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UNIVERSITY OF
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# THE INFLUENCE OF ORGANIC FARMING ON THE VEGETATION COMPOSITION OF UPLAND PASTURE

**FINAL REPORT**

**TO**

**MINISTRY OF AGRICULTURE FISHERIES AND FOOD**

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# CONTENTS

## EXECUTIVE SUMMARY

This work is a continuation of the investigation into the effects of the adoption of an organic farming regime in the uplands, on the dynamics of plant species and plant communities. The work comprises six vegetation trials: three investigating the differences between dynamics of organically and conventionally managed sub-units of each type of vegetation system on the unit (temporary ley, improved hill, semi-natural), two which investigated the effects of different UKROFS approved PK fertilisers on the composition of improved hill and in-bye swards, and one which is investigating the effect of different sources of external nitrogen inputs on the composition an in-bye sward.

The vegetation was monitored using fixed 1m$^2$ quadrats, surveyed either annually or biennially, depending on the dynamics of the system. The vegetation data were used to quantify differences in species abundance over time, and as inputs for a community level model.

The model used the National Vegetation Classification (NVC) as a reference point for comparison with the vegetation communities identified at Redesdale. The major plant community types found at Redesdale were placed in ordination space along with fixed positions of the NVC communities which typify these. The temporal movement in ordination space, of the Redesdale communities indicates the response of each management unit to the applied regime.

The NPK fertiliser trials finished in 1996 after 6 years, and the N trial is now in its third year. Although in all trials the sward exhibits a very dynamic response to the environment, there have been no differences between treatments.

On the less dynamic improved hill and semi-natural (native hill) communities, analysis at both the quadrat-scale and community-scale has shown that the behaviour of organically managed sites appears to be the same as the parallel conventionally managed system. This suggests that environmental and general management variables exert a greater influence on the dynamics of the system than differences between both management regimes. As monitoring has only taken place over a six year period, it is too early to say whether there are any differences in the dynamics of the semi-natural vegetation. Of particular interest on the semi-natural vegetation trial is the increase

(not significant) in cover of *Calluna vulgaris* on the heft where the stocking rate was reduced by 30%.

The organic management system adopted at ADAS Redesdale, has aimed to elevate and maintain a high cover of *Trifolium repens* on the improved and intensively managed leys. The quality of the organic in-bye swards has been consistently better in terms of raised *Trifolium repens* and reduced weed populations than in the conventional in-bye. However, the dynamics of these swards appear to respond more to site specific environmental forcing variables than to a particular variant of management regime.

# INTRODUCTION

The aim of this research was to investigate the ecological consequences of organic farming in the uplands for key plant and animal groups. The central hypothesis to be tested within this project was that the consequences of organic farming can be predicted from models linking management and life history characteristics of plants and animals.

The first phase of the research (to 1994) covered the effects of adopting an organic farming regime on the dynamics of vegetation and earthworm communities at ADAS Redesdale during the conversion phase from conventional farming practice to UKROFS Organic Farming Standards. Subsequent research (1994-1997) has concentrated on the vegetation dynamics. The project consists of six component studies:

1. Semi-natural vegetation trial (figure 1a).

a) Dargues Dipper heft (114.5 ha) was divided into Organic (60 ha) and Conventional (54.5 ha) subunits as described in the first interim report. The heft varies in altitude from 370m to 220m.
b) Cairn heft. (approx. 200ha). The Cairn heft (alt. 240-379m) was incorporated into the vegetation trials in 1995 to investigate the effect on the vegetation composition of a 30% reduction in stocking rate (compared to stocking rate on the Dargues Dipper heft).

2. Improved upland vegetation trial.

An area known as Ninety Acre (figure 1b), again divided into Organic (19 ha) and Conventional (20.5 ha) subunits. These areas were surface-seeded with *Lolium/Trifolium* mixtures and were limed at various dates between 1969 and 1983. The field has a south west aspect and varies in altitude from 290 m to 230 m.

3. In-bye trial.

Located at the Dargues farm which is *Lolium/Phleum/Trifolium* reseeded pasture on mineral soil (figure 1c). The total area monitored is 21.6 ha at around 170 m altitude. The trial is located at the Dargues farm site (1 conventionally managed field, 2 organically managed fields) and at Cleughbrae (1 organically managed field).

4. Peat-based soil NPK trial (figure 1b).

A trial to investigate the effects of specific UKROFS-approved organic fertilisers on herbage yield and on the dynamics of earthworm and vegetation populations in improved upland pasture. The trial was established on peat soil within the improved upland vegetation trial in early 1992 at around 290 m altitude.

5. Mineral-based soil NPK trial (figure 1c).

A similar investigation to that in trial 4, established on *Lolium/Phleum/Trifolium* pasture on mineral soil in the West Hayfield at Dargues farm in early 1992 at approximately 170 m altitude. The treatments were part of a larger trial monitored by ADAS Redesdale.

6. Mineral-based soil nitrogen trial (figure 1c).

This trial was set-up in 1995 on the Bridge Haugh field at Cleughbrae (alt. 164m). The objective of the trial is to look at potential effects of different sources of nitrogen on the vegetation composition of the sward.

In the second phase of the project, reported here, the vegetation dynamics were monitored and changes placed in a national context using the modelling system developed during conversion phase.

## GENERAL METHODS

Unless otherwise stated in the text, vegetation sampling was based on $1m^2$ quadrats. A record was made of each plant species present in each quadrat. In addition, quadrats were subdivided into one hundred 10 cm squares and the dominant and sub-dominant species in each square recorded. For each quadrat each species recorded was assigned a dominance score according to the following equation:

$$\text{Dominance Score} = D + (0.5 \times SD),$$

where $D$ = number of squares where that species was dominant,

and $SD$ = number of squares where that species was sub-dominant.

The maximum score for any individual was therefore 150, representing a single species stand.

# RESULTS OF TRIALS

## 1: Semi-natural vegetation trial.

*a) Dargues Dipper heft*

The Dargues Dipper was surveyed in 1992 after its division into organic and conventionally managed hefts. The survey positions were permanently marked and the survey was repeated in 1994 and 1996 in order to determine the effects of the change in management on the vegetation cover.

A significant increase over time, in the cover of *Deschampsia flexuosa* was observed for both treatments, and there was a significant decrease in cover of *Polytricum commune* in the organic treatment (figure 2). Otherwise there were no significant differences observed between any of the treatments in 1996, or between any of the species over time. *Nardus stricta* was observed to increase in both treatments. The cover of *Calluna vulgaris* and *Festuca ovina* was observed to be decreasing over time, in both treatments. The decrease in cover of *Calluna vulgaris* although not significant, is marked in both treatments. In the organic treatment it is being replaced by *Molinia caerulea* and *Deschampsia flexuosa*, whereas in the conventional treatment where *Molinia caerulea* is also decreasing in cover, the decrease of *Calluna vulgaris* coincides with an increase of *Holcus lanatus* and *Deschampsia flexuosa.*

*b) Cairn heft*

The results of the analysis of vegetation cover between the two sampling dates (1995 & 1997) is shown in figure 3. There were significant changes in the recorded cover of four species. A decline in cover was observed for *Polytricum commune* ($F=5.68$, $p=0.0190$), and *Eriophorum vaginatum* ($F=17.81$, $p<0.0001$). There was a significant increase in the cover of *Molinia caerulea* ($F=4.30$, $p=0.0405$) and *Carex nigra* ($F=19.96$, $p<0.0001$). A number of non-significant changes were observed in other common species, including an increase in the cover of the dominant species; *Calluna vulgaris*. Increases in *Calluna vulgaris* were more rapid in quadrats situated on parts of the heft burnt shortly before monitoring began. Other species which declined in cover were *Deschampsia flexuosa, Festuca ovina* and *Galium saxatile.*

## 2: Improved upland vegetation trial: Ninety Acre

There were no significant differences between treatments in 1997 (figure 4). The cover of *Trifolium repens* had been increasing in both treatments up until 1995, but subsequently declined, in both treatments and significantly for the organic treatment between 1996 and 1997 ($F=3.97$, $p=0.0008$). The 1997 decline in in *Trifolium repens* was observed in most other trials. The increase in cover of *Lolium perenne*, although not significant, has continued throughout the duration of monitoring. There appears to be fluctuation in the cover of *Poa pratensis* and *Agrostis* spp. which were showing a decline up to 1996 and *Holcus lanatus*, which appeared to be increasing up to 1996. Although there is no empirical evidence to substantiate this, there is some anecdotal evidence for an increase in *Juncus effusus* under the organic regime.

## 3: In-bye trial

*South Hayfield (conventional, figure 5)*

This is the only conventionally managed in-bye area studied in this project. The field was resown during 1992 and was therefore sampled for the first time in 1993. It was re-sown again in 1997, and so was not surveyed in this year. The trend in the vegetation dynamics from 1993 to 1996 are given here.

The sward had always been poor quality prior to the 1997 re-sowing, with high cover of the weed species *Holcus mollis* and to a lesser extent *Stellaria media*. The high cover of *Holcus mollis* can probably be attributed to the proximity of the field to an adjacent wood. Throughout the period of monitoring, the cover of *Holcus mollis* increased.

There were no significant changes in species composition from year to year, but there was a consistent decline in cover of *Lolium perenne* and less steeply of *Trifoium repens*. *Phleum pratense* increased in abundance throughout the lifetime of the sward. This trend in *Phleum pratense* was also observed in the organic in-bye swards .

*North Hayfield (organic, figure 6)*

The North Hayfield was resown in 1991 with a *Lolium/Phleum/Trifolium* mixture. There were early problems with broad-leaved weed invasion, notably by *Stellaria media*. The subsequent establishment of the sward was accompanied by a peak in the cover of the weed species *Poa pratensis* and *Ranunculus* spp., but the cover of these species has since declined significantly (*Poa*: F=10.34, p<0.0001, *Ranunculus*: F=10.99, p<0.0001). The cover of *Lolium perenne* and *Trifolium repens* has remained high since sowing, with annual fluctuations between the cover of the two.

*West Hayfield (organic, figure 7)*

This field was resown in early 1992. As with the North Hayfield, early establishment was hampered by invasion by *Stellaria media*. In 1993, *Stellaria media* was largely replaced by *Trifolium repens* and *Lolium perenne*. A low dominance score for *Bromus mollis* and records of *Anthriscus* spp. are misleading as these species tend to exhibit early growth and flowering, with relatively little regrowth after the first cut of the season. Therefore, since sampling took place in August, the low dominance scores are likely to underestimate the true extent of these species at the site. The cover of *Lolium perenne* has remained high since sowing, whilst the cover of *Trifolium repens*, which increased during establishment fell significantly in 1997 (F=11.03, p<0.0001). This fall was accompanied by a significant increase in the cover of *Phleum pratense*. Which has been increasing in cover since sowing. Other, weed species remain at low abundance overall. These species are most common in localised populations at the top part of the field

*Bridge Haugh (organic)*

This field was resown in early 1992, with a *Lolium/Phleum/Trifolium* mixture. The field has been subject to invasion of *Rumex obtusifolius* introduced by seed in slurry spread on the field. The problem of *Rumex obtusifolius* has dominated the management of this field, and half of the field was re-sown in 1996. The result of the re-sowing is shown in figure 8, with significant declines in the cover of *Trifolium repens* and *Rumex obtusifolius*, concurrent with a massive increase in the cover of *Stellaria media*. The subsequent (1996-7) crash in the population of *Stellaria media* coincident with an increase in the cover of *Trifolium repens* has been more marked than any observations of establishment of the in-bye swards. *Lolium perenne* and *Phleum pratense* have yet to establish in the re-sown area. Weed species cover still remains low, including *Rumex obtusifolius*, which since re-seeding has returned to 1992-1993 levels, increasing slightly, but not significantly.

**4: Peat-based soil NPK trial. (figures 9-13)**

A replicated small plot experiment was set up on improved upland pasture (Ninety acre) to investigate the effect of organic fertiliser treatments on peat-based soils. The location of the field trial was made on the basis of vegetation and soil trends in the field in addition to considerations relating to management. The field is a hill site, with a number of field drains, and therefore ease of access was also a major consideration in site selection. Consequently the trial could only be located in the top of the field, under the organic management regime. Vegetation and soil trends were presented in the first interim report of Young and Rushton (1994), but will be outlined briefly here.

Vegetation trends: A total of 14 species were found on the trial site, but the principal components of the vegetation of this area were (with mean percentage cover in parentheses) *Holcus lanatus* (48%), *Poa pratensis* (20%) and *Trifolium repens* (14%). Dominance of *Holcus lanatus* increased toward the north, but cover was uniform in the east-west direction. The cover of *Poa pratensis* was relatively even in the northern half of the field. *Trifolium repens* cover declined in the extreme north of the field.

Soil trends: Peat depth was deepest near the centre of the field, declining to both the north and south. pH was 4.1-4.3 where peat was deepest, rising to around 4.5 at the northern boundary indicating only a very shallow gradient. The trial was located in a position which would minimise any vegetation or soil characteristic gradient across the trial area. Plots were set out in early 1992, as a randomised block with three replicates of seven treatments (Table 1) and a plot size of 10 x 8 m.

Table 1. *Treatments used in the peat-based soil NPK trial*

| Treatment number | Treatment | Composition | | |
|---|---|---|---|---|
| | | N | $P_2O_5$ | $K_2O$ |
| 1 | Control | 0 | 0 | 0 |
| 2 | Ground rock potassium (GRK) | 0 | 0.70% | 11.2% |
| 3 | Kali vinesse | 0 | 0 | 27.6% |
| 4 | Ground rock phosphate (GRP) | | | |
| 5 | Ground rock potassium + ground rock phosphate | | | |
| 6 | Pelleted chicken manure | 5% | 3.73% | 2.89% |
| 7 | Ground rock potassium + ground rock phosphate + pelleted chicken manure | | | |

GRK and Kalivinesse are applied annually in autumn, pelleted chicken manure annually in spring. Ground rock phosphate is applied every three years at three times the annual rate. The application rates are equivalent to 60 kg $P_2O_5$ and 120 kg $K_2O$ $ha^{-1}yr^{-1}$.

The pattern of vegetation change observed in the plots of the NPK trial is the same as the pattern observed for the whole heft. The initial survey of the trial plots showed no significant differences in species cover, and there was no significant difference between treatments in 1996.

**5: Mineral soil NPK trial (figures 14-21)**

As with the previous trial the siting of the mineral soil PK trial was made on the basis of a vegetation survey in 1991. The site is the West Hayfield at Dargues Farm and the vegetation consists of sown grass species on mineral soil.

The vegetation quality of the field deteriorated in early 1992 to such an extent that reseeding was necessary to control the spread of *Bromus* spp. Whilst the main part of the field was ploughed and resown, the cultivation method used to reseed the plots was less severe, consisting of surface rotavation, followed by reseeding and rolling. The early summer vegetation sampling was abandoned as reseeding commenced.

The design of the trial is similar to that of the peat-based soil NPK trial. There are some additional treatments which are not considered here, but to aid comparison with other ADAS data we have used their numbering system for the treatments on this trial (Table 2)

Table 2. Comparison of treatment numbers for the NPK trials

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Peat-based soil NPK trial | 1 (control) | 2 | 3 | 4 | 5 | 6 | 7 |
| Mineral soil NPK trial | 1 (control) | 6 | 7 | 8 | 9 | 19 | 20 |

Here, as in section 4, trends in the cover of major species were the same as for the data for the whole field, although higher standard errors were observed in the trial. No significant differences were observed between treatments.

**6: Mineral soil nitrogen trial (figures 21-27)**

No significant differences have been detected between treatments in the nitrogen trial. All plots in the trial are characterised by a very high cover of *Lolium perenne* and *Trifolium repens*. The behaviour of the sward was consistent for all treatments, with a significant decline in the cover of *Lolium perenne* coincident with significant increases in the cover of *Trifolium repens*. *Phleum pratense* and *Stellaria media* remained at a very low cover, after a significant decrease in all treatments from 1995-1996. Again there was an unusual response in the conventional control (Nitram fertilised), with a significant increase in cover of *Phleum pratense*. This treatment exhibited an increase (not significant) in cover of *Lolium perenne* from 1995-1996.

