Euphytica 28 (1979) 489–494

SELECTION FOR ROOT HAIR LENGTH IN WHITE CLOVER (*TRIFOLIUM REPENS* L.)

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Received 9 October 1978

INDEX WORDS

Trifolium repens, white clover, heritability, root hair length.

SUMMARY

Results are given which show that the root hair length of a white clover population can be increased and decreased by selection. An increase of 50 μm in root hair length over the mean of an unselected population of the cultivar Tamar was achieved resulting in an 11% calculated increase in the volume of soil explored by root hairs. The realised heritability for selection in the long root hairs was 0.33, and for the short root hairs 0.44.

INTRODUCTION

Pasture grasses tend to have a competitive advantage over clover, when immobile nutrients such as phosphorus are in short supply (JACKMAN & MOUAT 1972). More extensive root systems allow grasses to explore the soil more thoroughly, at least in the upper layer of soil. Grasses have not only longer root systems but also a higher root surface area to root volume ratio as a result of their thinner roots and considerably longer root hairs (EVANS, 1977; CARADUS, unpublished). Root hairs increase absorption by the root by extending the effective root surface (NYE, 1966). There is some evidence that a plant's ability to grow in some soils containing little available phosphorus may be proportional to the extent of root hair development (BAYLIS, 1972; JOHNSON, 1976).

This paper reports data to show that root hair length of a white clover population can be increased by selection.

MATERIALS AND METHODS

Preliminary work (CARADUS, unpublished) showed that there were no significant differences in mean root hair length among five white clover cultivars measured. For this reason a single cultivar, Tamar was chosen for a closer examination. In this paper root hair band width is equated with root hair length since instead of measuring the length of single root hairs, measurements were made of the mean distance judged by eye, from the root surface to the tips of a number of root hairs formed closely together. Measurements were not made within 1 cm of a root apex since in this region root hairs are still elongating. The root hair band was measured on both sides of the radicle of 300 newly germinated Tamar seedlings using a microscope with a graduated eye-piece. The seeds were then individually planted into 10 cm diameter pots of sand in a glasshouse. *Rhizobium trifolii* was added along with 25 ml Mullards nutrient soln (CHARLTON, 1971). Pot positions were re-randomised monthly. After 23 weeks root systems were washed clean and with the use of a microscope transects were made through a portion of the root system and 10 roots up to 2 mm in diameter were selected on which to make the measurements. Several other plant characters (Table 1) were also measured so that their relationship with root hair length could be determined. Stolon tip propagules from each genotype were maintained.

From the 300 measured genotypes 20 with the shortest mean root hair length, and 20 with the longest mean length were selected (later referred to as selection I). Five measurements of root hair band width were made on separate roots of two four week old rooted stolon tips of each of the selected genotypes. This was done to determine the consistency of measurements on the seed grown plants. Twelve genotypes were selected (later referred to as Selection II), six with consistently short and six with consistently long root hairs.

Open pollinations were made within each of the selection II groups, (labelled 'S' for short root hair length selection and 'L' for long selection) each genotype being represented by one plant. Seed from each plant was individually harvested giving 12 half sib families. Root hair lengths of these half sib families were then compared by growing 10 plants of each in sand culture for six weeks, in a similar manner to the original Tamar parent plants. Also included in the comparison were 10 plants from both an equal blend of seed from the 'S' selection and equal blend of seed from the 'L' selection. These were included as an additional check on the effect of the selection. Ten seedlings from the original Tamar cultivar were also examined.

RESULTS

At both the radicle stage and at the 23 week harvest highly significant differences ($P < 0.01$) were found among the 300 genotypes in the base population for mean root hair band width. However there was no significant correlation between the two sets of measurements (Table 1). There were significant although very low correlations between several of the morphological characters examined and root hair length at the 23 week harvest (Table 1).

In selection I, the mean root hair length of genotypes in the short selection was 283 μm, and in the long selection 555 μm. The correlation between root hair length at 23 weeks and that of the stolon tips proved to be highly significant ($r = 0.34$, $P < 0.01$) showing that some degree of consistency existed between the sets of measurements and allowing a selection to be made of consistently long or short root hair genotypes.

The mean root hair band widths of the 'S' and 'L' selection (selection II) at 23 week harvest (i.e. parent plants) and at stolon tip harvest are given in Table 2. Progenies within the 'S' selection differed significantly ($P < 0.01$) in mean root hair length from progenies within the 'L' selection (Table 2). The mean root hair length of each half sib family was not significantly different from others in the same group, but was significantly different from every half sib family of the other selected group. The two blends

Table 1. Correlation of mean root hair length at 23 weeks with other plant characters (measured at 23 weeks unless otherwise stated). Measurements from all the 300 genotypes in the base population were used.

Characters	Correlation coeff. r	Significance level[1]
Root hair length (radicle stage)	0.002	NS
Width taproot base	0.18	**
Number primary stolons	0.16	*
Total primary stolon length	0.17	**
Primary stolon diameter	0.08	NS
Number nodes on primary stolons	0.22	**
Leaflet width	0.17	**
Shoot dry weight	0.22	**
Root dry weight	0.19	**

[1] NS = not significant; * = $P<0.05$; ** = $P<0.01$.

