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FACTORS AFFECTING SEED YIELD IN WHITE CLOVER

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SUMMARY

Eighteen clones of white clover chosen at random were examined for their seed setting possibilities. Large differences in the size of the inflorescence and the rate of fertilization were found among the clones, so that breeding strains of white clover with better seed-setting seems possible. The number of ovules per floret seemed not very variable.

INTRODUCTION

Although techniques for successful seed production of white clover are well known though extensive research, the average seed yield remains low. Furthermore, large annual variations in yields exist depending on weather conditions.

An increase in seed yields seems an absolute prerequisite in order to maintain seed prices at a reasonable level as expenses for producing the seed steadily increase.

As agricultural techniques have not brought forth the necessary increase, a genetical approach may perhaps be more successful. Valuable characters for this purpose are: number of inflorescences, length and position of the peduncle and seed yield per flower head.

It is clear that seed yield is basically dependent upon the number of inflorescences produced. Large variation exists for this character depending as much on the genetic constitution as on the environmental conditions.

A wide range of peduncle lengths occurs, but almost nothing is known about the possibility of keeping the peduncle in an upright position after fertilization. A tall, erect, peduncle should greatly facilitate seed harvest and limit seed losses.

Even with a sufficient number of inflorescences and a minimum of seed loss at harvest, the seed yield per inflorescence has to be as high as possible. This depends on the fertilization rate and the size of the flower head. ROBINSON (1937) reported that the number of florets varies from 10 to 80 and that 2 or 3 seeds are normally present in one floret. According to HOLLOWELL (1962) the number of florets lies between 40 and 80.

Detailed studies by DESSUREAUX (1951) showed that the number of ovules (between 0 and 8) and seeds per floret are determining factors for the seed yield. Dessureaux also stated that fertilization may be more efficient in some clones than in others.

BRIGHAM & WILSIE (1955) are convinced that in white clover there is a very high degree of heritability for amount of seed set.

The present research has been undertaken to investigate whether plants of white clover differ in their number of florets per inflorescence and in the amount of seed set per floret and if those characters may be improved by selection.

MATERIALS AND METHODS

Eighteen plants were at random selected out of the plants with luxurious growth and abundant flowering found in a population of 2000 plants descending from 80 clones. Every selected genotype descended from a different mother plant. In the spring of 1974 a polycross field was established with those plants and in 1975 this was repeated in another arrangement. After a cut at the end of May the plants were allowed to grow and flower freely.

Five inflorescences were collected at random on each clone in five different replicates in each of the two polycross fields at the end of August i.e. 25 heads in total. There were no bee-hives present in the neighbourhood of the polycross fields.

The period of flowering and ripening was completely different in the two experimental years. During the months of June, July and August 1975 there were 668 hours of sunshine versus 568 in 1974; 34 days of rain versus 49 in 1974; 141.5 mm of rainfall versus 223 in 1974. The average day temperature was 1.5 °C. higher than during that same period of 1974.

An analysis of the data of the two years combined was keyed as described by COCHRAN & COX (1950). In the F-test of the average effects of clones the average square for clones × years interactions was used as denominator.

Heritability estimates were computed following the procedure outlined by BURTON & DEVANE (1953).

In all calculations a single observation (the average from 5 heads or 50 pods) per replicate was used.

The number of seeds per pod was defined by extracting and counting the seeds from each floret separately. Fifty pods, chosen at random, were examined per replicate. As this way of operating is very tedious, a new and faster method was developed for later use, namely X-ray photography (10 kV, 20 mA, exposure 15 sec, distance 25 cm).

RESULTS

Number of florets per inflorescence

The average number of florets per flower head for the 18 clones is recorded in Table 1. It varies from 60.8 to 92.3 florets in 1974 and from 60.7 to 98.6 florets in 1975. The analysis of variance indicated that differences among clones were highly significant in both years. The variation within clones was relatively low as appears from the coefficients of variation, 6.5% and 6.8% for 1974 and 1975, respectively. The combined analysis also indicates a highly significant difference between the years, although this difference is rather small, 2.4 florets in favour of the dry and sunny year.

The interaction clones × years just exceeds the probability level of $P < 0.05$. This

Table 1. Number of florets per flower head in white clover in 1974 and 1975 (mean of 25 heads).

Clone	1974	1975	Clone	1974	1975	Clone	1974	1975
1	67.2	69.8	7	65.6	66.7	13	81.6	84.2
2	81.1	79.6	8	65.4	70.2	14	74.0	75.2
3	86.1	92.2	9	92.3	98.6	15	69.6	70.8
4	79.5	81.6	10	86.4	84.8	16	67.6	60.7
5	60.8	69.2	11	73.8	79.2	17	84.4	85.5
6	77.1	79.2	12	74.4	70.9	18	68.3	80.4

	F clone	*Coeff. of var.*	*Heritability*	*F interaction*	*Correlation*
1974	16.4**	6.5	0.75	–	–
1975	16.2**	6.8	0.75	–	–
1974–75	16.1**	6.6	–	1.9*	0.89**

Mean 1974: 75.3; mean 1975: 77.7.