# MODELLING

## 1: Modelling the dynamics of vegetation change under organic management using the National Vegetation Classification.

Pasture productivity is critical to and often limits the success of beef and sheep production in the uplands. Management of these pastures is designed to maximise herbage production. However, any major change in farming practice may have a considerable effect on vegetation composition and this may be critical to the success of the system in the long-term. Reduction in grazing intensity following adoption of an organic farming system may be expected to influence sward dynamics. Of particular interest are the rate at which in-bye and improved upland pastures suffer weed invasion and the degree to which the clover component is retained in the sward.

The aim of the modelling work described here is to describe vegetation dynamics under organic and conventional management regimes, to attempt to predict what changes are likely to occur in the future and to place the vegetation changes under investigation at ADAS Redesdale in a national context. The modelling procedures were described in Young and Rushton (1994), but are outlined here for information.

Analysis of vegetation data on a species-by-species basis tells us little about the overall effect of management changes at the community level. The National Vegetation Classification (NVC) (Rodwell, 1991, 1992) is a comprehensive description of the natural and semi-natural vegetation communities found in Great Britain. It provides a national database against which vegetation changes such as those recorded on the organic unit at ADAS Redesdale may be compared.

**Methods**

The modelling process involves three stages, 1, the selection of NVC community types to which vegetation in the study area may belong, 2, the creation of a base ordination of the NVC communities using pseudo-samples and 3, comparison of field data with the base ordination to assign samples to NVC community types as the vegetation responds to changes in management (figure 28).

*1. Selection of NVC communities.*

In theory it would be possible to include every NVC community type recognised by Rodwell (1991,1992) in the analysis, but this would be impractical in terms of the volume of data required. In practice the choice of which NVC communities to include was made using the descriptive information in Rodwell (1991, 1992). These descriptions indicate not only the species composition of each community but also the environmental (altitude, rainfall, pH), geographic and agricultural (ley duration, grazing pressure, fertiliser regime) factors which influence their occurrence. These data were used in conjunction with the known environment and climate information at Redesdale to select suitable communities (and subcommunities) for inclusion in the analysis. The communities used in this study were as follows (with descriptions of their ecology following Rodwell (1991,1992)):

Mesotrophic grassland communities

MG6. *Lolium perenne-Cynosurus cristatus* grassland

This is a grass dominated community where *Lolium perenne, Cynosurus cristatus, Trifolium repens, Holcus lanatus* are all constant. In younger sown grasslands the *Cynosurus* component may be rare and will increase only slowly with time, especially where grazing is of low intensity. Dicotyledons, with the exception of *Trifolium*, are frequent but low in cover. Three subcommunities were considered in the ordination, typical subcommunity (MG6a), *Anthoxanthum odoratum* subcommunity (MG6b) and *Trisetum flavescens* subcommunity (MG6c).

MG7. *Lolium perenne* leys and related grasslands

This community differs from MG6 in that *Lolium perenne* is usually the only constant species. In all cases the swards are species poor, often with as few as 5 species/sample. Only three of the six subcommunities are considered, *Lolium perenne-Trifolium repens*, subcommunity (MG7a), *Lolium perenne-Alopecurus pratensis* subcommunity (MG7d) and *Lolium perenne-Poa pratensis* subcommunity (MG7f). Subcommunity MG7a is typically found in newly sown temporary leys, where only sown species are found. In the context of the pasture at ADAS Redesdale one would expect to find this community on newly sown in-bye pasture only. MG7d is frequently found in damp pasture in river valleys, where species such as *Holcus lanatus, Agrostis* spp. and *Anthoxanthum odoratum* invade along with the dicotyledons *Taraxacum* spp., *Ranunculus repens, Cerastium fontanum* and *Rumex acetosa.* MG7f is, like the other subcommunities of MG7, dominated by *Lolium perenne*, but here *Poa pratensis* may achieve co-dominance. In some cases poor regeneration by *Poa pratensis* following trampling may lead to invasion by *Poa annua.*

Calcifugous grassland and montane communities

U4. *Festuca ovina-Agrostis tenuis-Galium saxatile* grassland

This community is characteristically grass dominated and *Festuca ovina, Agrostis tenuis* and *Anthoxanthum odoratum* are constant. Only one subcommunity, *Holcus lanatus-Trifolium repens* subcommunity (U4b) is considered in this work and here *Holcus lanatus* is often dominant, with *Trifolium repens* and *Cerastium fontanum* well represented. This is a species-rich community, with a mean of 20 species per sample. In the context of pasture at ADAS Redesdale this community represents an intermediate between semi-natural hill vegetation and the resown pastures of both improved upland and in-bye areas.

In this report a single ordination was carried out using a combination of NVC subcommunities representing the perceived likely community types within pasture at this site. These were derived from subcommunities MG6a, MG6b, MG6c, MG7a, MG7d, MG7f and U4b.

*2. Creation of pseudo-samples and base ordination.*

For each subcommunity considered, a set of pseudo-samples were created by allocating species and associated abundance data to each sample randomly, within the ranges described in Rodwell (1991, 1992). These data were effectively a set of samples covering the potential range of variation in community composition likely to occur in each community.

The data were then ordinated using Detrended Correspondence Analysis (DCA) (Hill, 1979). Ordination has the effect of reducing the dimensionality of the data by summarising the species variation in all communities into a few axes. This effectively creates a base ordination space for the NVC which allows the graphical presentation of the relationship between the communities. In this analysis, the first and second axis ordination scores obtained for each pseudo-sample were used to generate mean sample scores (centroids) for each NVC subcommunity.

*3. Classification of field data.*

Having defined a three-dimensional framework for the NVC communities, vegetation data from individual field samples were used to place the samples within the ordination space using weighted averaging of the species scores from the DCA ordination of the NVC pseudo-samples. It is important to note that the field samples played no part in the creation of the ordination itself, they were merely assigned within the ordination space on the basis of their species composition.

Each sample was then assigned to NVC subcommunity by calculating the relative distance of the sample from the mean scores of the pseudo-samples for each community. Samples were allocated to the community to which they were closest in ordination space. It was therefore possible to monitor how each sample 'moved' through ordination space (and hence between NVC subcommunities) with time.

## Site information

*Ninety Acre, Improved upland pasture.*

Data from ADAS Redesdale surveys between 1974 and 1980 were used in addition to data collected in this study between 1991 and 1997.

Data collected during this project were based on a grid of 24 permanent 1 $m^2$ sampling points. ADAS data was collected using 0.25 $m^2$ quadrats randomly distributed over patches of vegetation. Comparisons of the vegetation between the two studies were made by bulking up data collected with the smaller quadrat size and was used only where sampling points within the current study fell within the patches surveyed by ADAS.

*In-bye Pasture, Organic Unit*

The in-bye pasture of the organic unit includes 2 organic fields and a conventional field at the Dargues farm, and another organic field at Cleughbrae. In-bye pasture at this site is usually sown with a grass-clover mixture consisting of *Lolium perenne, Trifolium* sp. and *Phleum pratense*. In some cases the *Lolium/Trifolium/Phleum* mixture is oversown with a cereal-legume mixture as an aid to establishment. All in-bye fields have been cultivated and resown within the last seven years.

## Results

*Ordination of NVC communities*

In the 'in-bye' ordination *Lolium perenne-Cynosurus cristatus* grassland (MG6) subcommunities were closely grouped (figure 29), but they were widely separated from the other subcommunities. Axis 1 appears to represent separation on the basis of degree of agricultural improvement with low scores indicating increased improvement. Axis 2 appears to represent differences in the species composition of the *Lolium perenne* grassland (MG7) subcommunities, where negative values indicate increasing species richness.

*Changes in community membership*

1. Ninety Acre, Improved upland pasture.

Movement of the samples within the ordination framework is shown in figure 30.

The vegetation showed considerable change over the period 1975-1992 reflecting the establishment and subsequent dynamics of the sward. Early data (collected by ADAS staff) is included to illustrate the establishment of the sward in the period 1969-1975. All samples classified as semi-natural *Festuca ovina-Agrostis tenuis-Galium saxatile* grassland, *Holcus-Trifolium* subcommunity (U4b) swards between 1975 and 1980 were classified as the improved *Lolium perenne-Cynosurus cristatus* grassland *Trisetum flavescens* subcommunity (MG6c) or *Lolium perenne* leys *Poa pratensis-Lolium* perenne subcommunity (MG7f) swards by 1991. In this study the site has been split into two, one with organic and the other with conventional management regimes. The movement of communities within ordination space has followed the same pattern for both management regimes, staying within the *Lolium perenne-Cynosurus cristatus* grassland (MG6) subcommunities (a, b, and c). This suggests that both management regimes are stable, and the vegetation communities which have arisen from agricultural improvements are being maintained.

2. In-bye Pasture

Movement of the samples within the ordination framework is shown in figure 31.

North Hayfield. This field was resown in 1991 and consequently all quadrats were classified as *Lolium perenne* ley *Alopecurus pratensis* subcommunity (MG7d). Whilst the movement of this community has been away from MG7d towards the MG6 (*Lolium perenne-Cynosurus cristatus* grassland) subcommunities, the sward has remained species poor (productive MG7) sward.

West Hayfield. The field was resown in 1992 and like the North Hayfield it was classified as *Lolium perenne* ley *Alopecurus pratensis* subcommunity (MG7d), dominated by *Lolium perenne*, but with small quantities of broad-leaved weed species. The communities within the West Hayfield have followed the same pattern of those in the North Hayfield, with a general shift towards the MG6 subcommunities. These recorded movements in ordination space imply an increase of species diversity in the inbye swards, with the establishment of *Ranunculus* spp. *Urtica dioica* and *Anthriscus* spp.

Bridge Haugh. The Bridge Haugh was re-sown in 1991 and half of the main field was re-sown in 1996. The community dynamics from 1992-1995 are described here. In 1992 all quadrats were classified as *Lolium perenne-Cynosurus cristatus* grassland typical subcommunity (MG6a). The movement of Bridge Haugh communities within ordination space has been the least of any of the fields in any of the trials. This is surprising given the specific historical problem of *Rumex obtusifolius* confined to this field. These movements (or lack of) suggest an initially (relatively) high species diversity resulting from the presence of *Poa* spp., *Holcus* spp. and *Ranunculus* spp. The proliferation of *Rumex obtusifolius* between 1993 and 1995 will have contributed little to altering this classification.

South Hayfield. The initial placing of the South Hayfield communities within ordination space indicates that the community composition was within the MG7 (*Lolium perenne*) community group. The behaviour of the community in this field shows characteristic differences from the organically managed in-bye. This has been manifested by rapid deterioration to MG6a (typical subcommunity) and subsequently to between MG6b/MG6c (*Anthoxanthum odoratum* subcommunity and *Trisetum flavescens* subcommunity) subcommunities, of similar composition to the improved swards of the Ninety acre. *Holcus* spp. present with *Lolium perenne*/*Trifolium repens* make the greatest contribution to these communities at both sites.

## DISCUSSION

The organic farming system adopted here has been aimed at encouraging a high cover of *Trifolium repens* in order to reduce artificial or imported nitrogen inputs. The initial classification of in-bye swards as *Lolium perenne* ley (MG7d or MG7f), are representative of the low cover of *Trifolium repens*, which was initially slow in its establishment. As *Trifolium repens* establishes, there is movement towards the *Trifolium* subcommunity MG7a. The subsequent change in the composition of in-bye swards to one of the *Lolium perenne-Cynosurus cristatus* grassland (MG6) subcommunities represents in part, the establishment of other grass and herb species.

The dynamics of these communities have exhibited a greater response to environmental variables than to the particular management regime adopted. This is strongly evident in the similarity of behaviour between all treatments in both of the NPK trials (improved hill and in-bye), and the nitrogen trial on the in-bye. This was also shown clearly by the investigation of improved upland and in-bye systems at both scales of analysis, where the vegetation dynamics followed the same pattern over time. In the case of the organic in-bye communities, the dynamics now appear to be dominated by interactions between the three major species (*Lolium perenne, Trifolium repens* and *Phleum pratense*) in response to annual differences in environmental forcing variables. The dynamics of the improved hill communities appear to be affected by interactions between *Lolium perenne, Trifolium repens, Holcus lanatus* and *Agrostis* spp.

The vegetation dynamics observed in all of the swards appears also to be strongly influenced by site conditions such as proximity to sources of weed invasion and sensitivity to vectors of weed invasion, such as ground disturbance. The sources of weed species which contribute to sward deterioration or poor sward quality during establishment are generally through a persistent seed bank (e.g. *Juncus effusus* (Ninety acre), *Stellaria media* (establishment phase, in-bye)), directly via seed-shed (e.g. *Bromus mollis* (West hayfield)), or by invasion from adjacent land (e.g. *Alopecurus geniculatus* (West hayfield), *Holcus mollis* (South hayfield)). Most of the cultural techniques of either the organic regime adopted here, or of a conventional regime, do not differ sufficiently to suggest them as sources of differences in the vegetation dynamics.

For both types of in-bye system, the highly productive *Lolium perenne* and *Phleum pratense* are strongly competitive because they are growing on soils with a high nutrient status and where environmental conditions favour rapid plant growth. They are maintained by the intensive levels of management, which prevent succession to communities such as U4b (*Festuca ovina-Agrostis tenuis-Galium saxatile* grassland *Holcus-Trifolium* subcommunity). This potential succession is not simply averted because of the management; the source of propagules from species which could effect these changes, is a site specific issue.

On base-poor soils on the upland fringes where the growing season is restricted, swards are frequently invaded by *Agrostis* spp. and *Holcus lanatus*. The improved hill pasture of *Lolium perenne-Cynosurus cristatus* grassland (MG6) subcommunities would tend to degenerate to *Festuca ovina-Agrostis tenuis-Galium saxatile* grassland *Holcus-Trifolium* subcommunity (U4b). Although there are large populations of both *Agrostis* spp. and *Holcus lanatus*, there has been no evidence from the ordination model to suggest that the MG6 to U4b degeneration is occurring on the improved hill swards.

The monitoring strategy adopted would not be detect problems perceived to affect particular regions of a management unit. The use of grids or transects of fixed quadrat sites is designed for detecting changes at the level of management unit. Small scale phenomena, such as localised invasion or proliferation of weed species (e.g. *Rumex obtusifolius* on Bridge Haugh, *Juncus effusus* on Ninety acre) cannot be detected by a management unit scale of monitoring, unless the magnitude of the event reaches a scale which is relevant to that of the monitoring strategy. In order to address any perceived localised problems, a more intensive strategic monitoring program would be an appropriate way forward, running alongside data collection at the management unit scale.

The environmental conditions perceived by the semi-natural vegetation communities make them far less dynamic than both the improved hill and in-bye communities. Therefore it is not surprising that there has been little evidence for any differences emerging between the organically and conventionally managed extensive pastures. Here it would also be anticipated that both systems respond to environment more than minor differences between the management systems. It has emerged from analysis of the data from the Cairn heft that the increase in cover of *Calluna vulgaris* (not significant) is not simply due to re-growth on the burnt areas. It implies that this behaviour may be a response to the 30% reduction in stocking rate. Future data from the Cairn heft will be required to establish whether this behaviour continues. On the Dargues Dipper heft, given that there is no change to management (specifically in terms of stocking rate), it is not surprising that there have been no changes in the vegetation composition.

## ACKNOWLEDGEMENTS

The authors wish to thank the following for their invaluable assistance in fieldwork from 1995-1998:
Tanya Barden, Ali Bennett, Paul Boulton, Holly Craib, Elizabeth Fisher, Stephen McCready, Chris Mulcahy, Eleanor Oatway, John Scott, Andrew South and Philip Watson. We would also like to thank Dr Roy Sanderson for his assistance with fieldwork and with the analysis of the data.

