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INTERACTION BETWEEN SOME PASTURE SPECIES AND TWO *HIERACIUM* SPECIES

Summary: Possible control options are investigated for the introduced *Hieracium* weeds, particular problems in South Island high country, New Zealand. In a pot experiment regression of input to output ratios of above ground biomass over successive harvests, from binary mixtures was used to determine the competitive interaction between 13 pasture species and two *Hieracium* species, *H. pilosella* and *H. praealtum,* in a low fertility soil. Treatments also included a factorial of presence or absence of compartments separating root and shoots of species. Species differed in their mean growth rate, relative to *Hieracium* species. The ranking of mean growth rate relative to *H. pilosella* was *Trifolium repens* (best), *Bromus inermis, Sanguisorba minor, Festuca novae-zelandiae, F. rubra, Arrhenatherum elatius, Anthoxanthum odoratum, Lotus corniculatus, Hypochoeris radicata, Trifolium repens, T. hybridum, T. medium* and *Astragalus cicer*. Shoot partitions decreased *Hieracium's* interaction with white clover while root partitions increased interaction with *B. inermis*. However, the rates were not related to the proportion of *Hieracium* in the mixtures, indicating a general lack of specific competitive effects against *Hieracium*.

Keywords: competition; *Hieracium pilosella; Hieracium praealtum.*

Introduction

Mouse-ear hawkeed *(Hieracium pilosella* L.) and king devil *(H. praealtum* Gochant) are two hieracium or hawkweed species causing concern in the South Island high country. One possible method of control is sowing competitive pasture species which should ideally be persistent, productive, and have high competitive abilities against *Hieracium* species. Makepeace, Dobson and Scott (1985) have investigated competition between four pasture species, mouse-ear and king devil hawkweeds under contrasting soil fertility and water availability in glasshouse pot trials. They found that alsike clover *(Trifolium hybridum* L.) outgrew hawkweeds at higher soil fertilities, probably due to its shading effect and greater tolerance to allelopathogens produced by mouse-ear hawkweed. There was no significant interaction between cocksfoot *(Dactylis glomerata* L.), perennial ryegrass *(Lolium perenne* L.), white clover *(T. repens* L.) and *Hieracium pilosella*. In a separate experiment fescue tussock *(Festuca novae-zelandiae* Ckn.) was suppressed by mouse-ear hawkweed.

The relative competitive abilities of species are generally determined by growing them in both pure stands and binary mixtures in pots or plots, and then calculating one of the various indices of competitive ability derived from components of yield. Some of these are reviewed by Trenbath (1978), Hall (1978), and Snaydon and Satorre (1989). Besides competition, other forms of neutral, symbiotic, and mutual antagonistic interactions can be inferred from different forms of the relationship (Trenbath, 1978). However, as Muller (1969) and Makepeace *et al*. (1985) have indicated, these types of experiments should be more correctly called interaction or interference effects because they only demonstrate whether species behave differently in the presence of others.

Without additional specifically designed experiments, they cannot show whether species are vying for some common resource (competition in the true sense) as compared with some other mode of interaction (e.g., allelopathy).

There are also often three aspects in the usual competition experiments. The first is the probably unintended impression given by the wording used, that competitive ability is a unique attribute of a particular species, whereas it is probably always related to the particular set of species and environmental conditions in which the interaction is tested. The second aspect is that interspecific competition is generally defined in relation to a situation where competition can not occur, i.e., by reference to the performance of the components in pure stands. It would seem that competitive indices based on measures when both species were present would be more in keeping with the competition concept. The third aspect is the use of varying numbers of plants to give different proportions in the design of experiments, and the carrying of these through in the analysis of subsequent yield or growth response rather than using initial measurements as the base line. Again it would seem that the same attribute should be used in both the design and response stage of both replacement or additive type trials. These considerations influenced the method used in the trial to be described.

Earlier *Hieracium* study (Makepeace *et al.,* 1985) had also indicated that the important interaction effects might be both below ground in root competition or allelopathic effects, and above ground in shoot shading effects. Methods for studying such partitioning have been developed by Snaydon (1979).

The present work is a field pot trial investigating the competitive efficiencies of a range of species against two *Hieracium* species to assess their relative potential as oversown species for reducing the effects of *Hieracium*.

Methods

The trial, using an infertile high country soil, was an unbalanced factorial design of two *Hieracium* species, thirteen pasture species, two planting arrangements, two shoot separation states (separated and combined), two root separation states, two fertilisers, and three to six harvest dates.

