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An Examination of Different Shoot Age Groups and their Contribution to the Protracted Flowering Pattern in Birdsfoot Trefoil (*Lotus corniculatus* L.)¹

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ABSTRACT

Extended flowering, pod dehiscence, and seed loss, are major obstructions to the successful seed production of birdsfoot trefoil (*Lotus corniculatus* L.). In 1986, in a field trial at Palmerston North, New Zealand, possible causes of the extended flowering period were investigated and the contribution of different shoot age groups to the protracted flowering pattern was identified. Plants showed a 'continuous replacement' growth habit in which old shoots tended to die as new shoots emerged. The approximately three months flowering period resulted from this continuous shoot succession and the fact that shoots quickly became fertile under suitable flower induction conditions. Despite the protracted period of flower production, more than 70% of the inflorescences appeared during a contracted period of about 25 days. Although seven monthly shoot age groups (August to February) were identified as contributing to the total flowering period, only three made substantial contributions to the inflorescence population. Shoots tagged in October, November and December produced more than 75% of the total inflorescences. Indi-

vidual shoots in different shoot age groups had similar flower bearing capacity. The number of inflorescences produced within each age group was therefore primarily determined by the number of shoots formed. Since no sterile shoots were observed under suitable flower induction conditions, the inflorescence population was therefore strongly dependent on the number of shoots present at flowering ($r=0.83$). The implication of these results on seed crop management and some further prospects for improved seed yield in *Lotus corniculatus* are also briefly discussed.

Additional index words: seed production

INTRODUCTION

Birdsfoot trefoil (*Lotus corniculatus* L.) is a herbage legume which shows considerable promise as an important pasture species, particularly in areas where environmental conditions are too severe for good performance by some other species such as clovers and lucerne. The wide adaptability, high persistence, notable nitrogen fixation ability and relatively high yield of this plant make it superior to many other plants in such environments (Seaney and Henson, 1970). However, the comparatively poor seed production from this species is one factor limiting its more wide-spread use. Birdsfoot trefoil has an indeterminate flowering habit which often results in a long and sporadic flowering pattern. This, together with

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its pod dehiscence behavior, makes it difficult to select the optimum time for seed harvesting (Seaney and Henson, 1970). New flowers, young pods and ripe pods are often present simultaneously on plants at harvest. A considerable portion of the potential seed yield tends to be lost, either due to high levels of immature seed or pod shattering at harvest (Seaney and Henson, 1970; McGraw et al., 1986). Furthermore, the plant's low assimilate partitioning to seeds worsens the situation in birdsfoot trefoil seed production (McGraw et al., 1986).

To improve the harvestable seed yield in birdsfoot trefoil, knowledge of the cause or causes of the long flowering pattern is required. While the long flowering period character in this plant has been extensively mentioned by previous researchers (MacDonald, 1946; Joffe, 1958; Seaney and Henson, 1978; McGraw and Beuselinck, 1983; McGraw et al., 1986), there do not appear to be any detailed studies on this aspect of its agronomic performance.

In an indeterminate plant, a long flowering period may be due to a number of causes, including the sequential development of different shoot orders and the delayed development of flowers along stems in which there are several vegetative nodes between successive flowers (such as in white clover) (Thomas, 1980). The sequential development of shoots originating at different times may also be responsible for creating a long flowering period. In this age hierarchy, early shoots have an advantage at flowering time because of their earliness of formation (and often larger size) whilst flowering in late-formed shoots tends to be delayed, resulting in a long total flowering duration. It is also possible that the extended flowering period may also be caused by a combination of some or all of these factors. The present study examined the relative contribution of different shoot age groups, in terms of both numbers and reproductive capacity, to the inflorescence population in birdsfoot trefoil.