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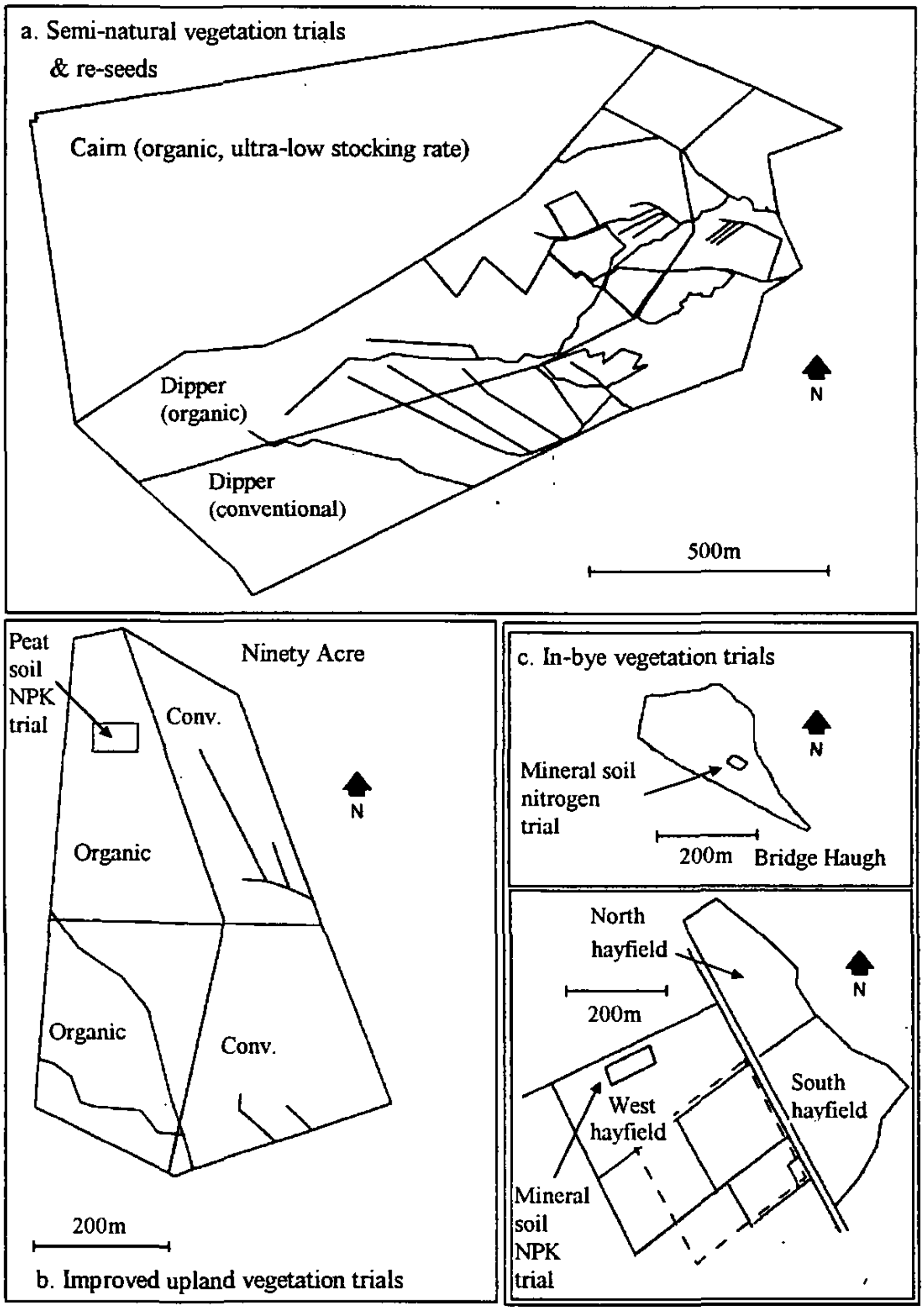
## FIGURES

Figures 2-27 show mean and SE mean cover scores of species over the stated time period. Letters adjacent to a datum indicate group membership as calculated by Student-Neumann-Keuls multiple range test.

Figure 1. Plan of experimental areas



**Semi-natural vegetation trial**

Figure 2.

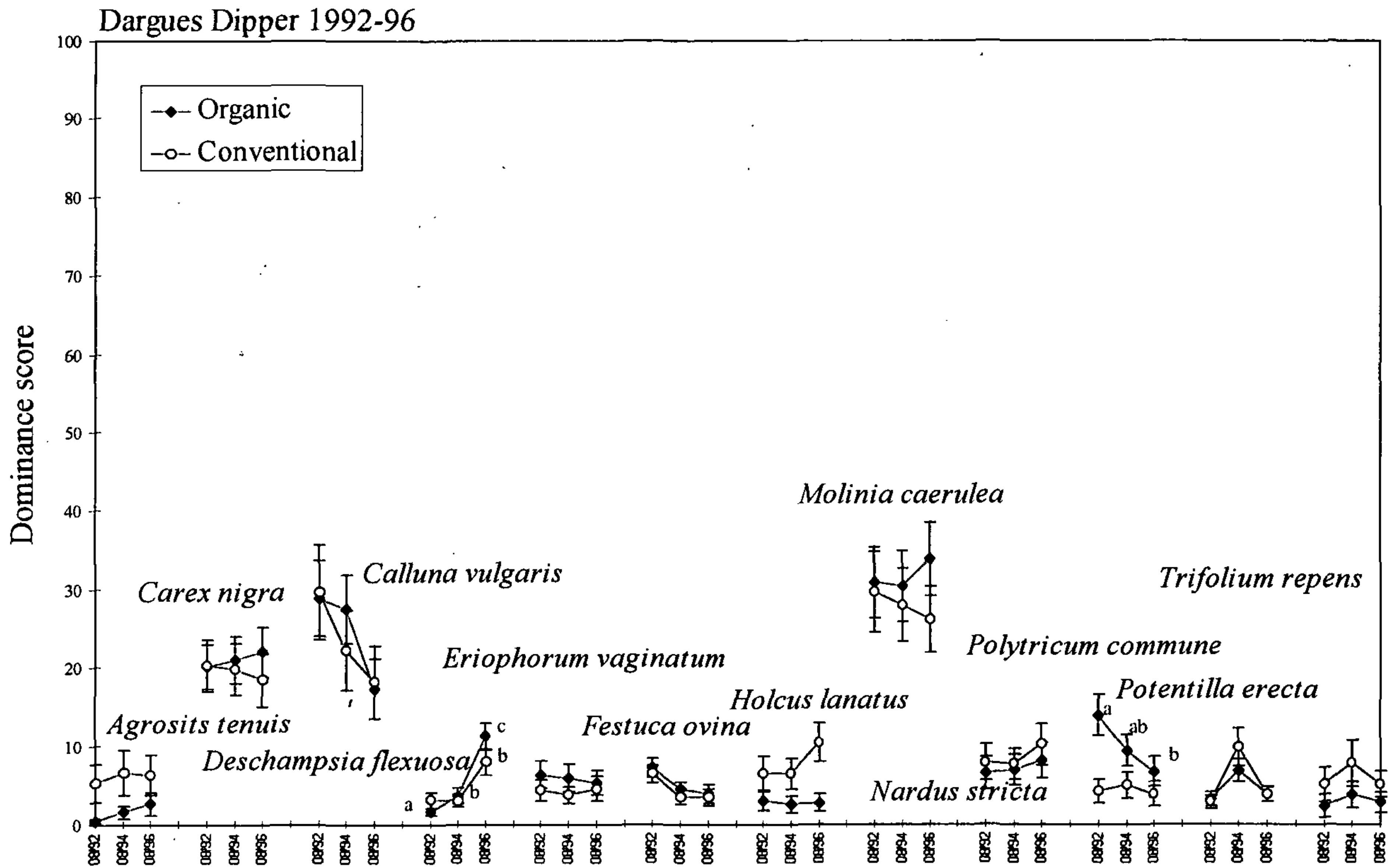
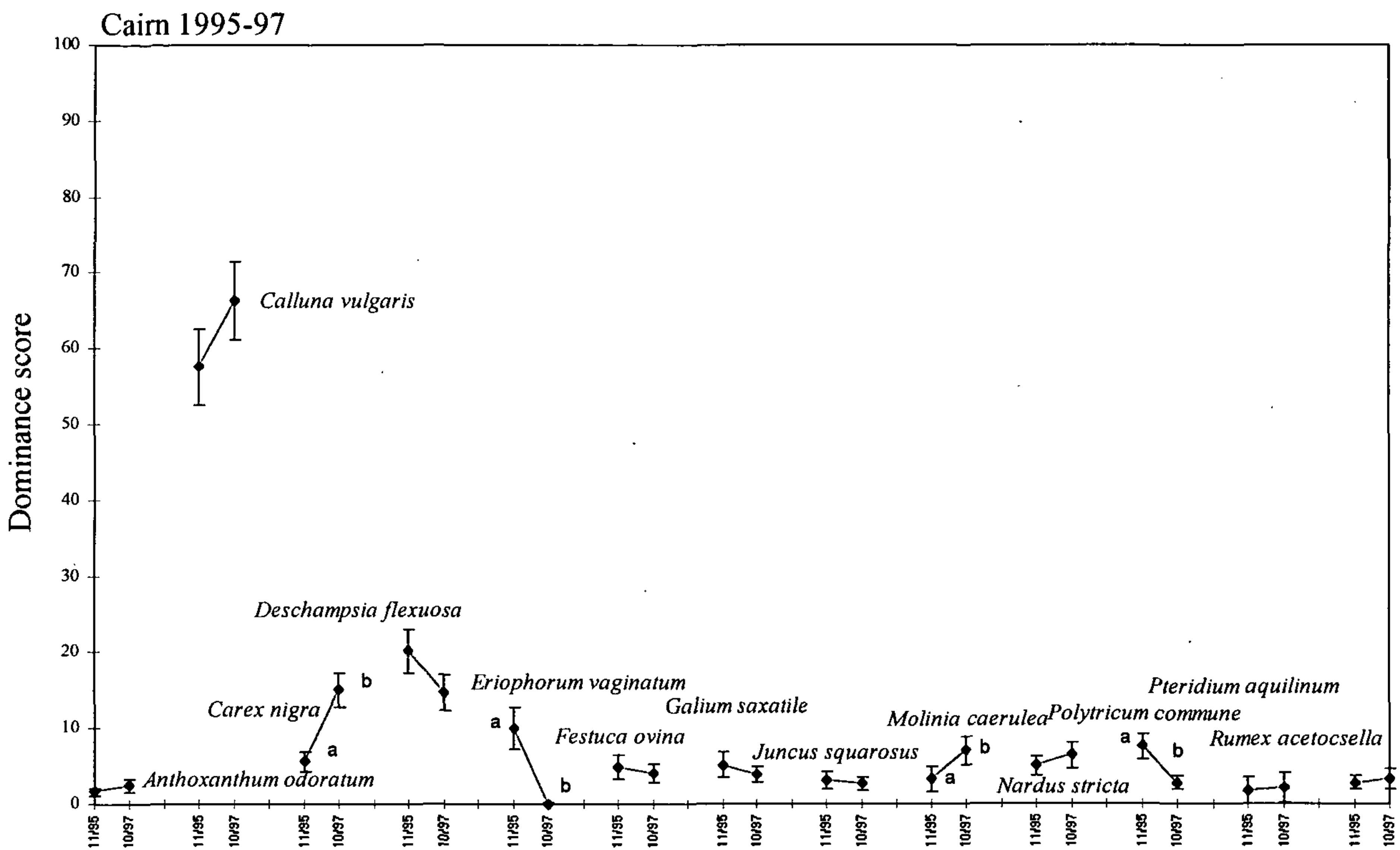


Figure 3.



Cairn 1995-97
Dominance score
0
10
20
30
40
50
60
70
80
90
100
11/95
10/97
Anthoxanthum odoratum
Calluna vulgaris
Carex nigra
Deschampsia flexuosa
Eriophorum vaginatum
Festuca ovina
Galium saxatile
Juncus squarosus
Molinia caerulea
Nardus stricta
Polytricum commune
Pteridium aquilinum
Rumex acetocsella
a
b

**Improved upland vegetation trial**

Figure 4.

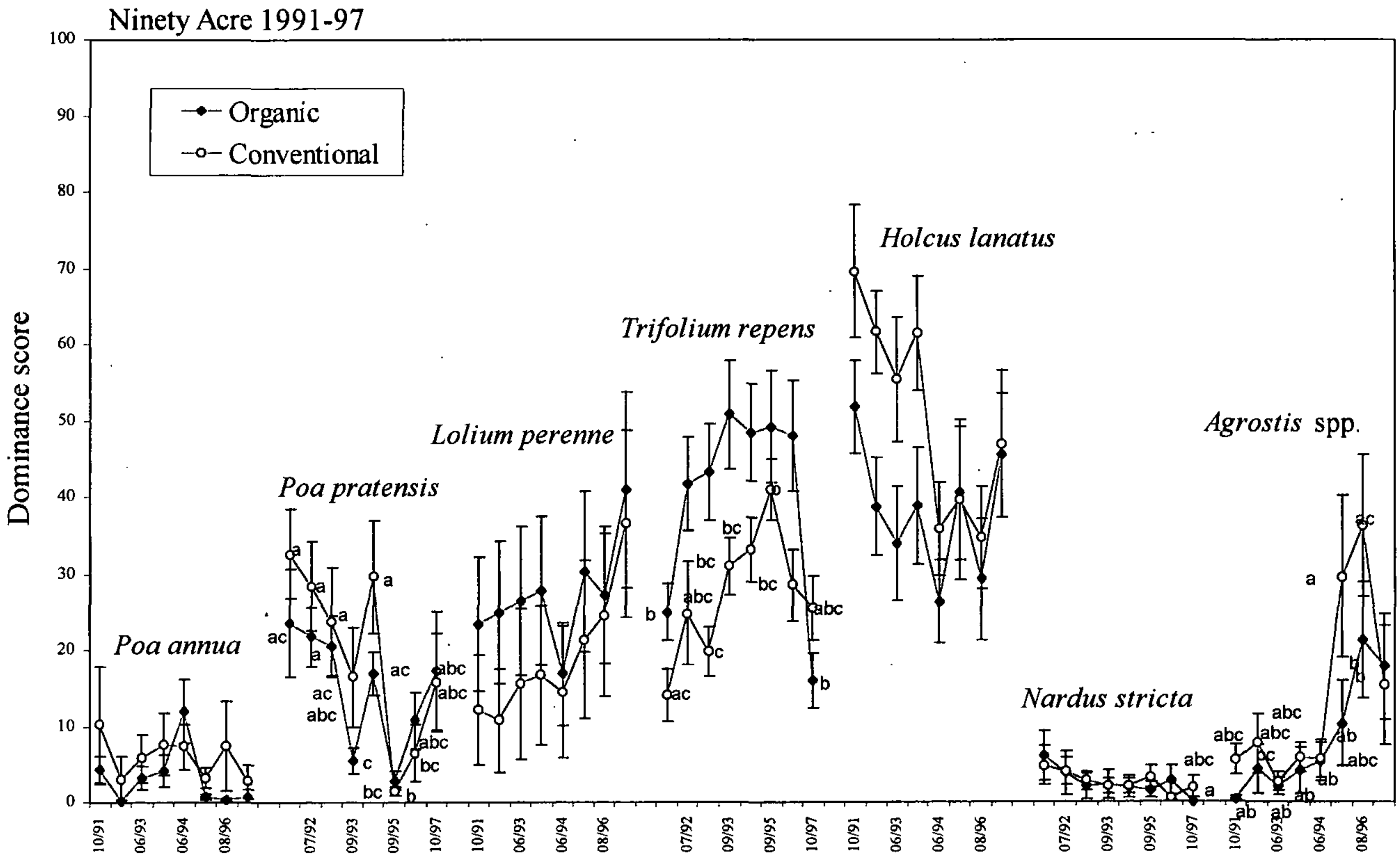
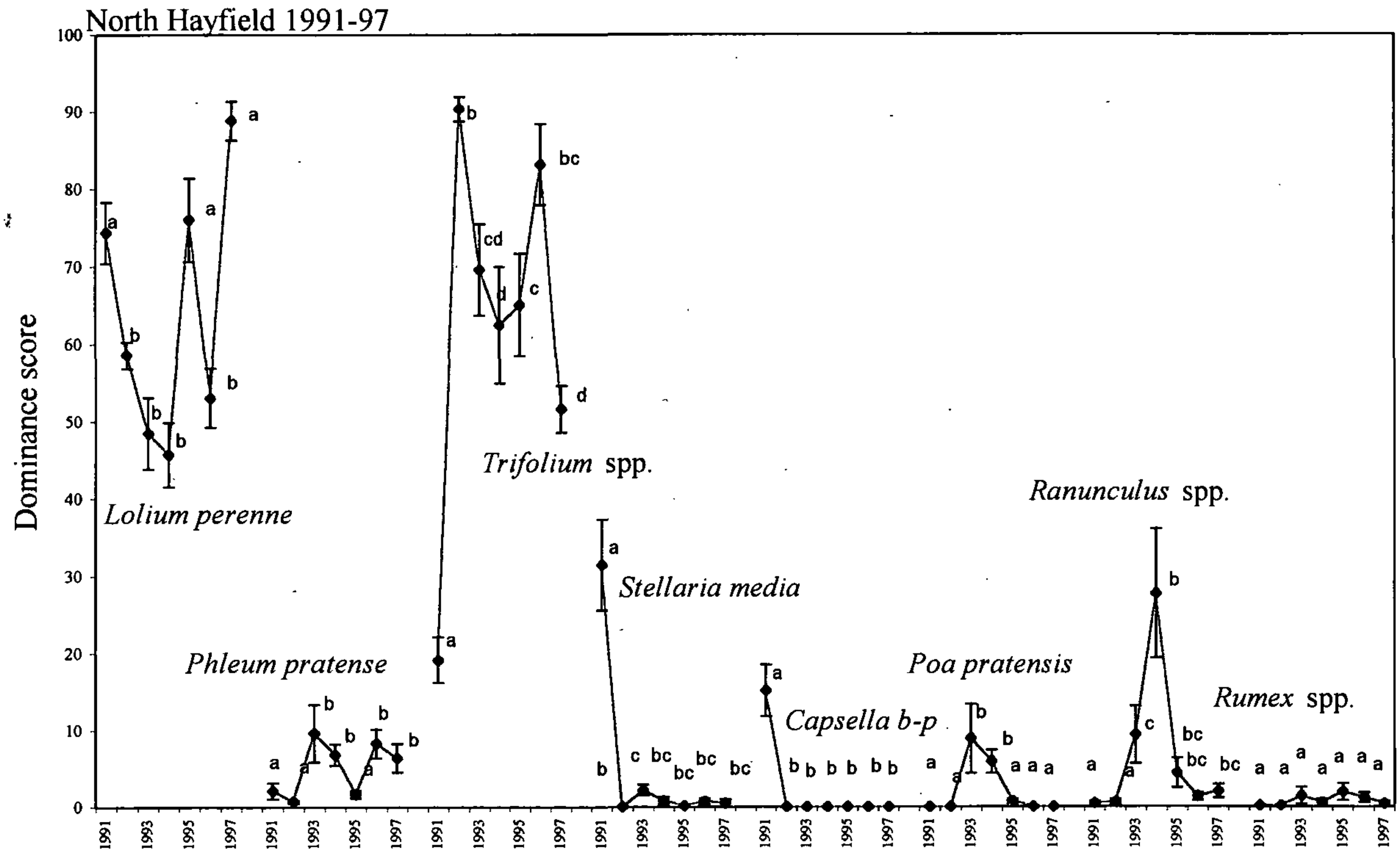


