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RESPONSE OF *HIERACIUM* IN TWO LONG TERM MANIPULATIVE AGRICULTURAL TRIALS

Summary: *Hieracium,* or hawkweed species, serious weeds in South Island high country, may be controlled by appropriate pastoral management. Experimental trials at Lake Tekapo, related to S and P fertiliser rates of 0-100 kg ha-l yr-l, 27 different combinations of over-drilled and resident species and different seasons or intensities of grazing treatments on *Hieracium* dominated fescue tussock were conducted. These were monitored for 9 years in terms of fertiliser inputs used, sheep stocking rates, and vegetation changes. *Hieracium* decreased or disappeared under high fertiliser and sowing inputs, but remained an increasingly important component under successively lower fertiliser inputs.

Keywords: *Hieracium pilosella;* high country; fertiliser; overdrilling; grazing; legumes.

Introduction

Hieracium or hawkweed species are perceived as a weed problem in the South Island high country because they out-compete and replace resident vegetation, with their low growth habits limiting feed availability in pastoral farming and displacing indigenous species. Control can only be achieved by intervention in some management sense, to alter the species or environment to obtain some vegetation considered more desirable. There can be a variety of approaches to finding those management options (Hunter, Mason and Robertson, 1992).

This paper will describe one experimental approach primarily designed towards increasing pastoral feed production, but conducted on a site in which *Hieracium pilosella* L. was originally dominant, *H. praealtum* Gochant and *H. caespitosum* Dumort common, and *H. X stoloniflorum* Waldst. et Kit and *H. lepidulum* (Stenstroem) Omang rare. Management consisted of oversowing with legumes and grasses under a range of fertiliser combinations and grazing managements.

This work followed an earlier pilot trial described by Scott, Robertson and Archie (1990). In that earlier trial the vegetation composition and its changes over six or seven years were presented for two sites (Figs. 1 and 2, and Table 1: Scott *et al.,* 1990). The principal results were that on both sites, variation in time of grazing management, without fertiliser and seeding, led to the maintenance of or increase in dominance of *Hieracium*. On the shallower, less productive soil there was a marked increase in *H. praealtum* and a less marked increase in *H. pilosella*. Even with fertiliser and seeding on the shallow, less productive soil the legume sward took 5-6 years to begin to suppress *H. pilosella,* which had, in that period, increased from low initial cover. It was only on the deep, moderately productive soil, with the addition of fertiliser and seeding, that legumes started to suppress *Hieracium* within two years, and it became rare after six years. The fertiliser and seeding on the moderately productive soil led to a six-fold increase in stock carrying capacity and, while *Hieracium* was still a component of the sward it had ceased to be a farm management constraint. Fescue tussock (*Festuca novae-zelandiae* Ckn.) decreased under all treatment combinations.

Methods

The present two continuing trials commenced in 1981 at the Mt John trial site, Lake Tekapo. Both were sown with complex mixtures of 27 different legumes and grasses using a rotary hoe drill which cultivated about a third of the area over which it passed. Experimental details and early results are given in Scott and Covacevitch (1987) and in Scott, Robertson and Burgess (1989).

The first trial is a response surface type trial of 27 combinations of phosphate and sulphur fertiliser (0,5, 10,20,50 or 100 kg element ha^{-1} yr^{-1}), with four of the combinations from the range repeated with potassium and micro-nutrient supplements. Plots are mob grazed simultaneously with sheep number varied according to feed availability.

The second trial is a split plot factorial of five growth regimes (0. 50. 100,250 or 500 kg ha^{-1} yr^{-1} superphosphate, and with spray irrigation standardised for the level required by the high fertiliser treatment), by three stocking rates at each fertility level (low, moderate or high in ratio of approximately 1:2:4 sheep grazing days in years 2-4 years and 2:3:4 in subsequent years), by two stocking methods (high sheep number for 5-7 days, i.e., mob stocking; or few sheep for long periods, i.e., sustained stocking), and two replications. Each plot is 8 x 50 m.

In both trials vegetation was monitored in November from the second year on after the same ungrazed regrowth period from mid winter. Species in each plot were visually ranked in order of their contribution to herbage bulk within that plot, simultaneously with visual estimation of the ratio of contribution of two of the species, so that the proportional contribution of species to herbage bulk in each treatment could be estimated using the geometric series relationship of the linear relationship between logarithm of percentage contribution and species' rank with the gradient determined from the ratio of two species (Scott, 1989). Using this method the proportional contributions of each species in each plot and each sampling occasion were then totalled or meaned for the values presented. In this paper the species have been grouped into five categories - *Hieracium (H. pilosella* and *H. praealtum* = H), sown legumes (L), sown grasses (G), fescue tussock (F), and others (0).