MATERIALS AND METHODS

The birdsfoot trefoil seed used in this study was a selection supplied by the Grasslands Division of the Department of Scientific and Industrial Research (DSIR). The experiment was carried out from May 1986 to February 1987 at Massey University, Palmerston North, New Zealand (Lat. 40°S, Long. 170°E). Seeds were sown directly into a cultivated field of Tokamaru silt loam on 26 March and emerged about one month later. A basal application of 350 kg ha⁻¹ of 30% potassic superphosphate was applied immediately prior to sowing. Plant population density was 44 plants m⁻². Starting on 10 May, 27 plants were randomly selected from three 35 m² plots. All new crown shoots formed in each month were identified by tagging with colored plastic rings to

allow later examination of flowering behavior. A new shoot was tagged when it had at least one unfolded leaf. Shoot age in this paper refers to the month in which the shoot was tagged (i.e., a shoot tagged in September is called a September shoot). The number of inflorescences in full bloom produced by different aged groups of shoots was recorded every 5 days (with the exception of first two countings) during the reproductive stage from 28 November 1986 to 21 February 1987. Honey bee populations were high during this time. The total number of inflorescences per shoot was examined when the shoot ceased flowering. It was observed that 2-4 days were needed for a new inflorescence (an inflorescence with only one yellow floret open) to reach full bloom (all florets open) and another 2-4 days were needed for these florets to wither. Therefore, a 5-day inflorescence counting interval avoided repeat or missed countings. In order to investigate flower carrying capacity in different shoot age groups, the position of the first flower to appear, the number of inflorescences per shoot and the number of florets per inflorescence were also recorded.

Plants were also tagged monthly from 20 May for the measurement of shoot growth and development in terms of increase in internode length and node number. Monthly development of node numbers was recorded by examining the number of nodes between two different colored rings tagged on successive months. Monthly growth in internode length was determined by measuring the length between two successive rings more than one month after tagging with the second ring. Number of shoots per plant and shoot survival in different marked age groups were recorded on 15 November, 15 December, 1986, and 15 January, 1987.

RESULTS

Birdsfoot trefoil has an aerial shoot system which comprises shoots arising directly from the crown (primary shoots) and a small number of shoots arising from nodes immediately above the crown on the primary shoots. These two types of shoots behave similarly in terms of size, growth and flowering (Plate 1). The middle section of each shoot usually bears no branches. Although a few tiny lateral branches were occasionally observed immediately below the first inflorescence (Plate 1), these behaved rather like peduncles as they bore only one or two leaves. They were extremely small compared with primary shoots, although they occasionally produced inflorescences. Late-formed shoots bore no lateral structures. The 'typical' plant from this experiment illustrated in Plate 1 clearly shows that in birdsfoot trefoil, lateral structures do not substantially influence flowering pattern, and that the duration of flowering is determined almost entirely by the behavior of the primary shoot population.

results emphasize the important role of new shoots, particularly December shoots, on the surviving shoot population at flowering.

The number of inflorescences changed dramatically with time, showing a sharp flowering peak on 2 January (Figure 1). Flowering extended over approximately three months from the end of November to the end of February. The total flowering period can be conveniently divided into three parts to describe the contributions made by early, intermediate and late flowers. Flowers formed during a period of about 25 days (from about 20 December to 7 January) contributed over 70% of the total inflorescence population. Early (pre- 20 December) and later (post- 7 January) flowers together contributed less than 30% of the flower population. This shows that although birdsfoot trefoil has a very protracted flowering period, major inflorescence numbers are concentrated into a comparatively short period of 3-4 weeks.

Shoots from different age groups (August to February) varied in their contribution to the long flowering pattern (Table 4). Although flowering in each of the seven shoot age groups did not last long (often less than one month) the cumulative effect of all flowering shoots resulted in a lengthy total flowering period. Although all seven shoot age groups (August to February) contributed to the flowering pattern, only three groups were major contributors to total flower number. October, November and December shoots contributed more than 75% of the total inflorescence population. August, September, January and February shoots made relatively minor contributions to flower numbers, but were responsible for greatly extending the total flowering period. October, November and December shoots also contributed nearly 90% of the total inflorescences present during an approximately 25 day period of most intense flowering from 20 December to 11 January.

Older shoots bore flowers at higher nodes while younger shoots commenced flowering at lower nodes (Table 5). This can be attributed to the effects of both shoot age and size. Early shoots, initiated before the weather became favorable for flowering, had already developed to a certain size (in terms of node numbers) before becoming fertile. Late shoots, originating under favorable flower-induction conditions, became fertile while comparatively young so they bore fewer nodes at flowering. Nevertheless, the number of flowers produced per shoot did not vary greatly in different shoot age groups until December or January. Similarly, the number of florets per inflorescence showed relatively small changes in all shoot age groups except for January shoots where a decline in floret number occurred, presumably because of the onset of unfavorable flowering conditions.