Figure 6.


North Hayfield 1991-97
Dominance score
Lolium perenne
Phleum pratense
Trifolium spp.
Stellaria media
Capsella b-p
Poa pratensis
Ranunculus spp.
Rumex spp.

**In-bye trial**

Figure 5.

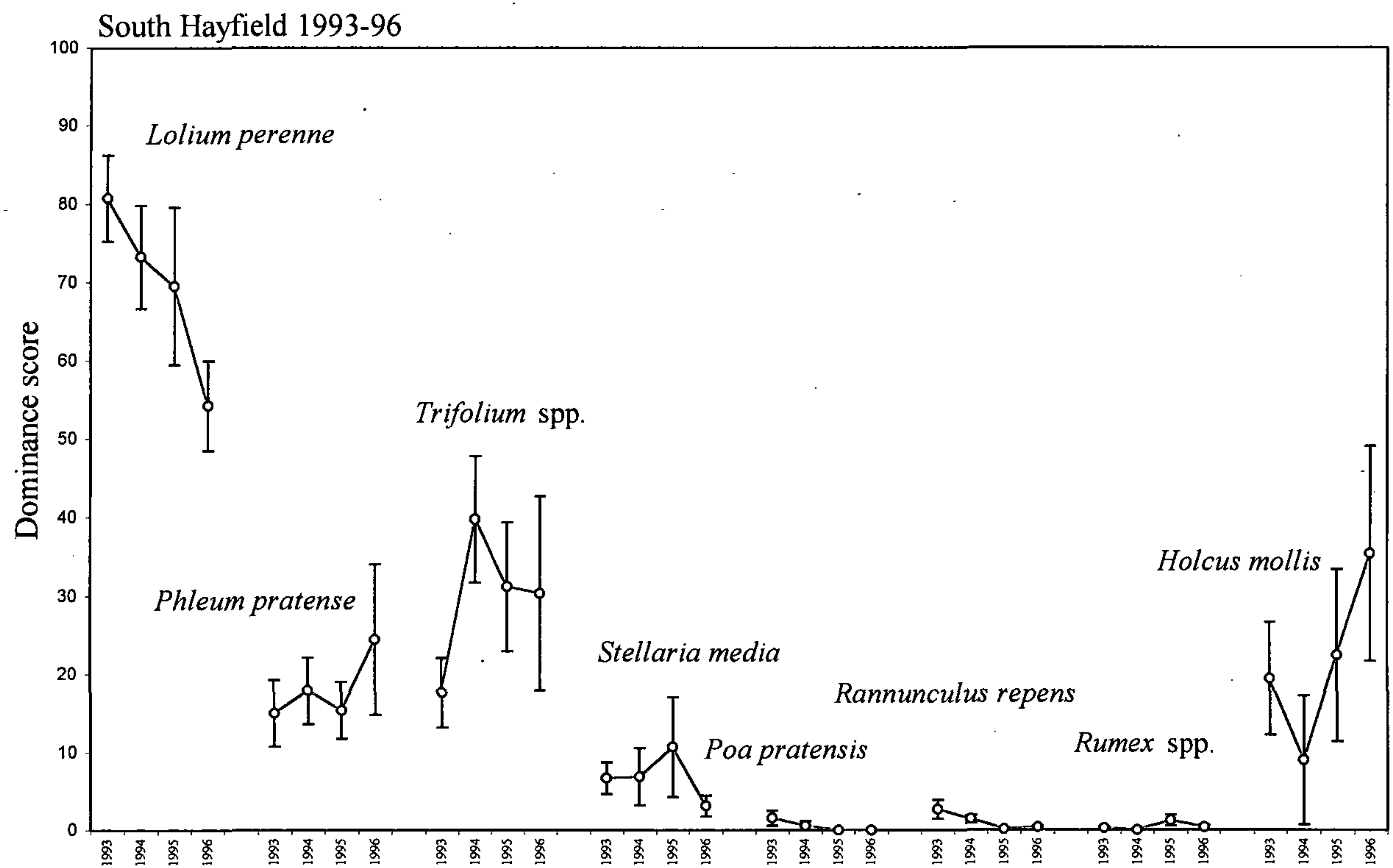


Figure 7.

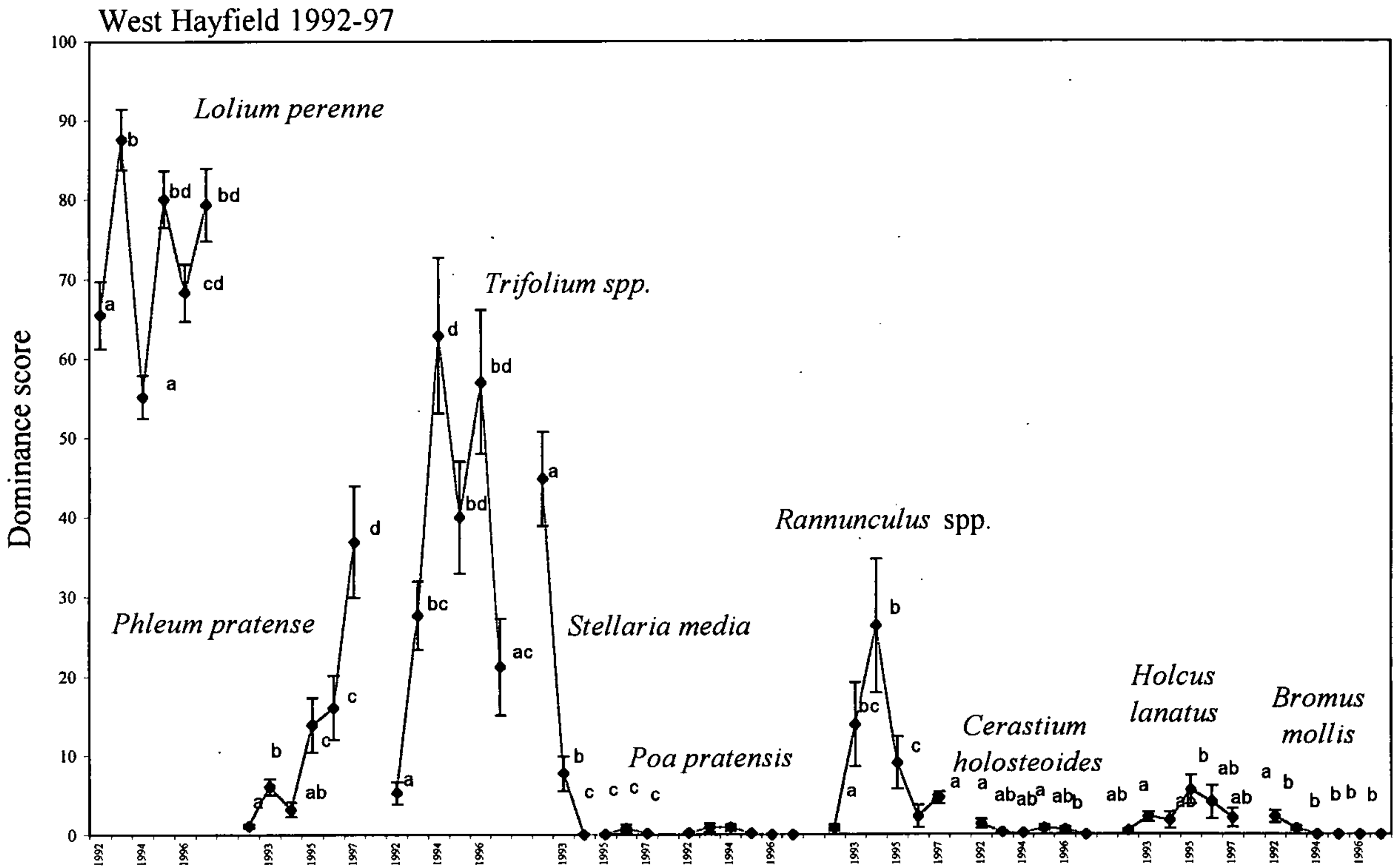
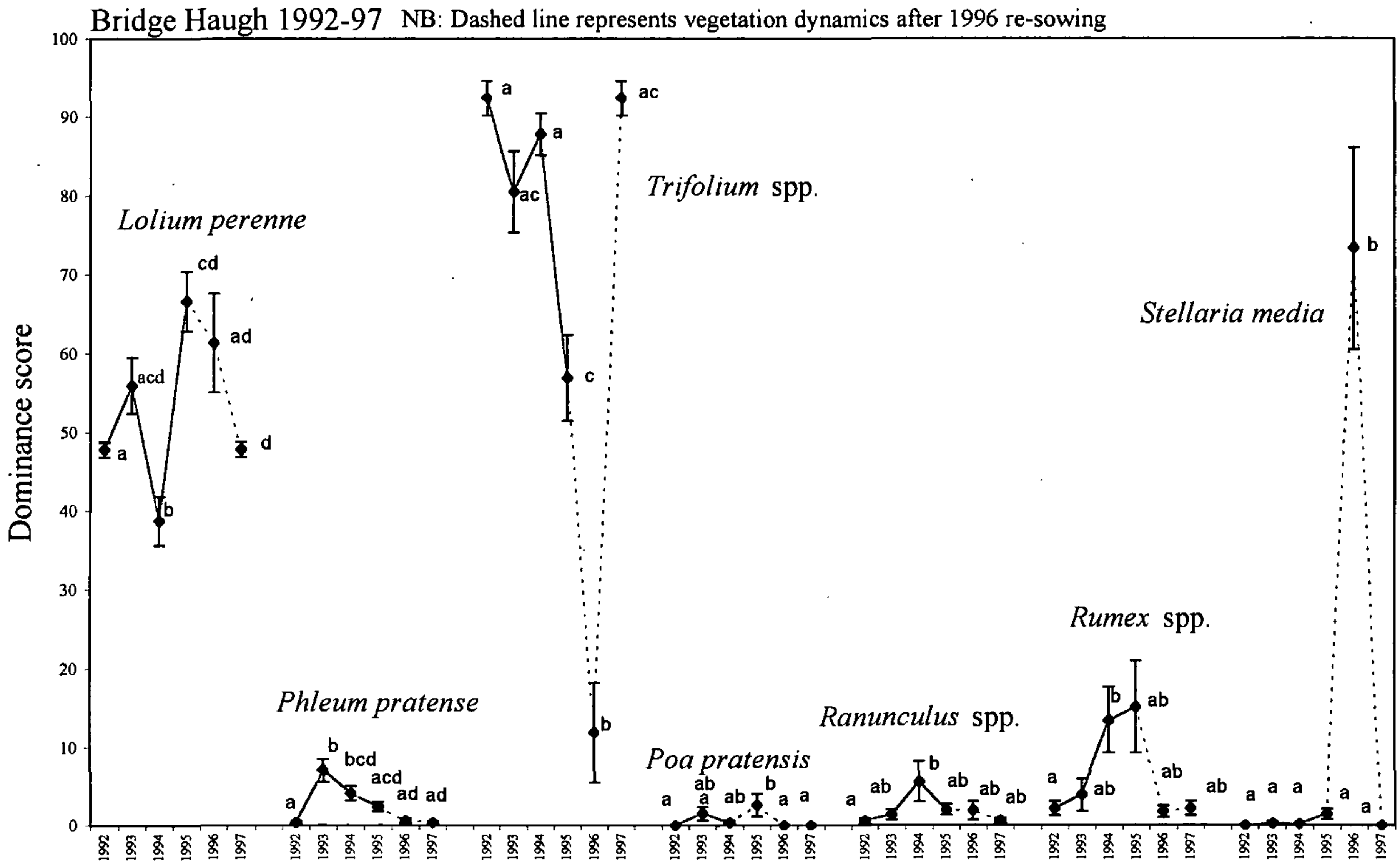

West Hayfield 1992-97
Dominance score
Lolium perenne
Phleum pratense
Trifolium spp.
Stellaria media
Poa pratensis
Rannunculus spp.
Cerastium holosteoides
Holcus lanatus
Bromus mollis

Figure 8.



Bridge Haugh 1992-97 NB: Dashed line represents vegetation dynamics after 1996 re-sowing
Dominance score
100
90
80
70
60
50
40
30
20
10
0
Lolium perenne
Phleum pratense
Trifolium spp.
Poa pratensis
Ranunculus spp.
Rumex spp.
Stellaria media
1992
1993
1994
1995
1996
1997

**Peat-based soil NPK trial - Ninety Acre**

Figure 9.