The material for the two *Hieracium* species were rosettes separated from colonies at Lake Tekapo, inland Canterbury, and hence probably represented one or a few clones of each species. The pasture species were grown from seed before transplanting at a two to four leaf stage. The legumes were inoculated with rhizobia. The species used were: white clover, alsike clover, zig-zag clover *(T. medium* L.), birdsfoot trefoil *(Lotus corniculatus* L.), milk vetch *(Astragalus cicer* L.), brown top *(Agrostis capillaris* L.), smooth brome *(Bromus inermis* Leyss.), fescue tussock, chewings fescue *(Festuca rubra* subsp. *commutata* Gaud.), sweet vernal *(Anthoxanthum odoratum* L.), tall oat grass *(Arrhenatherum elatius* (L.) Beauv. ex J. & C. Presl), catsear *(Hypochoeris radicata* L.), and sheep's burnet *(Sanguisorba minor* Scop.).

The outer shoot containers were 20 x 20 x 20 cm open-ended cubes with the vertical sides lined with 'Sisalation' aluminium foil. These were placed on top of 20 x 20 x 20 cm root containers. The species were compared in nineteen binary species' combinations at two proportions, a single plant of one species in the centre of the container surrounded by four plants of the other species, or *vice versa*. Within containers there were also all combinations of above and below ground partitions around the central plant; these partitions were made of 10 cm diameter x 20 cm high cylinders of 'Sisalation' foil. Most of the comparisons used unamended high country yellow-brown mixed topsoil/subsoil of the Craigieburn set collected from Porters Pass, Canterbury. For six of the species' comparisons there was also an additional high fertility treatment of weekly additions of a complete proprietary nutrient solution.

There were three to six replicates of each species' pair, root or shoot partition and fertility treatment. The containers were set up in a field under natural moisture conditions at Lincoln, Canterbury. Within each species' combination shoots of each plant was cut to ground level, dried, and weighed on three to six occasions over a year after their canopies had merged in most of the containers not having a shoot partition. The difference in frequency was related to the difference in mean growth of different species' combinations.

Analysis

The base measurements were the repeated sampling, for each container, of shoot dry weight of each species in a mixture. The analysis used a modification of the input ratio/output ratio method described by Trenbath (1978), with an assumption of a relatively fixed relationship between harvested shoot material and the plant reserve for subsequent regrowth. At each sampling, the measured yields of the two species in the mixture were expressed as a ratio and this value acted as the input ratio for a subsequent time interval as well as the output ratio for the previous time interval. In this manner successive harvests were treated as separate samples.

In the analysis the relative proportion of species at the start of each measurement period (input) are compared with the ratio at the end (output) against the null hypothesis of equal growth (ratio unchanged) and no interaction (Fig. la). Dissimilarity in mean growth between the two species (solid line) is expressed as a uniform departure from the equal growth line (dotted), while 'competitive interaction' is an intercepting gradient on that line (bold dashed) where the rate of change in the proportion in one species is dependent on the input ratio. However, the difference between mean growth and competitive interaction is confounded between the fitted intercept and gradient. The modification used was to make a 45° rotational

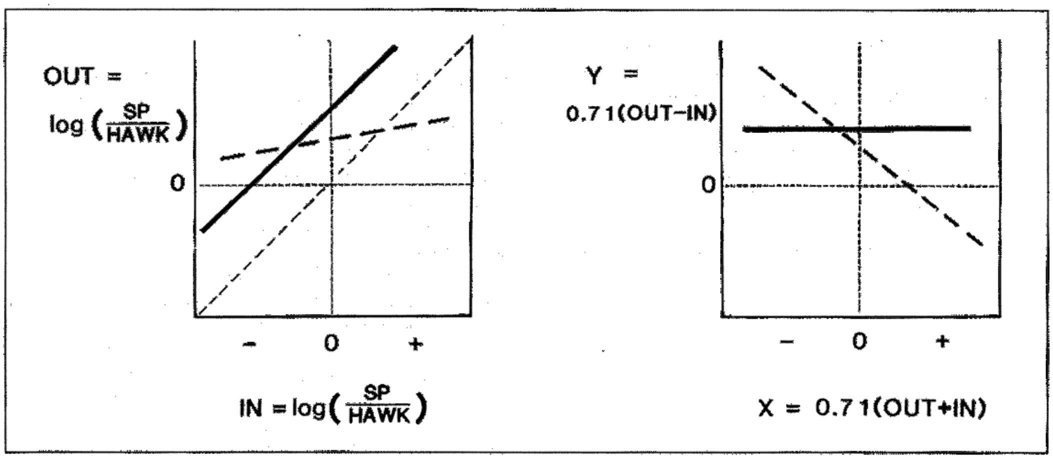

Figure 1: *Presentation of data in input/output competition experiments with binary mixtures. A: Logarithm input ratio (IN) versus output ratio (OUT) method; + = test species greater than hawkweed. 0 = equal. - = less than (Trenbath. 1978). B: Transformation of variables (X. Y) and rotation of axes for direct regression analysis. Light dotted line: central axes and expected ratio with equal growth of species. Bold line: expected if greater growth of test species but no competitive interaction. Bold dashed line: expected if competitive interaction.*