DISCUSSION

The plant structure described in this study has emphasized the almost complete dominance of primary shoots arising from the crown, and to a lesser extent, the smaller number of shoots arising from nodes immediately above the crown on primary shoots as contributors to reproductive growth. This effect is similar to that pictured by MacDonald (1946) although he did show more small, but non-flowering lateral branches arising further up main shoots. MacDonald's description (1946) and the structure shown in Plate 1 both support the suggestion that lateral structures make no substantial contribution to the long flowering period.

The present study has highlighted the lengthy (three months) flowering period in birdsfoot trefoil. Experiments conducted by Joffe (1958) and Mckee (1963) have shown that birdsfoot trefoil is a quantitative long day plant, requiring a 14-14.5 hour minimum light period for flowering. In Palmerston North, the period from the beginning of November to the beginning of February of the following year meets this day length requirement for flower-induction with a maximum of 15.3 hours reached on 21 December (Gerlach, 1974). This suggested flower-induction period agrees well with the flowering pattern shown in Figure 1 where flowering began in mid-November and finished in mid-February.

The death of old shoots when new shoots emerged resulted in a continuous replacement by shoot succession. Under favorable flowering induction weather conditions, new shoots became reproductive very quickly after emergence. Each shoot age group was responsible for a particular part of the total flowering pattern. Older (early emerged) shoots contributed to the early part of the flowering sequence while new replacement shoots were responsible for supporting later flowering. Because shoot production is a continuous process, flowering in birdsfoot trefoil appears to last as long as climatic conditions permit. The flowering results show that more than 70% of inflorescences appeared within a period of less than one month, resulting in a contracted peak of flowering within a protracted total flowering period. The profuse flowering of October, November and December shoots reinforces the importance of shoots formed at these times as major contributors to seed yield in this plant. The low inflorescence numbers during the early stages of flowering simply reflects the lack of shoots available at that time. The subsequent onset of unfavorable weather conditions in February diminished flowering potential, resulting in low inflorescence numbers in late formed shoot populations (January and February), despite the fact that there were plenty of shoots present during that time.

Table 4. Contribution of different shoot age groups to total inflorescence population (data collected from 27 tagged plants).

Date	Month of shoot origin							Total	%
	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.		
29 Nov.	0	1	5	0	0	0	0	6	0
13 Dec.	16	17	23	2	0	0	0	58	3
23 Dec.	28	44	121	86	8	0	0	279	18
28 Dec.	14	37	84	103	177	0	0	315	20
2 Jan.	11	22	80	81	289	0	0	483	31
7 Jan.	4	4	11	6	140	13	0	178	11
12 Jan.	0	0	0	0	33	16	0	49	3
17 Jan.	0	0	0	0	10	18	0	28	2
22 Jan.	0	0	0	0	13	41	0	54	3
27 Jan.	0	0	0	0	16	43	0	59	4
1 Feb.	0	0	0	0	8	29	0	37	2
6 Feb.	0	0	0	0	2	13	0	15	1
11 Feb.	0	0	0	0	2	8	7	17	1
16 Feb.	0	0	0	0	1	4	11	16	1
21 Feb.	0	0	0	0	0	2	8	10	0
Total	73	125	324	278	699	187	26	1584	
%	4	7	19	16	41	11	2		100

Table 5. First flower appearance position and relative flower bearing ability of shoots from different age groups

Shoot groups	Month of shoot origin					
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
First flowering node	--	20th	16th	14th	10th	9th
No. of inflorescences per shoot	3.1	3.4	3.2	3.2	2.6	2.0
No. of florets per inflorescence	--	5.7	5.9	5.9	5.2	4.4
No. of shoots on 27 plants (x)	30	56	74	83	438	157
No. of inflorescences on 27 plants (y)	73	125	324	278	699	187
Regression equation	$y = 92.6 + 1.35x$			$r=0.83$		