* $P < 0.05$; ** $P < 0.01$.

is due to the clones 2, 10, 12 and 16. However, a highly significant correlation of 0.98 was found.

The heritability or the proportion of the total variance due to genetic effects is high and identical (H = 0.75) in both years and indicates the possibility of selecting white clover plants containing a high number of florets per inflorescence.

Number of seeds per pod

The average number of seeds per pod, determined on 5 × 50 florets, was 2.52 in 1974 and 3.90 in 1975. There were very large differences among the clones namely from 1.56 to 3.66 seeds per pod in 1974 and from 2.58 to 4.92 seeds per pod in 1975 (Table 2). The F value exceeds the significance level of 99% in both years separately as well as in the combined analysis.

Table 2. Number of seeds per pod in white clover in 1974 and 1975 (mean of 250 florets).

Clone	1974	1975	Clone	1974	1975	Clone	1974	1975
1	1.56	3.02	7	2.54	3.56	13	2.55	2.78
2	2.97	4.03	8	3.29	4.51	14	1.88	3.41
3	2.46	4.27	9	2.23	4.40	15	2.90	3.60
4	2.11	4.22	10	1.68	2.58	16	3.66	4.41
5	2.27	4.46	11	2.29	3.68	17	2.54	3.71
6	3.22	4.42	12	2.48	4.92	18	2.79	4.29

	F clone	*Coeff. of var.*	*Heritability*	*F interaction*	*Correlation*
1974	11.3**	14.7	0.67	–	–
1975	16.1**	9.3	0.75	–	–
1974–75	3.22*	14.1	–	6.46**	0.53*

Mean 1974: 2.52; mean 1975: 3.90.

* $P < 0.05$; ** $P < 0.01$.

Both years being different, it is not surprising that the fertilization and, consequently, the number of seeds per pod differed between the two years.

The very high interaction between clones × years does not prevent the correlation between the average number of seeds per pod in 1974 and 1975 from being significant ($r = 0.53$). Clone 10 consistently showed a low seed set, while clones 6, 8 and 16 had always a high number of seeds per pod. Clone 13 showed only a small difference between the years.

The heritability was very high in both years.

Distribution of the number of seeds per pod

In both 1974 and 1975, 4500 pods were examined individually. The distribution of the pods in relation to the number of seeds they contained, is given in Table 3. The influence of the year is clearly shown. The percentage of seed-bearing florets was 82.2 in 1974 and 97.6 in 1975. In general there is one seed per pod more in 1975.

In 1975 pods containing 8 seeds were found in clone 9; twelve clones had at least one pod with 7 seeds and all clones had pods with 6 seeds. In 1974 only six clones had pods with 7 seeds, fifteen clones had pods with 6 seeds, and pods with 5 seeds were found in all clones.

Number of ovules per floret

Examination of the number of seeds per pod showed that all florets had at least 5 ovules in 1974 and 6 ovules in 1975. One clone had florets with 8 ovules.

As the percentage of pods with 8 and 7 seeds exceeded the percentage of florets with 7 or 8 ovules found by DESSUREAUX (1951) in his material, one hundred florets were examined.[1] Ten florets were sampled on the vertical axis of ten inflorescences. Five different origins were involved with two flower heads per origin.

The distribution of the number of ovules found in each origin is listed in Table 4 together with the results of Dessureaux. Florets with less than 4 ovules were never found. The most frequent number of ovules was 6, except for the variety Milka, where the frequency of 5 and 6 ovules was nearly the same.

When the results are compared with those of DESSUREAUX (1951), the differences are striking. Dessureaux found 4.3% florets with less than 4 ovules.

Our material is clearly different from that of Dessureaux, and it may be concluded that rather important differences for the number of ovules exist.

Table 3. Frequency distribution (%) of the number of seeds per pod in white clover in 1974 and 1975 (4500 pods examined).

	Seeds per pod								
	8	7	6	5	4	3	2	1	0
Percentage 1974:	–	0.3	2.9	10.1	17.6	21.8	19.4	10.2	17.8
1975:	0.2	1.4	11.6	24.2	26.0	19.9	10.0	4.3	2.3

Mean 1974: 2.52; mean 1975: 3.90

[1] We acknowledge the assistance of Ir R. A. A. De Roo for counting the ovules.

Table 4. Number of ovules per floret in white clover in 1975 (100 florets).

Material	Number of ovules					
	8	7	6	5	4	mean
Milkla	–	2	9	8	1	5.60
Blanca	–	1	12	6	1	5.65
R.v.P. 1	–	1	16	3	–	5.90
R.v.P. 2	–	4	15	1	–	6.15
Progeny clone 9*	2	5	10	3	–	6.30
TOTAL	2	13	62	21	2	
Dessureaux	0.1	0.6	21.1	26.1	47.7	

* 3 florets possessed an extra ovule, half as big as a normal ovule. Those extra ovules were not taken into account.