Plots were grazed from November to Mayas required. In the first trial this was mob stocking on two to three common occasions each year for 5-10 day periods using partly fasted sheep to limit nutrient transfer onto and off plots; the number of sheep grazing days was recorded. In the second trial the number of grazings per year varied with the fertiliser rates. For grazing the plots were grouped into threes for the different stocking rate treatments at each of the fertiliser and stocking methods. The plots were grazed as required based on the moderate stocking rate plot with the other two plots receiving their differential stocking rates for the same period. For the mob stocked treatment this ranged from no further grazings for the nil fertiliser treatments, to four to five further grazings per year in the high fertility plus irrigation mob stocked treatments. The high fertility and irrigation treatments with sustained stocking had some sheep on them for most of the growing season.

The grazing days, adjusted for plot areas, gave an estimate of the relative sheep carrying capacity of the different treatments. Attempt was made to scale these values to annual carrying capacities. Simple division by 365 gave unrealistically high estimates and it was found necessary for an additional division by 2.5 to give values comparable to large-scale, less managed farm values in a similar environment.

The analysis of species' proportions and grazing capacities in the first trial were by response surface regression analysis with inclusion of linear and quadratic effects for P and S levels and their interactions, and linear and quadratic effects for time trends. The analysis of the second trial was by general ANOVA for split-split plot design with contrasts for linear and quadratic time trends.

Results

Trial One - P and S fertiliser levels

Regression analysis of the first trial showed there were highly significant time trends (P=0.001 for both linear and additional quadratic trends) in the *Hieracium,* sown legume and sown grass categories as related to P and S fertiliser treatments and their interaction. The mean standard error for the proportions of these three categories in each year were 0.14, 0.22 and 0.16 respectively.

The results for the 31 fertiliser combinations of the first trial have been meaned into nine combinations of low (0 and 5 kg ha^{-1} $yr.^{-1}$), moderate (10 and 20) and high levels (50 and 100) of P and S fertiliser (Fig. 1). The *Hieracium* class included both *H. pilosella* and *H. praealtum,* though largely the former. These show a marked effect of fertiliser on vegetation composition and trends. The effects were more marked for variation in P than S fertiliser levels. The initial effect was the decrease in proportional contribution of *Hieracium* to the sward between the second and third year, the first measurement period. This relates to the continued initial growth of the overdrilled pasture species.

Hieracium was a major vegetation component at the lower fertiliser levels making up 30-40% of available herbage in the low P and S combination. It decreased in the first five years at the high fertiliser combinations but remained as a small component in other fertiliser combinations. There was a small trend for it to be increasing in most of the fertiliser combinations in the last three years.

Fescue tussock remained as only a minor component in the initial years at the lower fertiliser levels. There was a small increase in later years in some moderate fertiliser combinations, e.g., moderate P and low S.

Sown legumes were the major contributor to vegetation in most fertiliser combinations for most of the period, making up more than half of the