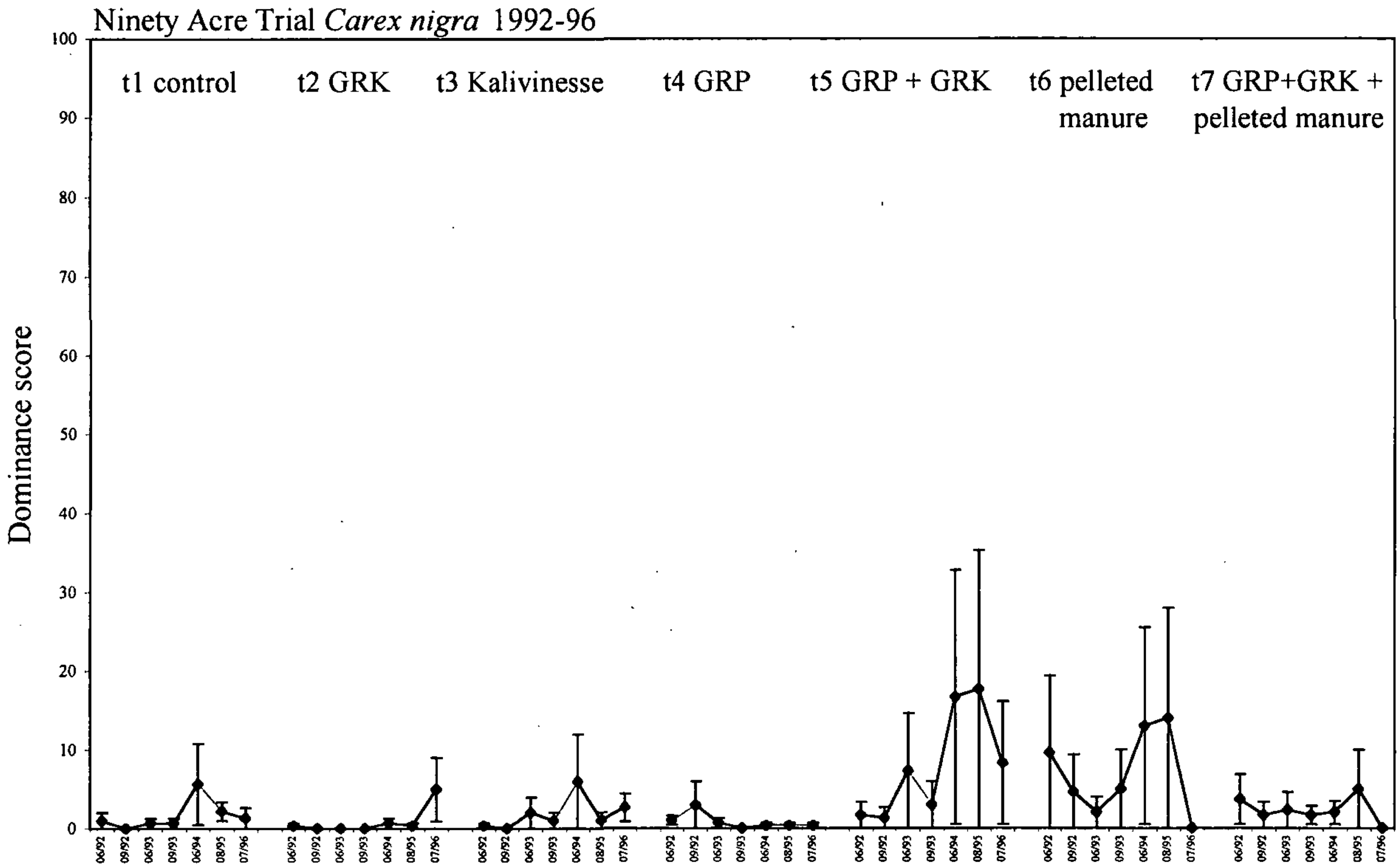
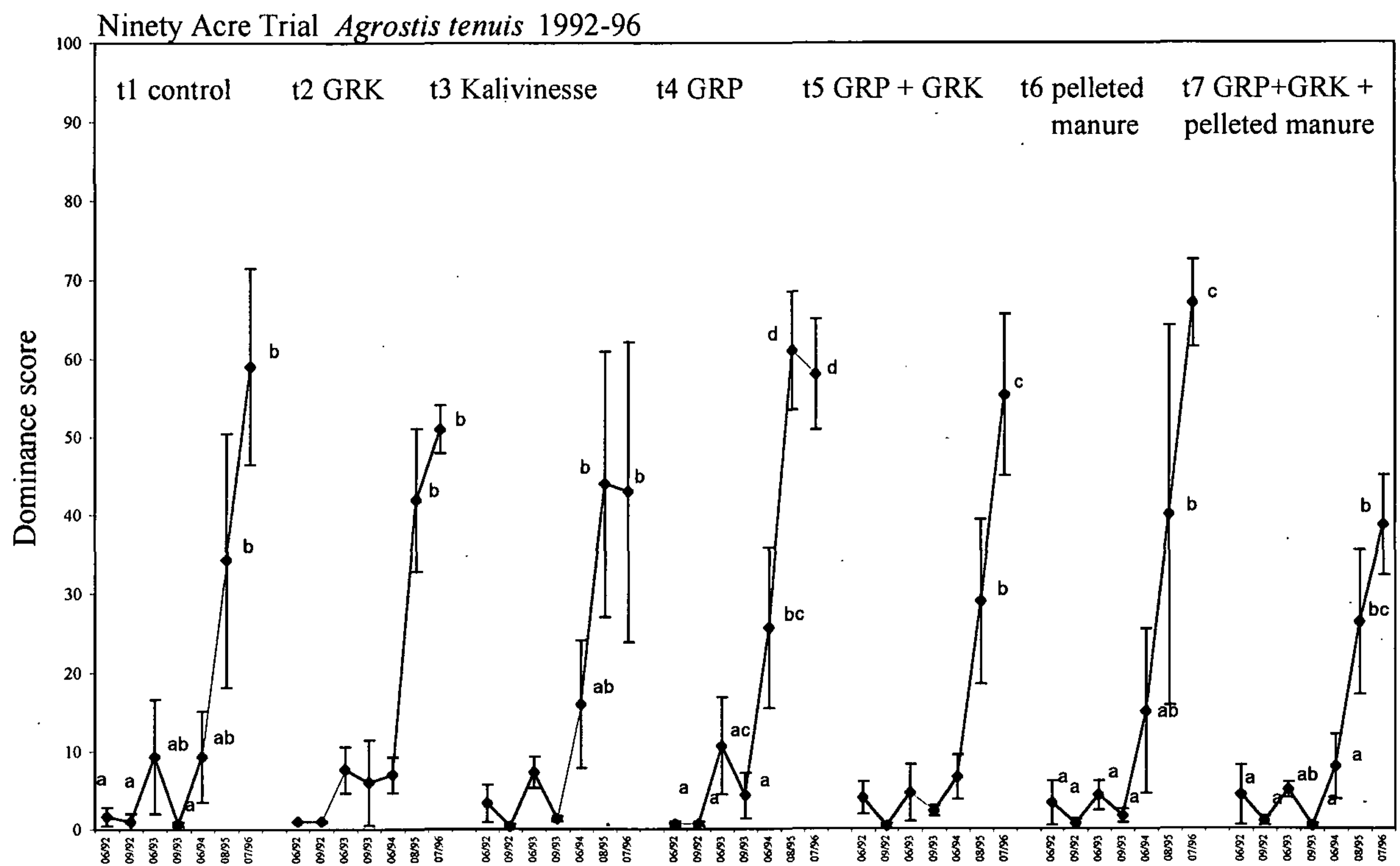
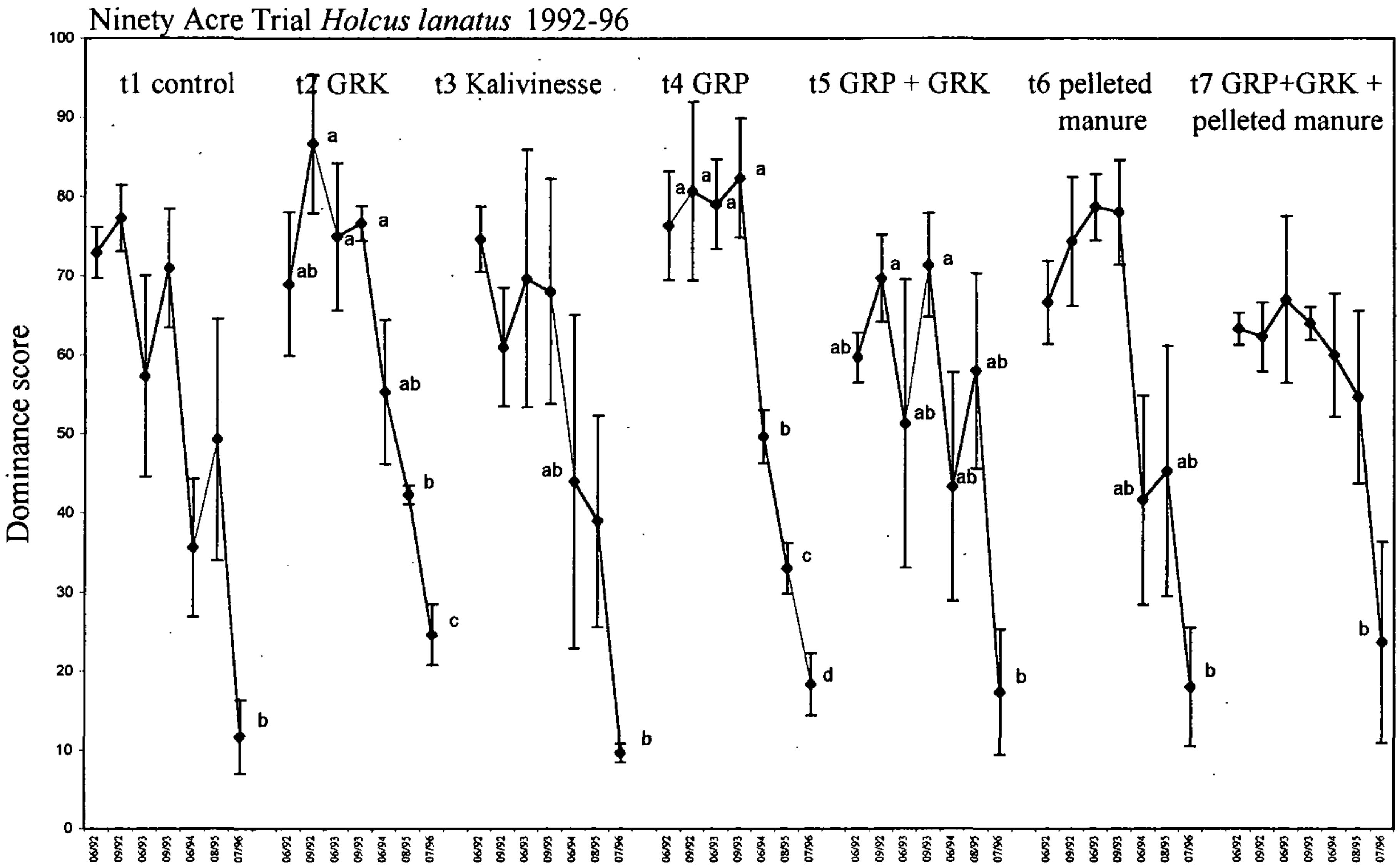


Figure 10.



Ninety Acre Trial *Agrostis tenuis* 1992-96
Dominance score
t1 control
t2 GRK
t3 Kalivinesse
t4 GRP
t5 GRP + GRK
t6 pelleted manure
t7 GRP+GRK + pelleted manure
0
10
20
30
40
50
60
70
80
90
100
06/92
09/92
06/93
09/93
06/94
08/95
07/96

Figure 11.



Ninety Acre Trial *Holcus lanatus* 1992-96
Dominance score
t1 control
t2 GRK
t3 Kalivinesse
t4 GRP
t5 GRP + GRK
t6 pelleted manure
t7 GRP+GRK + pelleted manure

Figure 12.

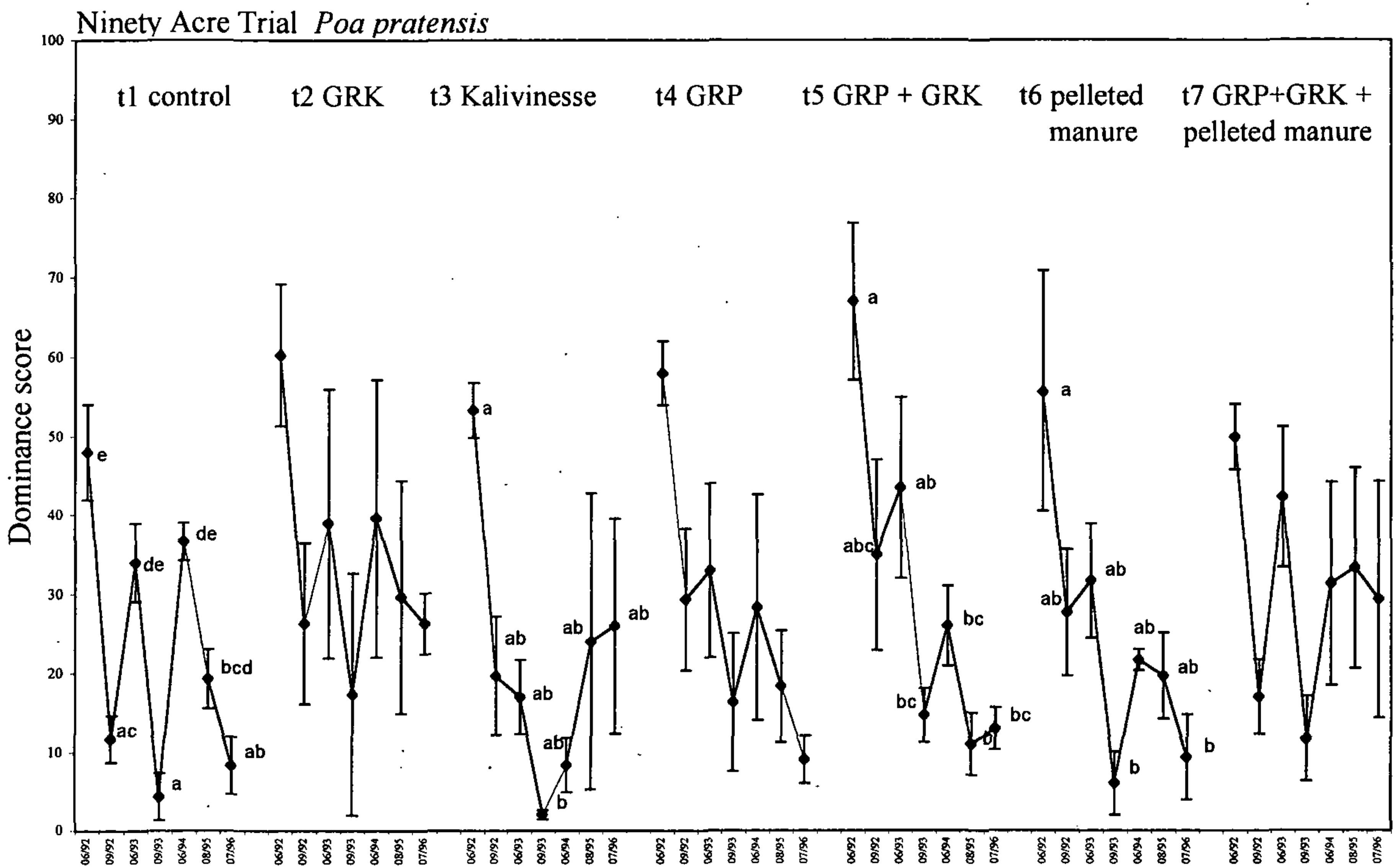
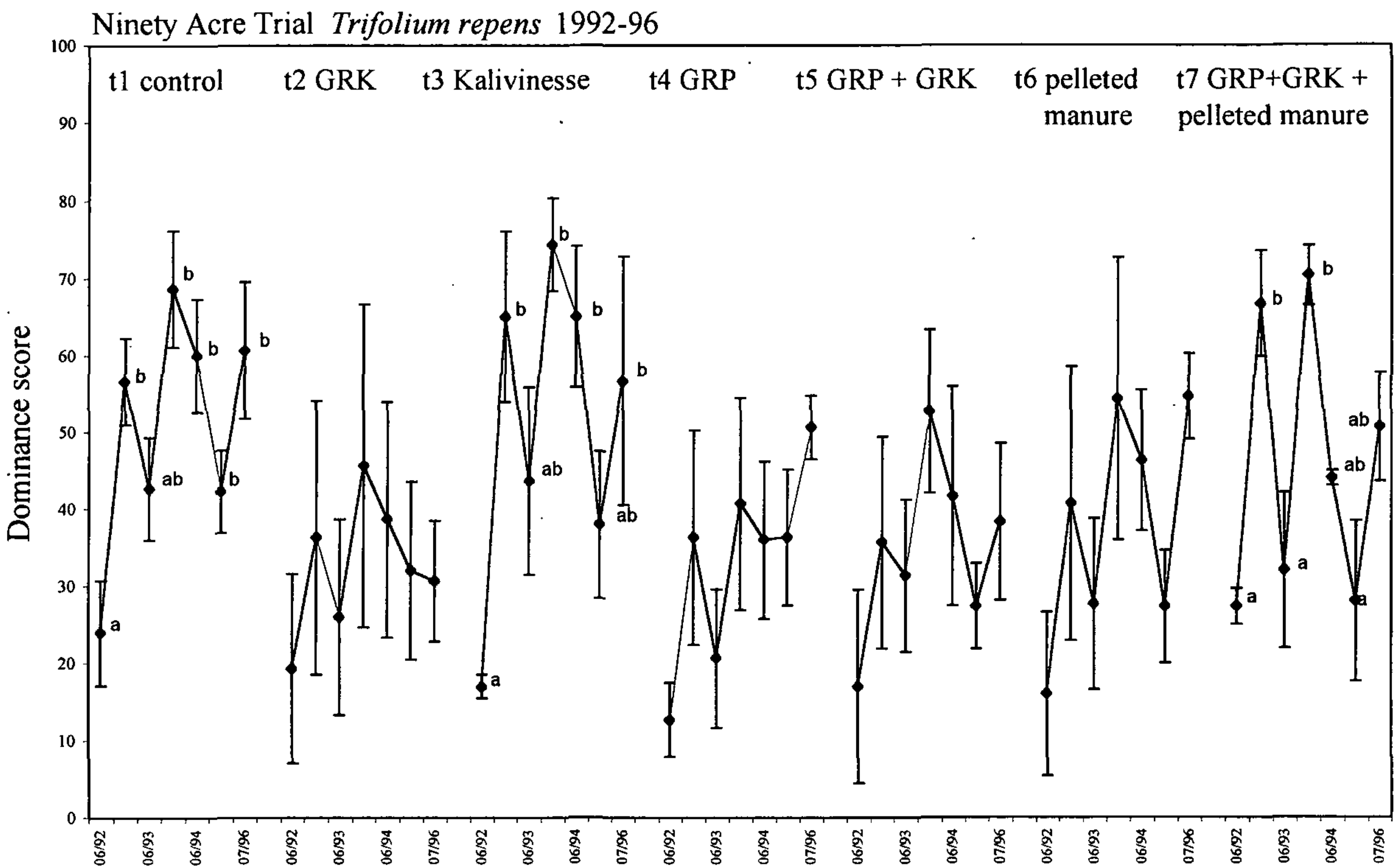