It is worth mentioning that the progeny of clone 9 had 3 florets in which a supplementary ovule, half the size of a normal one, was found.

The fertilization

The percentage of fertilization is given in Table 5. The calculation is based on the supposition that all 18 clones had an average of 6 ovules per floret and that this characteristic remains stable from year to year.

Fertilization was very low in 1974. Averaging 42.1%, with 25.9 and 61.1% as extreme values, it exceeded 50% only in 3 clones. Seed set was better in 1975, the average being 65.1% with limits of 43 and 82%. Two clones showed less than 50% seed set. Clones 1, 10 and 13 had a low level of fertilization in both years.

The analysis for each year separately, as well as for the 2 years combined, gives an F value for differences among clones above $P < 0.01$. It may be concluded that fer-

Table 5. Fertilization (%) in 1974 and 1975, assuming 6 ovules per floret.

Clone	1974	1975	Clone	1974	1975	Clone	1974	1975
1	25.9	50.3	7	42.3	59.3	13	42.5	46.3
2	49.5	67.2	8	54.9	75.1	14	31.3	56.9
3	41.1	71.2	9	37.2	73.4	15	48.3	59.9
4	35.2	70.2	10	27.9	43.0	16	61.1	73.5
5	37.8	74.3	11	38.2	61.4	17	42.4	61.9
6	53.6	73.7	12	41.4	82.0	18	46.5	71.5

	F clone	*Coeff. of var.*	*Heritability*	*F interaction*	*Correlation*
1974	11.84**	14.2	68	–	–
1975	16.08**	9.3	75	–	–
1974–75	3.37**	–	–	6.41**	0.49*

Mean 1974: 42.1; mean 1975: 65.1.

* $P < 0.05$; ** $P < 0.01$.

tilization is more effective in some clones than in others. An alternative explanation is that certain clones have fewer and others more than 6 ovules per floret.

DESSUREAUX (1951) too was convinced that pollination was more effective in certain clones than in others.

Relation between the size of the inflorescence and the fertilization

It is known that in certain crops the size of the inflorescence has a negative influence on pollination by insects.

Comparison of the size of the flower heads (Table 1) with the fertilization (Table 5) gave correlation coefficients of $r = -0.24$ and $r = -0.095$ for 1974 and 1975, respectively. Both coefficients are statistically not significant ($r = 0.468$ for $P < 0.05$ with 16 d.f.).

The size of the inflorescence of white clover thus should not have a direct influence on fertilization.

DISCUSSION

Breeding for more florets per inflorescence and for more effective pollination appears to provide a means of developing strains of white clover with a higher rate of seed-set.

The size of the inflorescence (number of florets per inflorescence) shows wide variation, not only within a clonal line, but also among genotypes. A random sample of 5 inflorescences gives a good estimation of the size of the flower heads. With 18 clones, chosen at random, and 25 heads per clone, a high and very significant correlation coefficient ($r = 0.89$) between head sizes was found during two consecutive years.

The variation in the number of ovules per floret (only 100 florets from 5 origins were counted) was small. Even with such a small variation and a restricted sample, a difference of 1.07 ovules was found in the average number of ovules per floret. Such a difference, however, gives the possibility of an increase in seed production potential by 6 to 7%.

In the very favourable year 1975, with 3.90 seeds and assumably 6 ovules per floret, the fertilization reaches only 65%; if 5 ovules per floret are assumed, it amounts to 78%. Although a fertilization rate of 100% seems unattainable, considerable increase should be possible. This should be possible in the first place by increasing the number of pollinating insects. It appears from the results that differences in efficiency of pollination exist. For example, the fertilization of clone 10, assuming only 4 ovules per clone, does not even reach the 65% level. Such a low fertilization can be explained only by an imperfection in the genotype, resulting in florets less attractive to the pollinating insects or in less efficient pollination.

The size of the flower head does not seem to have a real negative influence on the efficiency of pollination.

Plants with large inflorescences, with many ovules per floret, and without factors prohibiting the efficiency of pollination, should be selected with the aim of obtaining a variety of white clover giving a fair seed yield.

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BOOK ANNOUNCEMENTS

K. LUTTGE & M. G. PITMAN (Ed.), 1976. Transport in plants. ii. Part A: Cells 400 + xix pp. DM 128, US $52.50. Part B: Tissues and organs. 456 + xix pp. DM 138, US $56.60. Springer Verlag, Berlin-Heidelberg-New York.

In the Encyclopedia of Plant Physiology, New Series Volume 2 (A and B) has appeared. Part A concerns 'Cells' and Part B 'Tissues and organs'. Part A is divided into 3 sections consisting of 5, 3 and 5 chapters, respectively. Chapter 8 concerns the red beet, carrot and potato, while the other chapters either describe general phenomena or particular ones in algal and fungal cells. Part B is also divided into 3 sections consisting of 2, 4 and 4 chapters. For plant breeders the chapter on genotypic variation in transport is probably the most interesting one.

Both books are concluded with an author index, symbols, units and abbreviations and a subject index.