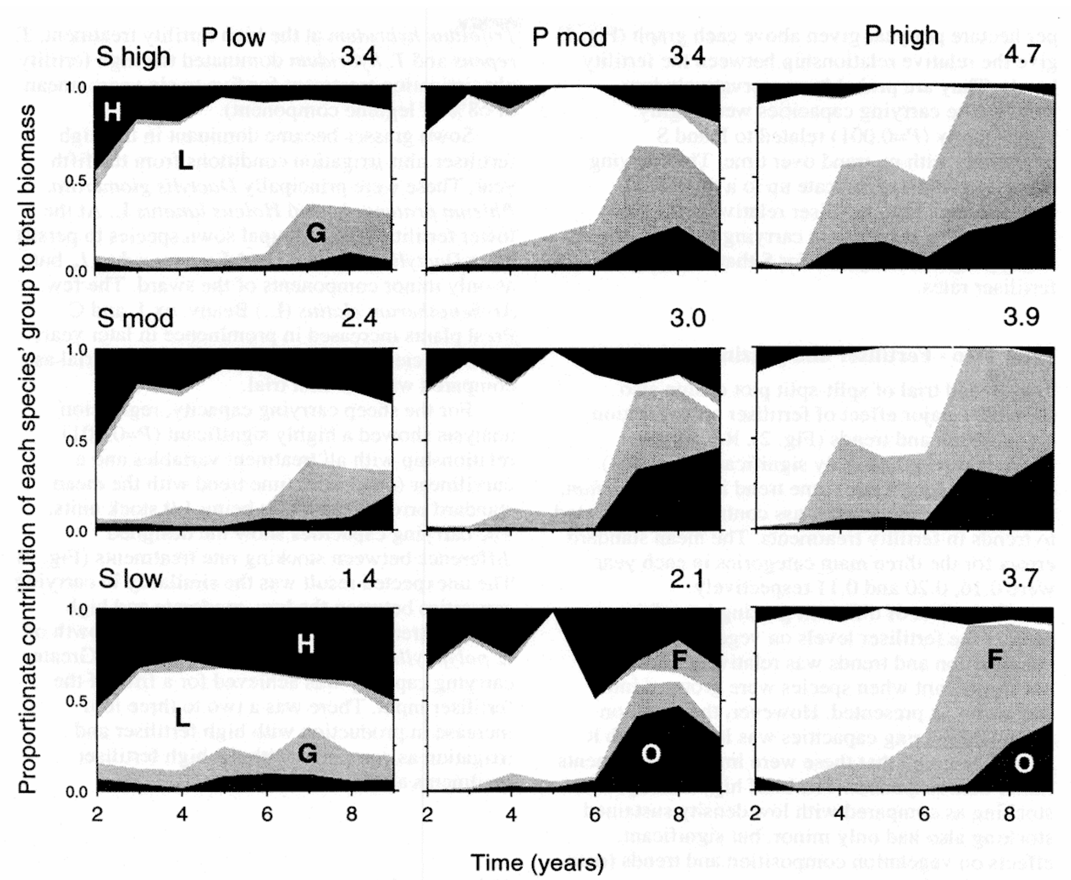

Figure 1: *Vegetation composition and trends over eight years under nine phosphate (columns) and sulphur (rows) fertiliser combinations. Species categories' within each graph:* Hieracium *(H, top, solid); fescue tussock (F, upper light hatch); sown legumes* (L, *clear); sown grasses (G. lower light hatch); and others (0, bottom. dark hatch). Fertiliser levels: low (0 or 5 kg ha^{-1} yr^{-1} of element); moderate 10 or 20 kg* ha^{-1} yr^{-1}*); and high (50 or 100 kg ha^{-1} yr^{-1}). Estimated carrying capacity as stock unit ha^{-1} estimated from grazing days achieved over whole period are given above each graph. Years are from* 1982-1989.

herbage (Fig. 1). The major species were *Lupinus polyphyllus* Lindley at the low and moderate fertility levels (an average of 60% of the legume component), and *Trifolium hybridum* L. and *T. repens* L. at the high fertility levels (average of 40% of the legume component). The period of the legume-dominant phase was also positively related to fertility levels - being shortest at the high fertility levels, particularly the high P levels. There was a common reduction in legume proportion in the sixth and seventh year of sampling (November 1986 and 1987); the proportion only increased slightly for some legume species in later years.

Sown grasses, principally *Dactylis glomerata* L., replaced legumes as soil fertility built up in intermediate to later years, particularly at the higher P levels. The indications are that sown grasses ceased to increase in the last two years. There was also an increase of resident grass species, principally *Agrostis capillaris* L. and *Anthoxanthum odoratum* L.

The estimated carrying capacities in stock units per hectare per year given above each graph (Fig. 1) give the relative relationship between the fertility levels. They are probably conservatively low values. The carrying capacities were highly significantly *(P*=0.001) related to P and S treatments with no trend over time. The carrying capacity estimates indicate up to a three-fold increase with high fertiliser relative to the low fertiliser. The response in carrying capacity is only slightly significantly less for S than P for equivalent fertiliser rates.

Trial Two - Fertiliser and grazing management

The second trial of split-split plot design also showed a major effect of fertiliser on vegetation composition and trends (Fig. 2). Regression analysis showed a highly significant *(P*=0.001*)* curvilinear (quadratic) time trend in the *Hieracium,* sown legume and sown grass contribution as related to trends in fertility treatments. The mean standard errors for the three main categories in each year were 0.16, 0.20 and 0.11 respectively.