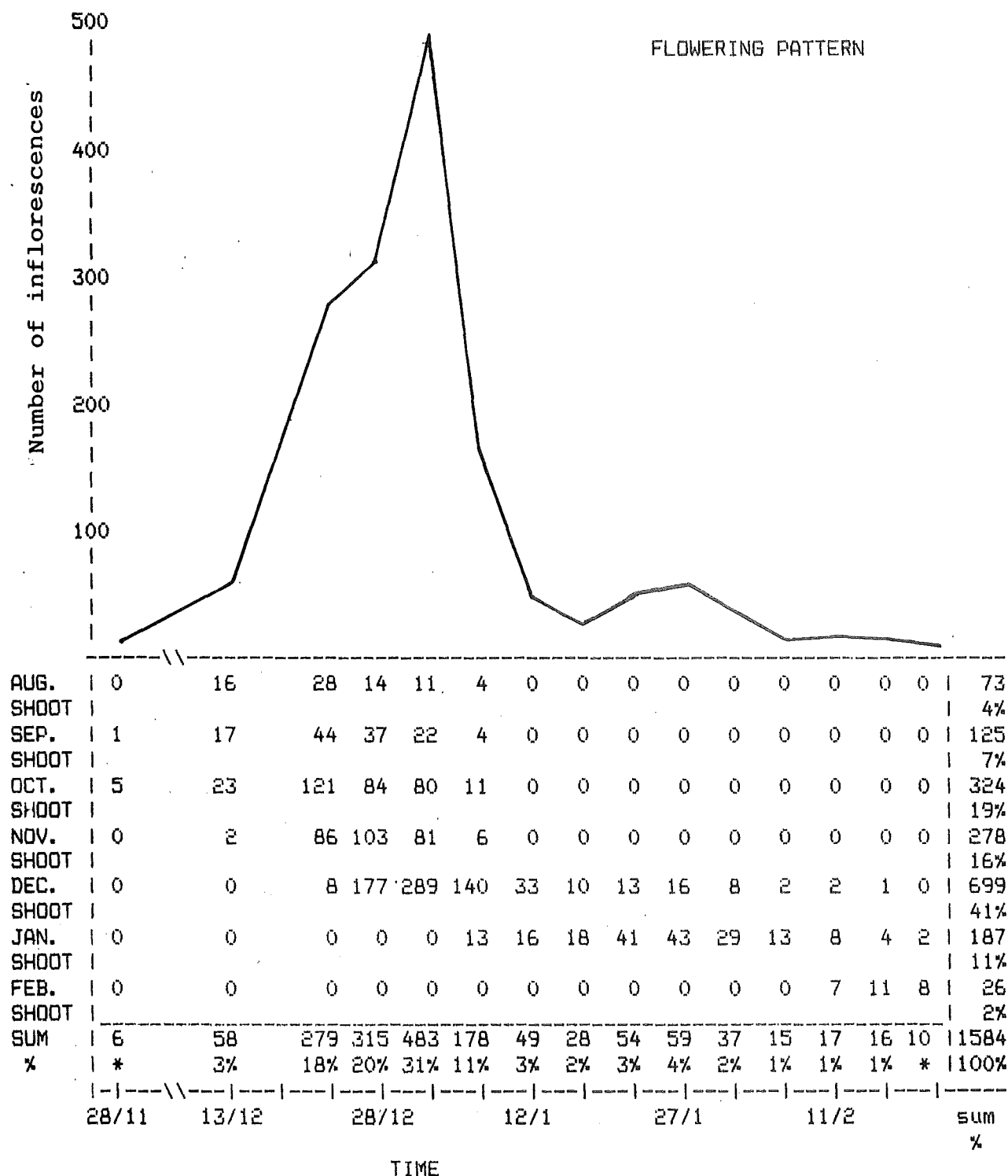


Figure 1: Flowering pattern in *Lotus corniculatus*

The relative flower bearing ability in terms of number of inflorescences per shoot and number of florets per inflorescence in different shoot age groups does not vary greatly compared with the extreme variation in the number of inflorescences produced within different shoot age groups. The decline in flower bearing ability on late shoots (December and particularly January) was likely to be influenced by the onset of sub-optimum or inappropriate weather conditions, particularly day length. However, the depression in the number of inflorescences in mid-January and the decline in flower bearing ability on individual December formed shoots may also have been influenced by extreme drought conditions in late December and early January. The weather during this time included a 45 day period from 1 December 1986 to 15 January 1987 with only 26 mm rainfall, often accompanied by hot, dry westerly wind.