Table 1: *Interaction between two* Hieracium *species and thirteen pasture species in binary mixtures in a competition experiment in a low fertility soil. Pooled estimates of least significant difference.* 1 = *inclusion of fertiliser comparison;* * = *significant at 5% level; and* ** = *1% level.*

Comparison	Sample size	Main intercept	Growth advantage over *Hieracium* (%)	Regression with other significant factors
With *Hieracium pilosella*				
white clover[1]	52	0.13	35	0.17** - 0.12* x shoot
browntop	24	0.12	31	
smooth brome	24	0.11	28	0.02^{ns} + 0.18* x root
sheep's burnet [1]	6	0.06	15	
fescue tussock	16	0.04	10	
chewings fescue	24	0.03	6	-0.40** + 0.21** x time
tall oat grass	40	0.01	3	
king devil	48	0.00	3	
sweet vernal	24	0.00	0	
birdsfoot trefoil	32	-0.01	-3	0.58** - 0.24* x time
catsear	32	-0.06	-15	
zig-zag clover	15	-0.17	-50	
alsike clover	27	-0.18	-50	
milk vetch[1]	27	-0.25	-79	-0.77** + 0.34* x time
With *Hieracium praealtum*				
white clover[1]	66	0.03	8	0.11** - 0.18** x shoot
sheep's burnet[1]	62	-0.02	-4	
catsear	32	-0.11	-7	
alsike clover	29	-0.11	-28	0.31^{ns} - 0.14** x time
milk vetch[1]	19	-0.38	-138	-0.71** + 0.39* x fert
LSD 5%		0.17		

transformation of the initial input and output ratio data so that differences in the intercept became a direct test of differences in mean growth, and the gradient of the fitted line a direct test of the 'competitive' or 'interaction' effect (Fig. 1b).

Stepwise multiple regression analysis, testing for these effects, was done independently for each mixture, with the inclusion of the presence of shoot or root compartments, fertiliser, and time of sampling as other covariables in an additive model.

Results

The growth rates of all species were generally low due to both the low fertility soils used and the shading from the relatively tall container walls. Growth rates from the initial and final shoot weights averaged about 15-20 mg plant^{-1} day-lover all harvests.

No test species showed significant gradients relating to proportions of components, indicating a general lack of specific competitive or interaction effects against *Hieracium*. As indicated by the intercept, there were differences between test species in mean growth relative to the *Hieracium* component (Table 1- 2nd column). Regression analysis and ANOV A for this effect only showed a significant difference between species *(P*= 0.05), and species are listed in decreasing order of mean growth relative to the *Hieracium* species in Table I. For example the intercept for the white clover/H. *pilosella* combination indicates that white clover had a 35% greater growth ($10^{0.13}$ =1.35). None of the positive growth effects differed significantly (P=0.05) from *Hieracium,* while the alsike clover, zig-zag clover, and milk vetch were significantly less vigorous than *Hieracium*.

There were some instances of other significant treatment effects in some species' combinations (regression with significant variable included in Table I). Several of the comparisons showed significant differences between successive harvests. In four cases there were significant temporal trends with relative growth of alsike clover and birdsfoot decreasing with time, and that of chewing fescue and milk vetch increasing. Only white clover showed a decrease in growth with respect to both *Hieracium* species with the presence of a shoot partition. Smooth brome increased its mean growth with respect to *H. pilosella* in the presence of a root compartment. Six mixtures also included a soil fertility contrast, but the only significant effect was the increased growth of milk vetch in comparison to *H. praealtum*.

Discussion

Competitiveness is one of those concepts which seem self evident but difficult to define precisely, quantitatively, and separately from other species' interactions. Thus the suggestion to find pasture species which 'out-compete' *Hieracium* seems simple in concept but is difficult in practice. The distinction needs to be made between the relative differences in growth of species, as represented in the ratio used here, in the environment of interest, and any specific changes in the growth of one of the species due to the presence of the other.