Ninety Acre Trial *Poa pratensis*
Dominance score
t1 control
t2 GRK
t3 Kalivinesse
t4 GRP
t5 GRP + GRK
t6 pelleted manure
t7 GRP+GRK + pelleted manure
0
10
20
30
40
50
60
70
80
90
100
06/92
09/92
06/93
09/93
06/94
08/95
07/96

Figure 13.



Ninety Acre Trial *Trifolium repens* 1992-96
Dominance score
t1 control
t2 GRK
t3 Kalivinesse
t4 GRP
t5 GRP + GRK
t6 pelleted manure
t7 GRP+GRK + pelleted manure
0
10
20
30
40
50
60
70
80
90
100
06/92
06/93
06/94
07/96

**Mineral soil NPK trial - West Hayfield**

Figure 14.

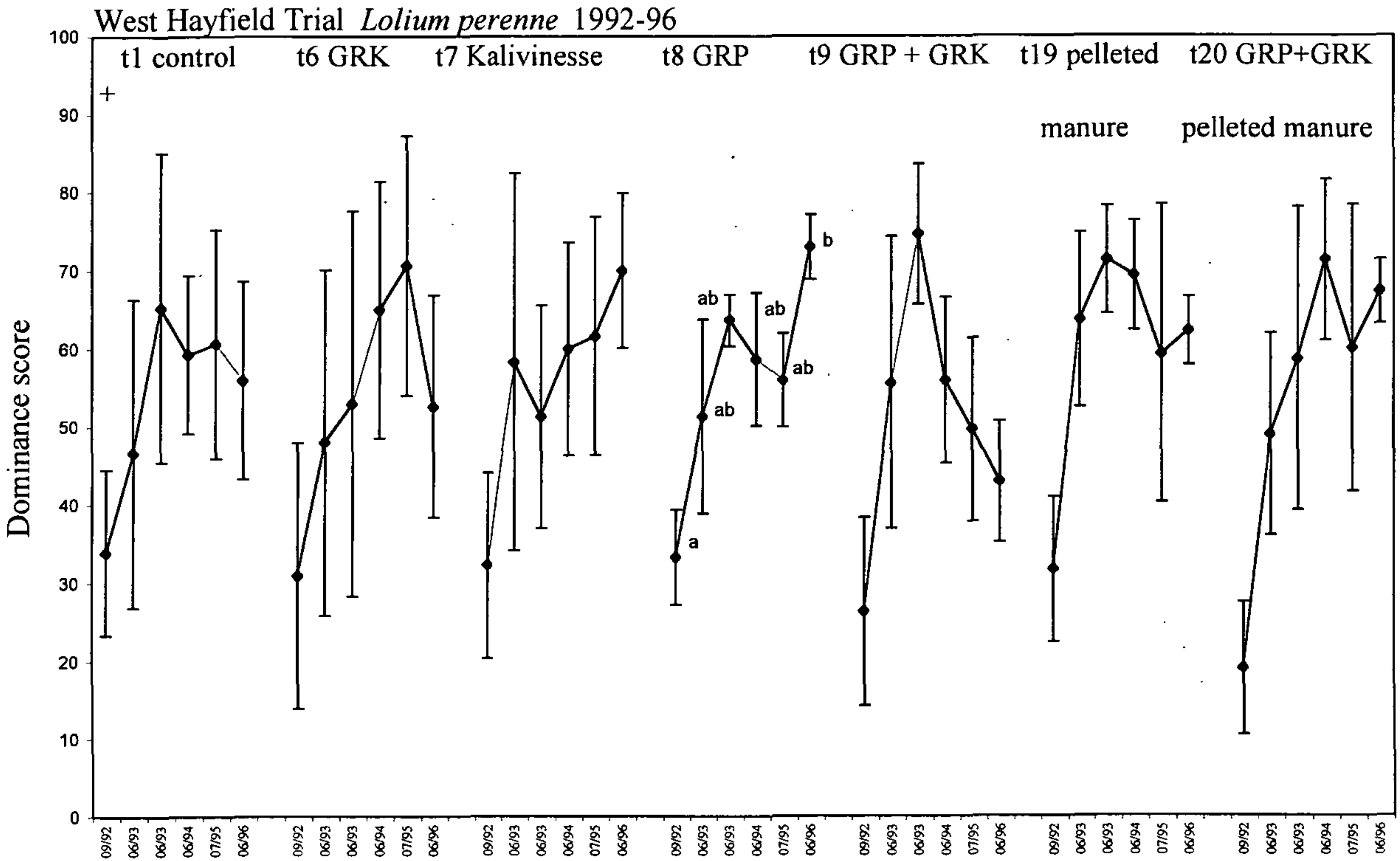


Figure 15.

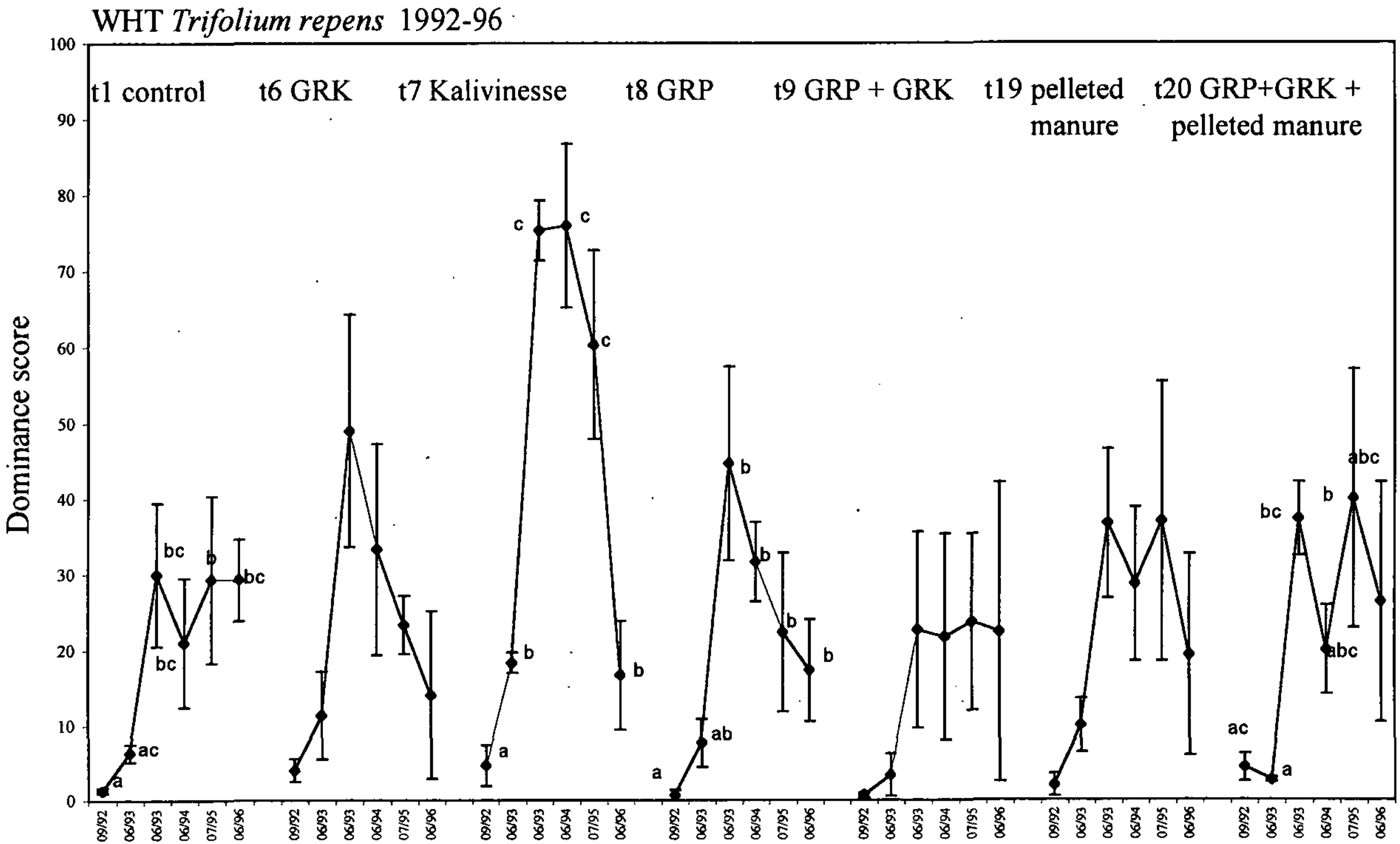

WHT Trifolium repens 1992-96
Dominance score
t1 control
t6 GRK
t7 Kalivinesse
t8 GRP
t9 GRP + GRK
t19 pelleted manure
t20 GRP+GRK + pelleted manure
09/92
06/93
06/93
06/94
07/95
06/96

Figure 16.

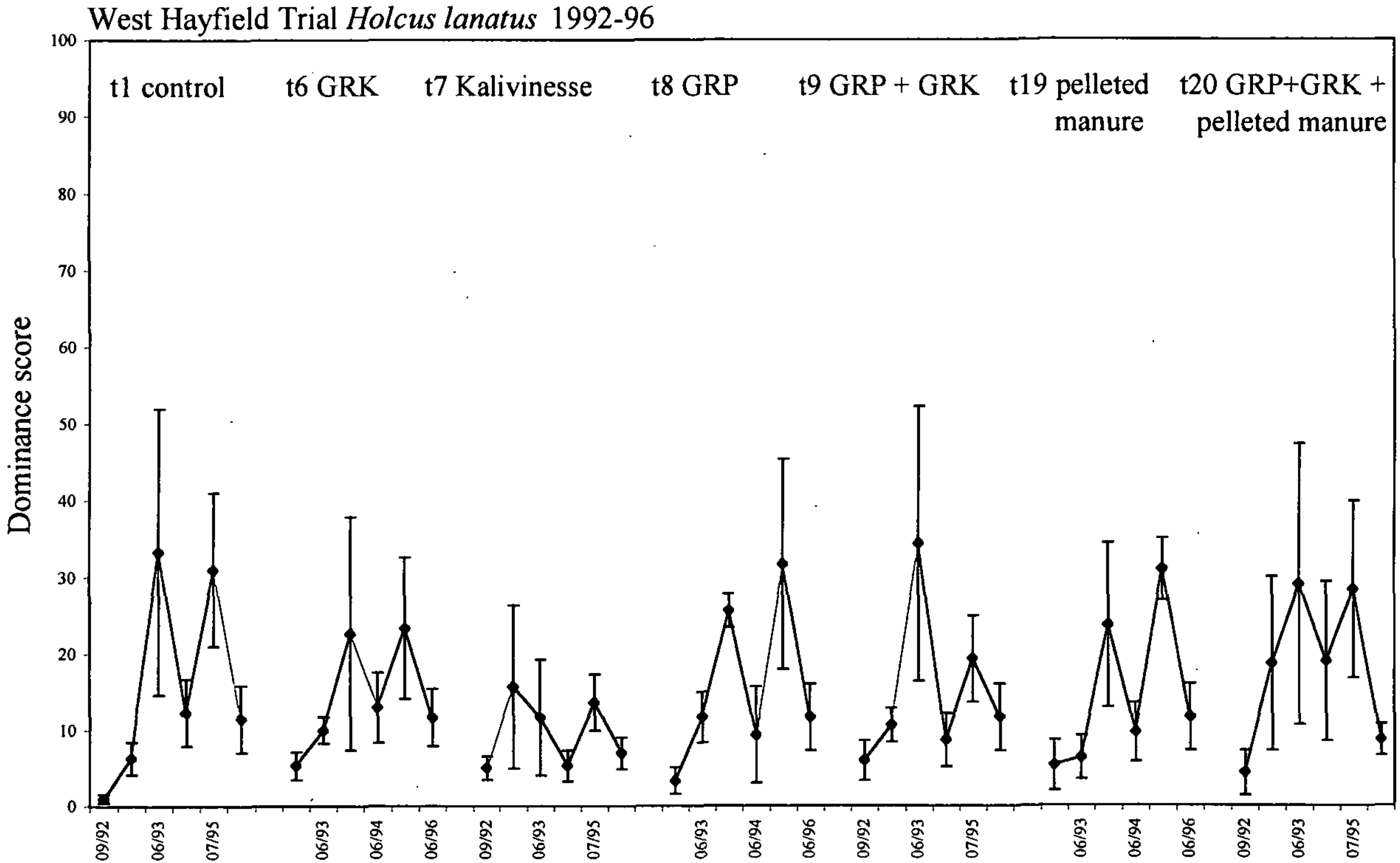

West Hayfield Trial *Holcus lanatus* 1992-96
Dominance score
0
10
20
30
40
50
60
70
80
90
100
t1 control
t6 GRK
t7 Kalivinesse
t8 GRP
t9 GRP + GRK
t19 pelleted manure
t20 GRP+GRK + pelleted manure
09/92
06/93
07/95
06/93
06/94
06/96
09/92
06/93
07/95
06/93
06/94
06/96
09/92
06/93
07/95
06/93
06/94
06/96
09/92
06/93
07/95

Figure 17.