Virtually no sterile shoots were observed during the period of most profuse flowering in this study, a result also reported by McKee (1963) and Nitter and Kenny (1964). It is, therefore, reasonable to suggest that the number of shoots present represents the number of fertile shoots in each shoot age group. This further emphasizes that the number of shoots present at flowering is the most important single factor determining the flowering pattern. The good fit of the regression of the number of inflorescences on the number of shoots ($r=0.83$ Table 5) strongly supports this point.

Seed yield in birdsfoot trefoil is mainly determined by the number of inflorescences (Mos, 1983; Stephenson, 1984). Number of inflorescences is mainly determined by the number of shoots rather than other factors such as the flower-carrying ability of individual shoots. Manipulation of shoot numbers is therefore an important aspect for improving seed production in birdsfoot trefoil. Since shoot numbers are largely responsible for the number of inflorescences, seed production may be improved by manipulation to achieve a high shoot population at peak flowering time.

The present study indicates the importance of higher numbers of shoots formed in October, November, and particularly December in contributing to seed yield. However, earlier shoots make a minor contribution to flowering and seed yield and may play an important role in supporting the development and growth of later shoots.

Although late formed shoots (January and February) added considerably to the total shoot population, they emerged too late to contribute to flowering in the current year. Late shoots may even have a detrimental effect on seed yield by competing with flowers and pods developing simultaneously on earlier shoots. In addition, these late formed vegetative shoots may increase seed crop lodging which can severely affect seed yield in birdsfoot

trefoil (MacDonald, 1946; Anderson and Metcalfe, 1957). January and February shoots may, therefore, be considered to be undesirable for seed production in this species. This suggests that one management strategy which could be used to improve seed production would be to suppress late shoot growth and development. A systematic approach to improve seed production might combine the effect of manipulating shoot status from two directions. Early in the pre-flowering season it may be important to encourage the shoot population to attain high shoot numbers. Subsequently, at around peak flowering, management to suppress late shoot development may allow more assimilate translocation to the reproductive organs already formed on middle season shoots (October to December) and result in a high and contracted period of seed production. Although results are not presented in this paper, it is perhaps worth noting the successful use of Fatol Super C, a sucker killer commercially used in tobacco crops as a post flowering vegetative shoot inhibitor. Further work on this aspect of shoot age manipulation and longevity would be a potentially fruitful area of agronomic research.

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Kansas Wheat Seed: A Comparison of the Quality of Wheat Seed Planted in 1973 and 1984¹

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ABSTRACT

This study investigated the quality of 662 samples of wheat (*Triticum aestivum* L.) seed planted by Kansas farmers in 1984. Information on seed and farming practices was collected on a questionnaire and seed quality information was obtained through laboratory analysis. Results were compared to those of a similar survey conducted in 1973. Information gathered from the questionnaire showed that in 1984 wheat farmers were using better management practices, planting more varieties on their farms, and planting more seed that is certified or fewer generations from certified than in 1973. Seed analysis showed an increase in germination, mechanical purity, and seed weight; however, there was a more extensive weed problem than in 1973. Approximately one-half of the samples had some type of varietal impurity present and six percent were incorrectly reported as to variety. Newer varieties and varieties closer to certified status had highest varietal purity.

Additional index words: purity, weeds, inert matter, germination

INTRODUCTION

There are many factors that affect yield potential of a crop, with quality of seed being a primary consideration. Tekrony (1984) listed five factors that determine seed quality: (1) genetic (varietal) purity, (2) mechanical integrity, (3) seed-borne disease infection, (4) germination and vigor, and (5) freedom from crop and weed seed contamination. These factors separate quality seed from bin-run seed. In spite of source and handling of bin-run seed, difference in quality between it and seed produced within established practices has been documented by Tekrony (1984). In the past decade, organizations within the U.S. have conducted surveys on wheat to determine the quality of the seed being planted.

In Oregon, Goetze (1976) found that of 99 wheat seed samples collected in 1976, most had a germination rate of at least 85%. The mechanical purity of the seed samples was not as encouraging, with inert material ranging from 0.09 to 5.12%. Thirty four of the samples contained weed seeds.

Ball et al., (1982) collected 325 samples of spring wheat in North Dakota and found that 59 did not pass minimum standards for certification because of excessive inert material and eight other samples had low germination or weed or other crop seeds in excess of acceptable limits. Fifty-two percent of the wheat samples were reproduced either one or two years from certification. All but three samples were reported to have been cleaned, and 69% of those were conditioned at a local elevator.

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