The trial attempted to investigate both those aspects using a high country soil, though in a lowland environment. The intercept estimate in the analysis relates to the first question on difference in general growth between the species and effect of some other treatment variables. The regression intercepts given in Table 1 show a range in response of pasture species relative to *Hieracium* species.

The search for pasture species which have particularly strong competitive abilities relative to *Hieracium,* as would have been reflected in significant gradients to the fitted line in the analysis, has been negative. While the data were somewhat variable, the mean standard errors of the regression analysis would have been able to detect significant gradients of the order of 5-7% decrease in growth when species were in equal proportions. Also with most of the other treatment effects being non-significant there were high degrees of freedom (4-64) for investigating this main effect, As these trials included a reasonable range of the species which might be used in oversowing grasslands depleted by *Hieracium* the implications are that searching for species having particular competitive abilities against *Hieracium,* as defined in the analysis section, is probably not a useful allocation of research effort.

Mason (1987), using the same technique, also investigated the interaction between caucasian clover *(Trifolium ambiguum* M. Bieb.) and zig-zag clover at five fertiliser levels, and similarly found no indication of significant specific competition effects. The lack of specific competitive effects in both studies was unexpected and indicates that either the conditions in the experimental protocol in both studies had not progressed to the stage that the species were vying for environmental resources, or, as in the 'stress tolerating' species within the C-S-R concept (Grime, Hodgson and Hunt, 1988), that in stressed environments, species may have evolved to separate resource capture from growth so that in mixtures they may 'be doing their own thing' rather than competing. Either scenario seems unlikely to be more than a partial explanation. In the present study growth had progressed to the stage where there was intermingling of shoot and roots in the treatment combinations that allowed it. Also while several of species used have been rated as having stress tolerating characteristics by Grime *et al*. (1988) none would have been rated as exclusively stress tolerating.

Several aspects of this study differ from those of Makepeace *et al*. (1985) who used a full replacement series. Their work had indicated a competitive advantage of alsike clover and a neutral effect of white clover, where the difference in mean growth rates was the reverse in this study. Similarly fescue tussock was relatively neutral in their study. The differences may relate to the differences in environmental conditions in the two trials. Our trial was mostly under low fertility whereas the Makepeace trial included high fertility and moisture treatments.

With allelopathy possibly being one of the mechanisms aiding the spread of *H. pilosella* in the high country it was thought that this might have been reflected in the root partition treatments, as the main allelochemical, umbelliferone, is released only by basal recently dead leaves (Makepeace *et al.,* 1985). There was no indication of such a trend, except for smooth brome.

While the modified input/output ratio method failed to detect significant interactions in this instance the method appears to have number of advantages for such studies. The uniformity of initial plant sizes is not as critical as in the replacement series approach since it is necessary to use the first harvest as the input ratio for the second and further harvests. This is a useful advantage when working with slower growing species, or poor growing conditions, and where field transplants or ramets are the most logical source of plant material. Also, the use of relative harvest weights at one harvest as estimates of input for the next harvest would seem to be a more accurate estimate of their relative contribution than plant number.

References

Grime, J.P.; Hodgson, J.G.; Hunt, R. 1988. *Comparative plant ecology: A functional approach to common British species*. Unwin Hymen Ltd., London, U.K. 742 pp.

Hall, R.L. 1978. The analysis of significance of competitive and non-competitive inference between species. *In:* Wilson J.R. (Editor), *Plant relations in pastures,* pp. 163-174. CSIRO, Melbourne, Australia. 425 pp.

Makepeace, W.; Dobson, A.T.; Scott, D. 1985. Interference phenomena due to mouse-ear and king devil hawkweed. *New Zealand Journal of Botany 23*: 77-79.

Mason, C.R 1987 (unpublished). *Rhizomatous legumes for hawkweed dominated grasslands*. M. Appl. Sc. Thesis, Lincoln College, Canterbury, New Zealand. 126 pp.

Muller, C.H. 1969. Allelopathy as a factor in ecological processes. *Vegetatio 18*: 348-357.

Snaydon, RW. 1979. A new technique for studying plant interactions. *Journal of Applied Ecology 16*: 281-286.

Snaydon, RW.; Satorre, E.H. 1989. Bivariate diagrams for plant competition data: modifications and interpretation. *Journal of Applied Ecology 26*: 1043-1057.

Trenbath, B.R 1978. Models and the interpretation of mixture experiments. *In:* Wilson, J.R. (Editor), *Plant relations in pastures,* pp. 145-162. CSIRO, Melbourne, Australia. 425 pp.