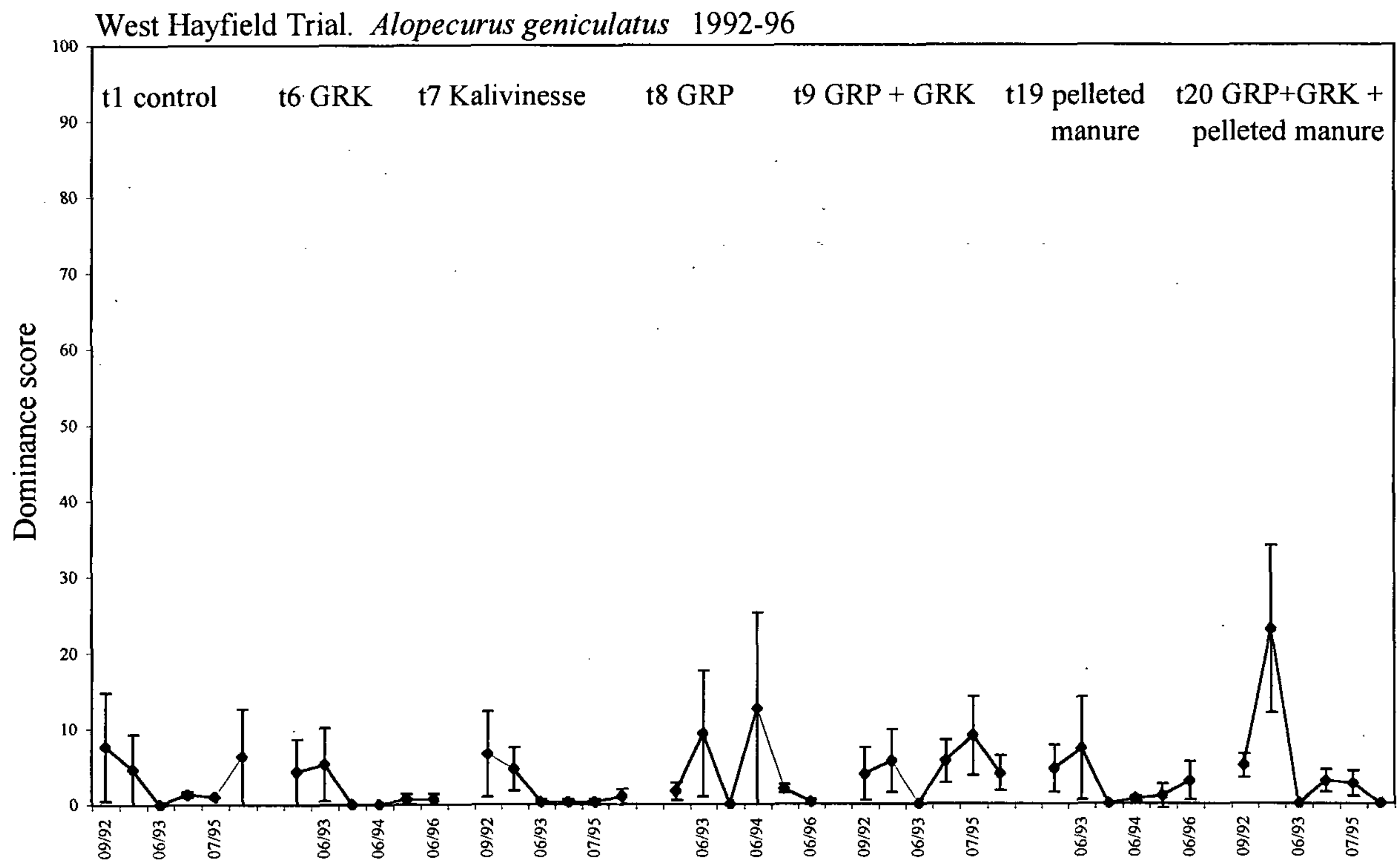

West Hayfield Trial. *Alopecurus geniculatus* 1992-96
Dominance score
0
10
20
30
40
50
60
70
80
90
100
t1 control
t6 GRK
t7 Kalivinesse
t8 GRP
t9 GRP + GRK
t19 pelleted manure
t20 GRP+GRK + pelleted manure
09/92
06/93
07/95
06/93
06/94
06/96
09/92
06/93
07/95
06/93
06/94
06/96
09/92
06/93
07/95
06/93
06/94
06/96
09/92
06/93
07/95

Figure 18.

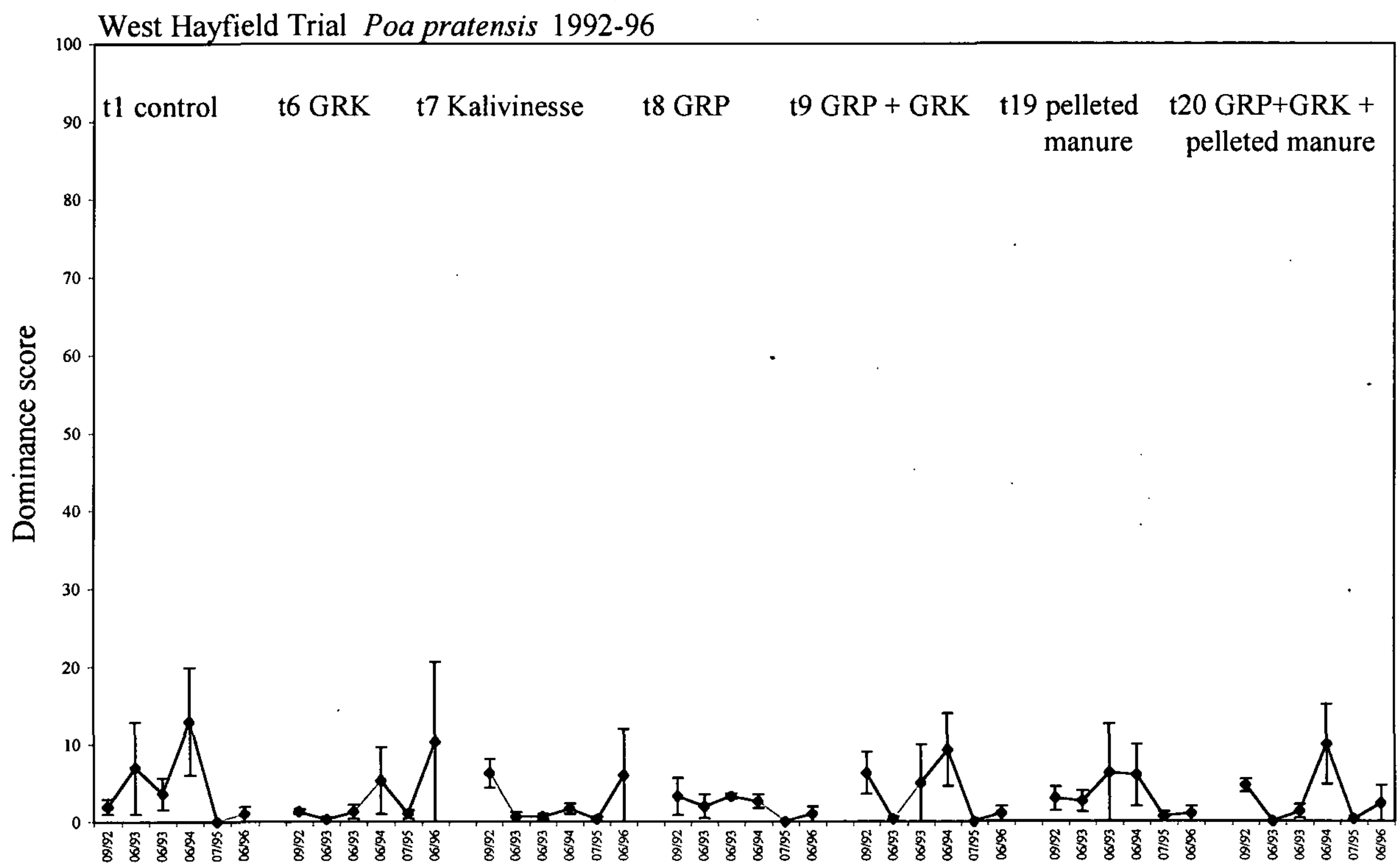
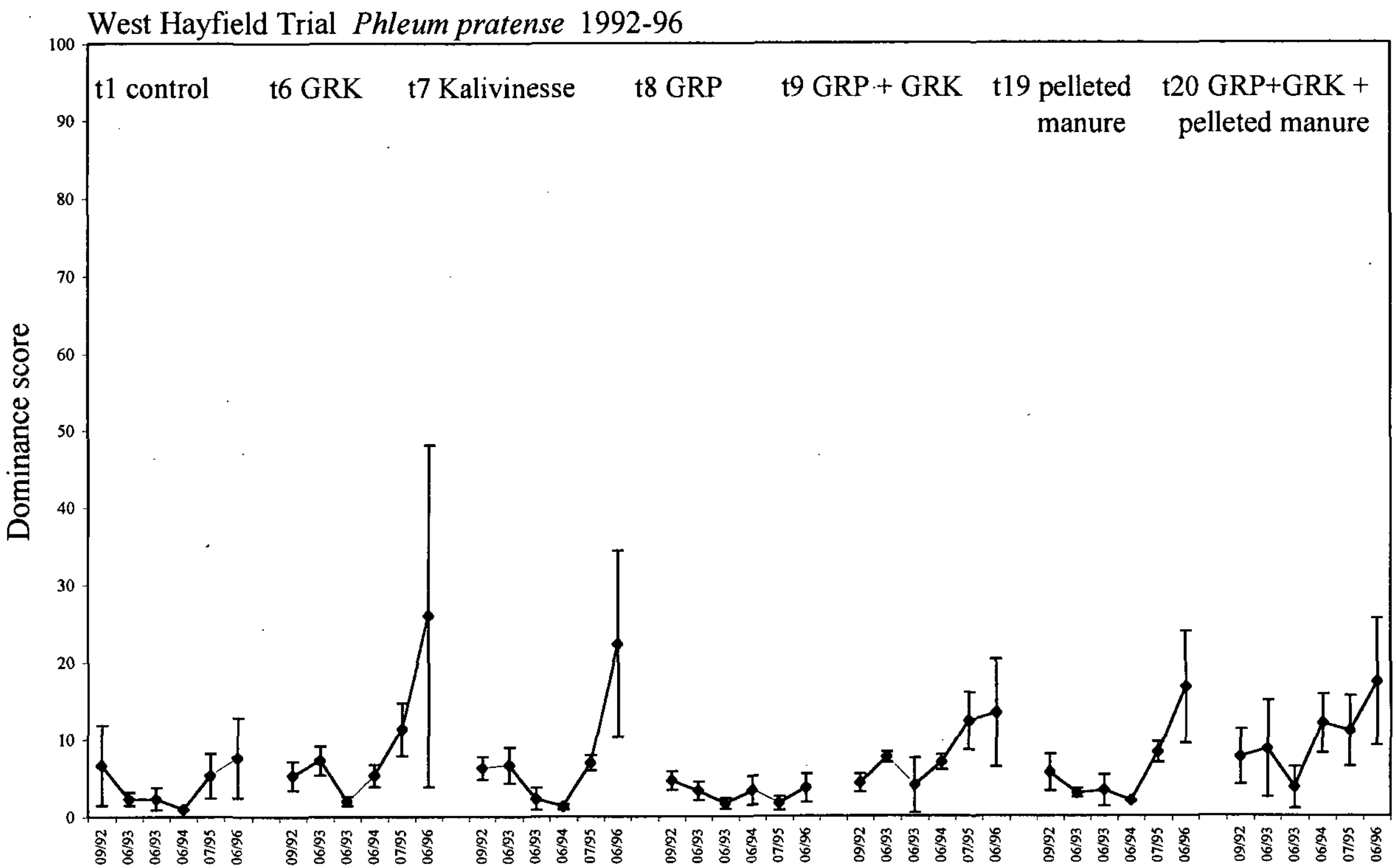
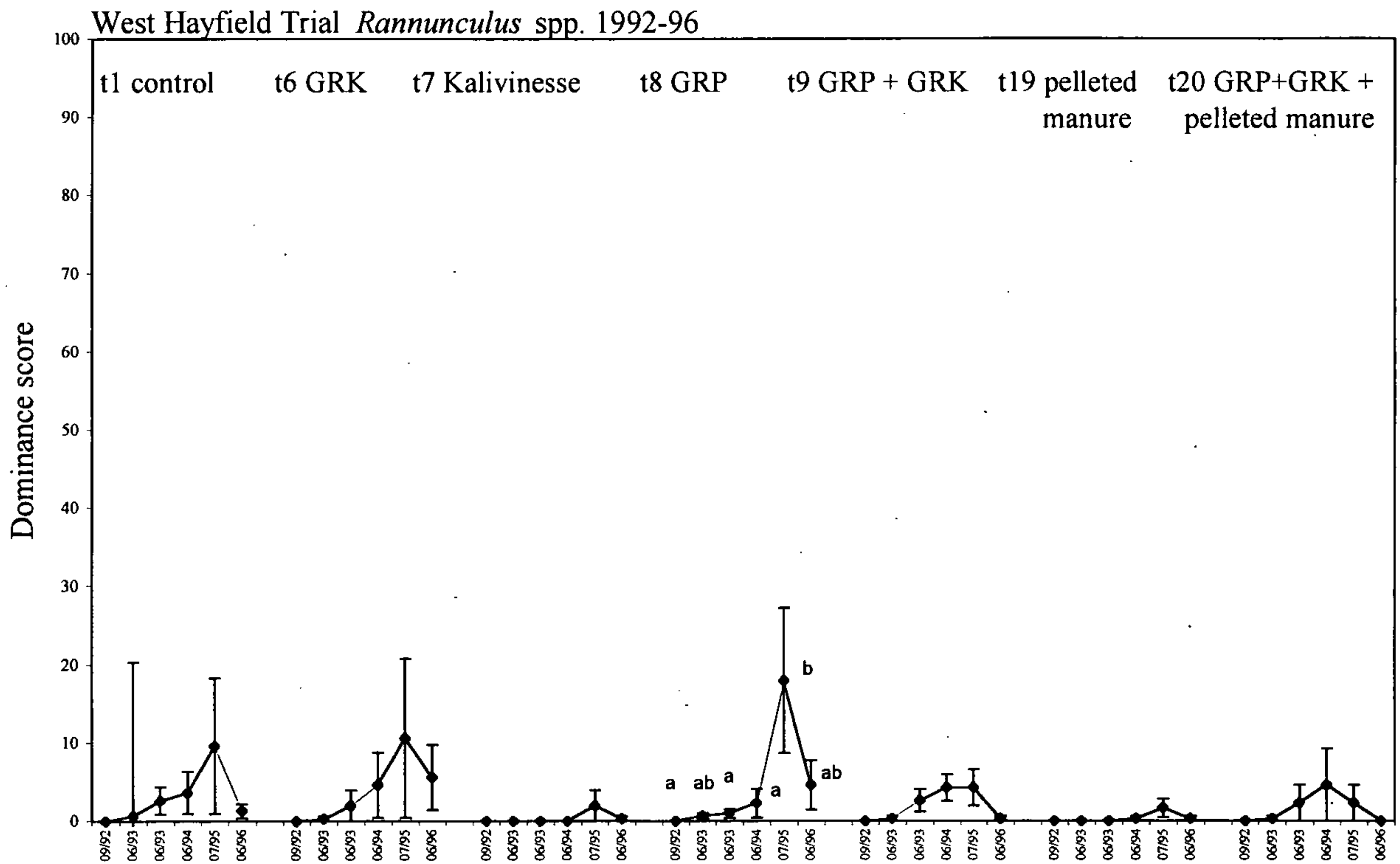

West Hayfield Trial *Poa pratensis* 1992-96
Dominance score
0
10
20
30
40
50
60
70
80
90
100
t1 control
t6 GRK
t7 Kalivinesse
t8 GRP
t9 GRP + GRK
t19 pelleted manure
t20 GRP+GRK + pelleted manure
09/92
06/93
06/93
06/94
07/95
06/96

Figure 19.



West Hayfield Trial *Phleum pratense* 1992-96
Dominance score
0
10
20
30
40
50
60
70
80
90
100
t1 control
t6 GRK
t7 Kalivinesse
t8 GRP
t9 GRP + GRK
t19 pelleted manure
t20 GRP+GRK + pelleted manure
09/92
06/93
06/93
06/94
07/95
06/96

Figure 20.


West Hayfield Trial *Rannunculus* spp. 1992-96
Dominance score
0
10
20
30
40
50
60
70
80
90
100
t1 control
t6 GRK
t7 Kalivinesse
t8 GRP
t9 GRP + GRK
t19 pelleted manure
t20 GRP+GRK + pelleted manure
09/92
06/93
06/93
06/94
07/95
06/96
a
ab
a
a
b
ab

**Mineral soil N trial - Bridge Haugh**

Figure 22.

