sampled were calculated and are shown in Table 3.

Table 3. Percentage of pods at different stages of development at different cutting dates.

	Purple (%)	Green (%)	Yellow -brown (%)	Brown (%)	Black (%)	Diseased (%)	Dehisced (%)	Viable seed in pod population
7 July	32.3 (3.494)	29.0 (3.390)	18.7 (2.977)	8.3 (1.900)	11.0 (2.345)	0.3 (0.231)	0 (0)	33.1
15 July	1.9 (0.924)	14.0 (2.630)	19.0 (2.947)	13.0 (2.522)	43.7 (3.759)	0.9 (0.659)	6.7 (1.977)	62.7
22 July	1.7 (0.963)	13.7 (2.65)	10.3 (2.415)	18.3 (2.950)	40.7 (3.729)	5.3 (1.792)	9.7 (2.305)	56.8
29 July	1.7 (0.963)	7.0 (1.830)	5.3 (1.827)	9.3 (2.270)	52.7 (3.977)	19.3 (2.968)	4.3 (1.647)	56.5
Probability	0.001 ***	0.033 *	0.011 *	0.210 **	0.002	0.001 ***	0.001 ***	
SED	(0.271)	(0.396)	(0.259)	(0.484)	(0.273)	(0.285)	(0.260)	

Log transformed data are in brackets.

- * $P < 0.05$
 ** $P < 0.01$
 *** $P < 0.001$

Pods which were dried in a greenhouse after harvest had higher levels of viable seed at the purple and green stages and higher thousand weights at the green, yellow-brown and brown stages (data not presented).

DISCUSSION

The data from tagged pods agree with previous work by Winch and Macdonald (1961), which also showed rapid attainment of maximum pod size after flowering, with seed developing rapidly to reach maximum viability. Physiological maturity appeared to be reached at the yellow-brown stage and the very low number of seeds germinating normally suggests that full maturity was followed by the rapid onset of hard seediness, as shown by Li and Hill (1989).

Thousand seed weight and viability was highest in the yellow-brown and brown categories and declined in black and diseased pods. As it is unlikely that the more mature black pods would contain seed of lower viability, it may be that some of the pods classified as black may have been turned black by fungal infection rather than by the process of drying and maturation. For a practical guide to time of harvest, the best time appears to harvest as soon as the maximum population of viable seeds is achieved. This occurred at the harvest on 15th July when there was still a wide spread of pods in the different colour categories but only 16% were purple or green. An earlier harvest would result in a larger proportion of non-viable seed

from purple and green pods, while a later harvest would result in more diseased pods. This experiment was conducted in a relatively wet season and during the period of this experiment relative humidity remained high, never falling below 63%. Seed loss through dehiscence was low with maximum dehiscence 9.7%. This compares with the results of Anderson (1955) who found only 2% seed loss in similar conditions. Lower humidity during the period of seed formation and maturation would be likely to produce much greater loss through pod dehiscence, making timely harvest more important, although loss of quality through fungal attack may be less significant in such conditions.

The natural tendency for seed growers to use the proportion of seed in the desirable stages of maturity as a guide to optimum harvest date is called into question by these results. The most obvious change in the proportions of different colours of pod was the sharp reduction in green pods from 32.3% to 1.9% between 7th to 15th July, which coincided with the appearance of maximum viability. The proportions of pods of other colours was more difficult to judge due to their relatively small changes, with the additional problem that diseased pods might be mistaken for the mature black category. From this study we would recommend that the time of rapid reduction in the number of purple pods to near zero should be followed quickly by harvest. In warmer, drier and sunnier seasons or sites, this development may take place more rapidly.

Data from post-harvest drying suggested that seed quality might be improved further by drying seed in the pods

before threshing, possibly due to post-harvest maturation or to a reduction in mechanical damage, but more data are required to test the significance of these findings. This would justify further investigation.

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