The effect of different grazing intensities at each of the fertiliser levels on vegetation composition and trends was relatively minor and not significant when species were grouped into categories as presented. However, the effect on estimated grazing capacities was large, though it should be noted that these were imposed treatments rather than responses. The brief high density mob stocking as compared with low density sustained stocking also had only minor, but significant, effects on vegetation composition and trends (data not presented).

The "*Hieracium*" category again included two species with only an insignificant contribution by *H. praealtum*. *Hieracium* is a major contributor to herbage bulk under the nil fertiliser conditions with its proportion increasing over time. Its absolute amount may have only increased slightly, its greater apparent contribution relating to the decrease of other species through the grazing pressure. *Hieracium* made up 10-20% of herbage in the low, moderate, and high fertiliser dryland (i.e., non-irrigated) conditions with a slight increase over time. Only under high fertiliser plus irrigation did *Hieracium* become insignificant or disappear.

Fescue tussock only made a statistically significant contribution *(P*=0.05*)* in the nil fertiliser, lax and moderate grazing treatments.

Sown legumes dominated the low, moderate and high fertility dry land treatments with, again, *Lupinus polyphyllus* dominating the low and moderate fertility (on average forming 62% of the legume component), and co-dominating with *Trifolium hybridum* at the high fertility treatment. *T. repens* and *T. hybridum* dominated the high fertility plus irrigation treatment for five to six years (mean of 68% of legume component).

Sown grasses became dominant in the high fertiliser plus irrigation conditions from the fifth year. These were principally *Dactylis glomerata, Phleum pratense* L. and *Holcus lanatus* L. At the lower fertilities the principal sown species to persist were *Dactylis glome rata* and *Festuca rubra L,* but as only minor components of the sward. The few *Arrhenatherum elatius* (L.) Beauv. ex J. and C. Presl plants increased in prominence in later years. Other species were not conspicuous in this trial as compared with the first trial.

For the sheep carrying capacity, regression analysis showed a highly significant (*P*=0.001) relationship with all treatment variables and a curvilinear (quadratic) time trend with the mean standard error of estimates being 1.9 stock units. The carrying capacities show the designed difference between stocking rate treatments (Fig. 2). The unexpected result was the similarity in carrying capacities between the low, moderate and high fertiliser treatments. This was due to the growth of *L. polyphyllus* at the lower fertiliser levels. Greater carrying capacity was achieved for a fifth of the fertiliser input. There was a two to three fold increase in production with high fertiliser and irrigation as compared with the high fertiliser treatments alone.

Discussion

The ecology of *Hieracium* is being studied with view to identifying environmental factors to which it is vulnerable, and which are capable of economic management. There are two components: i) identifying critical environmental restraints, and ii) identifying possible economic manipulative practices.

It is in the priority and emphasis given to these two identifying aspects where the philosophies of the field ecological survey approach and the agricultural approach most differ. The field survey ecologists' stance, as indicated by many of the reports to the *Hieracium* workshop and the references therein (Hunter *et al.,* 1992), is that we first have to identify what are the factors controlling the growth and distribution of *Hieracium,* and then hope that some of those are capable of managerial manipulation (e.g., there is no value in identifying altitude and rainfall being critical factors for *Hieracium* if these can not then be manipulated in