Table 2. Mean root hair lengths of the six parent plants at the 23 week harvest and at the stolon tip harvest, and of 60 progeny genotypes resulting from crosses within each of the selected groups, comparing the short and long root hair selections with each other and the mean of an unselected Tamar population. Mean shoot growth rate for selected groups and an unselected population for both parent and progeny plants, is also given. The short and long blends refer to populations made up with an equal sample of seed from each progeny line within each selected group.

Selection	Root hair length (μm)			Shoot growth rate (mg F.W./week)	
	parent plants		progeny plants	parent plants	progeny plants
	23 weeks	stolon tip stage			
Short (S) $\bar{x}$	278	238	278	77	76
S.E.	6	6	7	14	5
Long (L) $\bar{x}$	545	442	380	173	94
S.E.	6	19	8	34	7
Significance of difference[1]	**	**	**	*	NS
Short blend $\bar{x}$	–	–	291	–	80
S.E.			23		9
Long Blend $\bar{x}$	–	–	390	–	85
S.E.			19		10
Tamar $\bar{x}$	405	–	334	120	83
S.E.	5		11	4	14

[1] NS = not significant; * = $P<0.05$; ** = $P<0.01$

of progeny of each group were themselves significantly different ($P<0.01$). The mean root hair length of both selected groups was significantly different from that of the unselected Tamar population examined at the same time (Table 2). However of the blends only the 'L' selection blend was significantly ($P<0.05$) different from the unselected Tamar population.

At the 23 week harvest of the parent plants there was a significant positive correlation between plant size and root hair length. Table 2 shows that the growth rate of the 'L' selection plants was considerably higher than that of the 'S' selection plants. However, for the progeny of these two groups there was no correlation between plant size and root hair length and no significant difference between the two groups for growth rate (Table 2).

DISCUSSION

Varietal differences for root hair length have been observed in apple (MUROMCEV, 1948) and vine (LITVINOV & STAPKIN, 1965). However, no documented reports have been made of differences between populations within a cultivar resulting from selection for root hair length.

Within Tamar white clover a significant relationship between plant vigour and root hair length was recorded in the 23 week old parent plants (Table 1 and 2). Such a correlation has been observed in other species, including maize (TAVCAR & KENDJELIC, 1971), apple (MUROMCEV, 1948) and vine (LITVINOV & STAPKIN, 1965). The low correlation coefficients recorded in Table 1 suggest that none of the characters measured in this paper are suitable markers to use when screening for root hair length.

The change in mean root hair length due to selection was 50 μm in both directions from the mean of the unselected Tamar population (Table 3). Therefore, by taking the mean root diameter of white clover to be 0.26 mm (EVANS, 1977), and assuming continuous cover of root hairs, it was possible to calculate the expected percentage change in volume within the root hair cylinder and surface area per metre of root resulting from selection (Table 3). The percentage improvement of the 'L' selection population over the mean root hair length for Tamar was 10% for root surface area and 11% for volume within the root hair zone (Table 3). The percentage difference of the 'L' selection population over the 'S' population is 25% for both root surface area and volume within root hair zone. Therefore assuming similar root lengths, plants of the 'L' populations will be in contact with up to 25% more soil than those of the 'S' population.

Table 3. Calculated values for surface area of root hair cylinder and volume of soil explored by root hairs per metre of root for plants of the long and short root hair populations, and an unselected Tamar population.

	Population		
	long root hairs	unselected Tamar	short root hairs
Mean root hair length (mm)	0.38	0.33	0.28
Radius of root and root hair cylinder (mm)	0.51	0.46	0.41
Surface area of root hair cylinder per m of root (mm^2)	3206	2917	2565
% change in surface area from Tamar	+10	–	–12
Volume of soil explored by root hairs per m of root (mm^3)	1550	1393	1236
% change in volume from Tamar	+11	–	–11

Estimation of realised heritability of root hair length within Tamar white clover can be obtained by dividing the response due to selection by the selection differential (FALCONER, 1961) for each selected group. For the long root hair selection the response to selection is taken to be the difference between the progeny mean and the mean of the randomly selected Tamar population grown at the same time (i.e. 380–334 = 46). The selection differential is the difference between the unselected original Tamar population and the mean of selected parents (i.e. 545–405 = 140). Therefore the realised heritability for the long root hair population is 0.33. For the short root hair selection the response to selection is, 334–278 = 56, and selection differential is, 405–278 = 127. Thus the realised heritability for the short root hair population is 0.44.

Although many workers suggest that root hairs improve the P uptake capacity of a plant (BAILEY & ROVIRA, 1970; DREW & NYE, 1969; LAUCHLI, 1967), some doubt about this has been expressed by BOLE (1973). He found that P uptake was not enhanced as root-hair proliferation increased among chromosome substitution lines of wheat showing a parental difference in root hair development. However, all he achieved was to crowd the root hairs closer together rather than increase their length to explore new soil. Compared with wheat he found that rape and flax, species with none or very few root hairs, absorbed more P per unit root length, and then concluded that the species difference in ion uptake efficiency was not due to root-hair development or root morphology. Although this may well be the case it does not negate the possibility that a greater root hair length may further increase P uptake.

In the present paper it has been shown that root hair length can be increased by selection. Further work will be required to ascertain whether this is an advantage to white clover growing in a low P environment in competition with grasses.

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