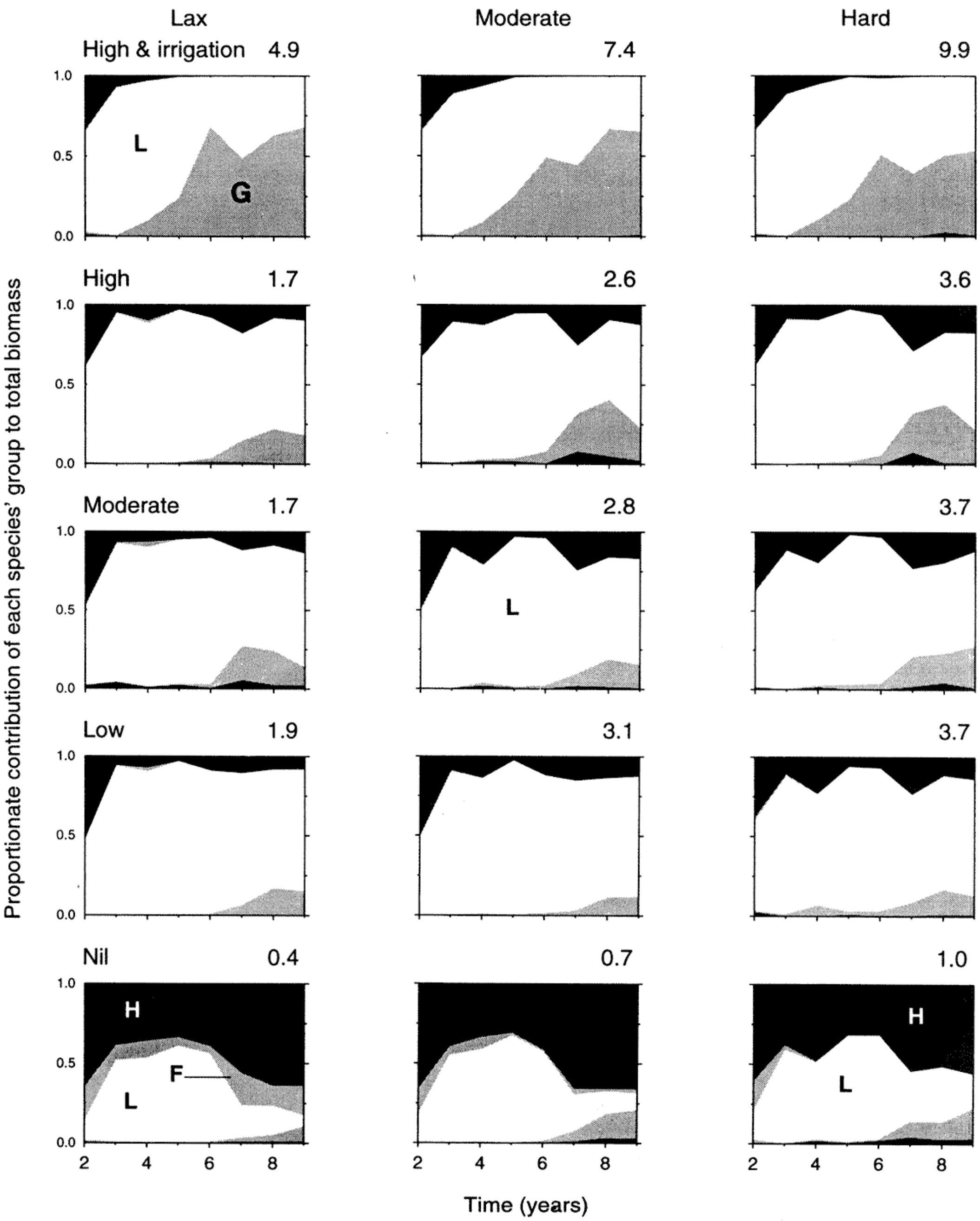

Figure 2: *Vegetation composition and trends over eight years under combinations of five fertility levels (rows) and three stocking rates (columns). Fertility levels are high fertility (500 kg ha^{-1} yr^{-1} plus fortnightly spray irrigation, high fertility (250), moderate fertility (100), low fertility (50) and nil. Stocking rates are low:moderates:high in approximote ratio 2:3:4. Other coding as in Fig. 1.*

practice). By contrast the stance of the manipulative agricultural scientists is to first ask what factors can be changed in a management sense, try them, see if they work and in the process get the costs involved and the outcomes. It can be debated which is the more efficient method of determining practical control options. The two approaches are not mutually exclusive and indeed the survey ecologists' initial conclusions will have to go through the manipulative experimental stage for validation and costing.

While the perceived problem is *Hieracium* itself, it must be questioned if that is the real problem to which solution is being sought. For pastoral agriculture *Hieracium* is a problem not because of toxicity or lack of acceptability, but rather because of its habit, limiting direct stock feeding, and its invasiveness, excluding other diet species. In that sense the problem is stock feed limitation rather than *Hieracium per se*. The key value in the results presented is the usefully high sheep stocking rates achieved even in the presence of significant levels of *Hieracium,* remembering these are better regarded as relative and conservative rather than absolute. From these and other values presented the returns can be estimated for the costs involved, hence indicating which combination options are both sustainable and give best returns on investment. In this regard the sown grass and legume component is more important than the *Hieracium* component in relation to farming.

For the conservationist, the problem is the displacement of indigenous species and vegetation by *Hieracium*. The real dilemma in that situation is to identify factors which could be manipulated, especially since it is likely that another conservation requirement would be to alter the environment as little as possible. There manipulation has to be directed at the *Hieracium* species themselves through various specific biological control agents.

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