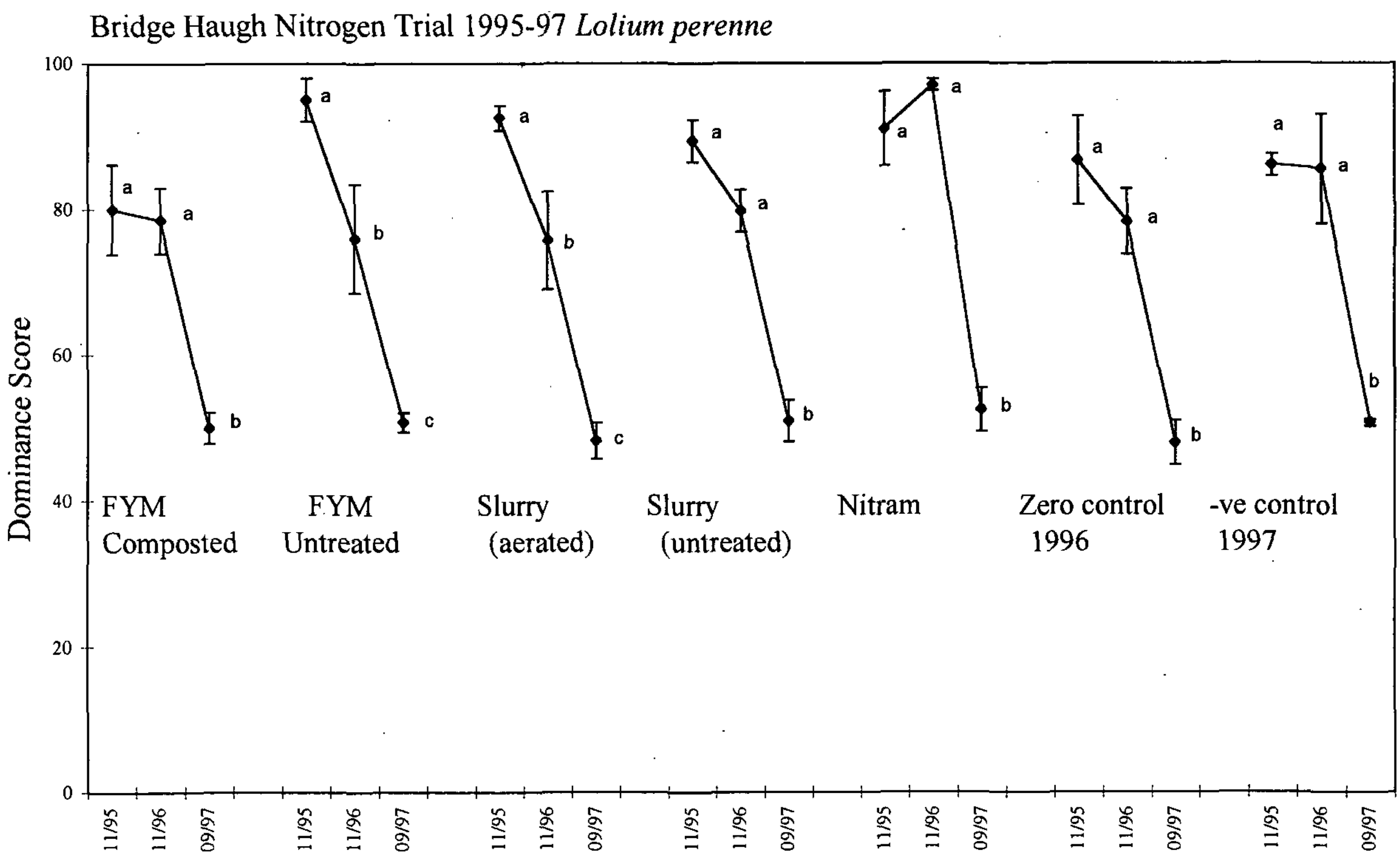
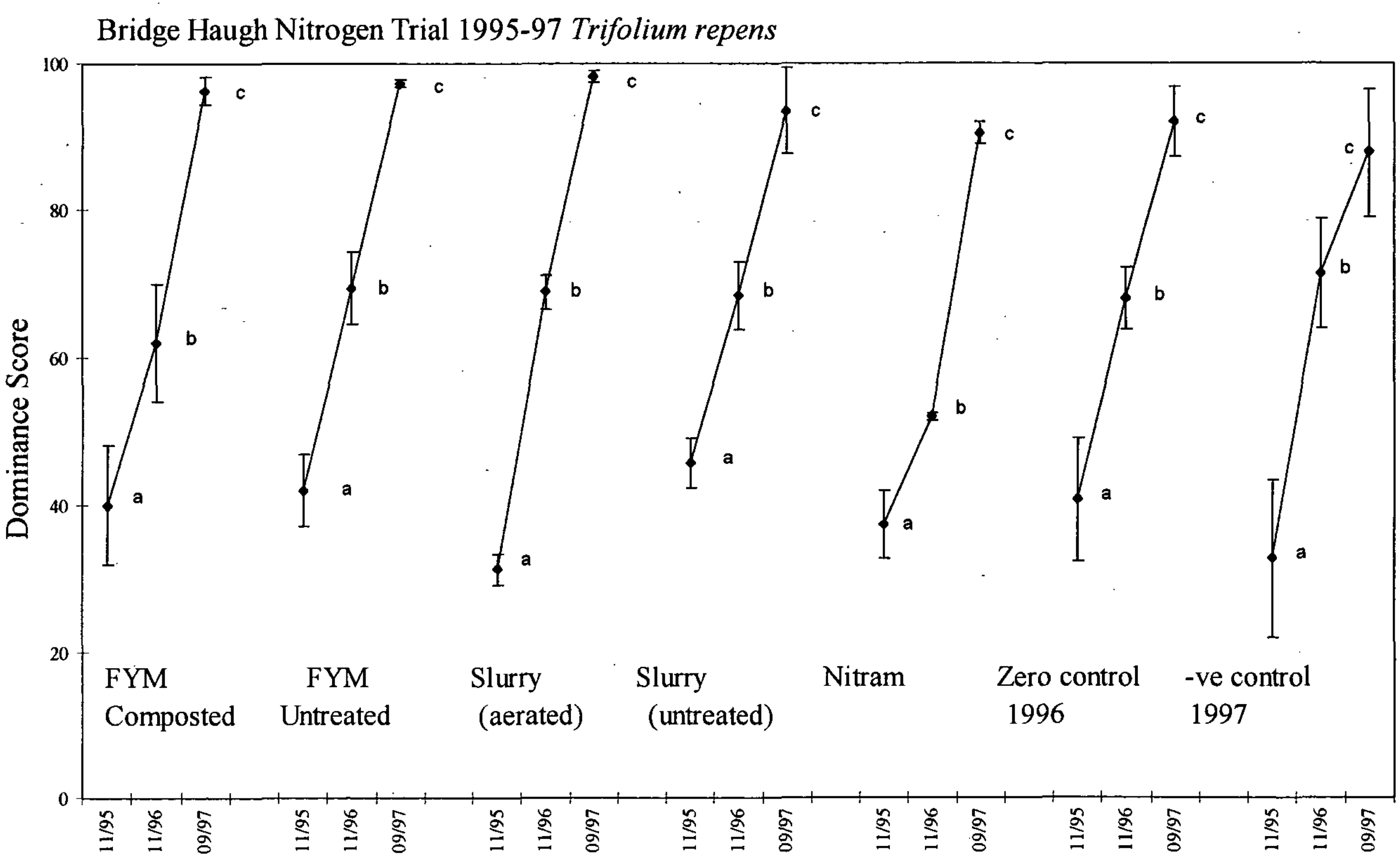
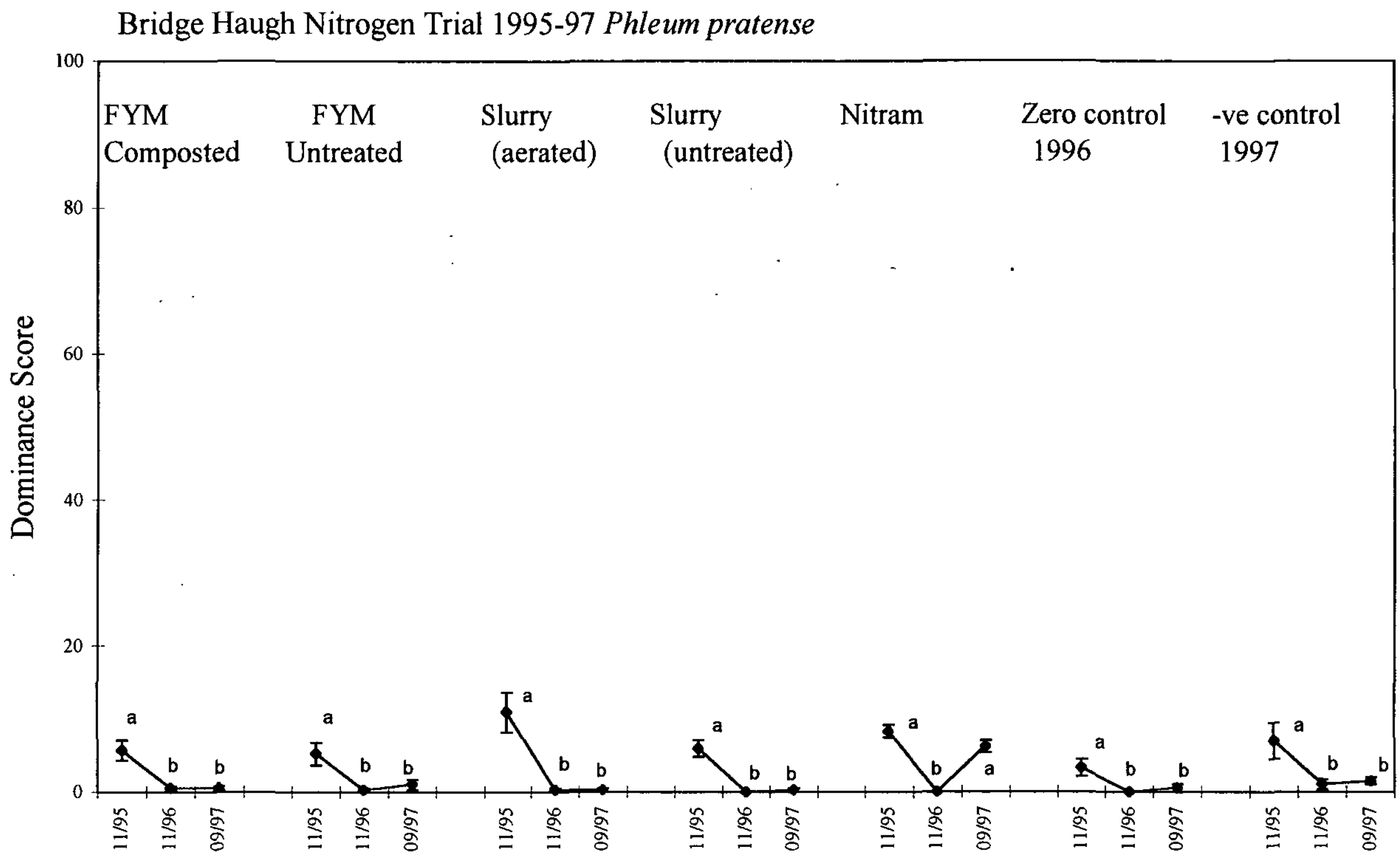


Figure 23.



Bridge Haugh Nitrogen Trial 1995-97 *Trifolium repens*
Dominance Score
0
20
40
60
80
100
FYM Composted
FYM Untreated
Slurry (aerated)
Slurry (untreated)
Nitram
Zero control 1996
-ve control 1997
11/95
11/96
09/97
a
b
c

Figure 24.



Bridge Haugh Nitrogen Trial 1995-97 *Phleum pratense*
Dominance Score
100
80
60
40
20
0
FYM Composted
FYM Untreated
Slurry (aerated)
Slurry (untreated)
Nitram
Zero control 1996
-ve control 1997
a
b
11/95
11/96
09/97

Figure 25.

Bridge Haugh Nitrogen Trial 1995-97 *Rannunculus repens*

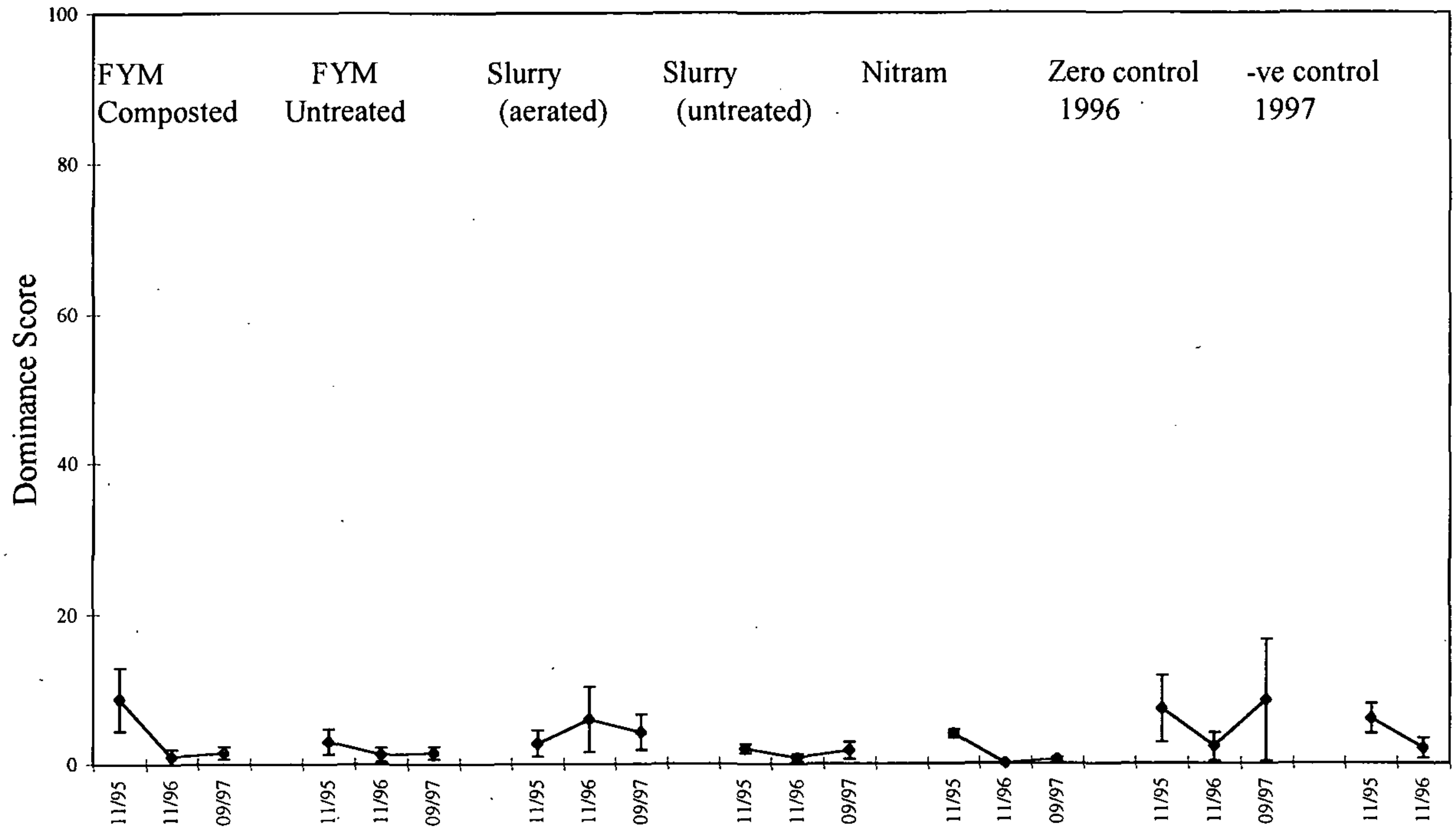


Figure 26.

Bridge Haugh Nitrogen Trial 1995-97 *Rumex obtusifolius*

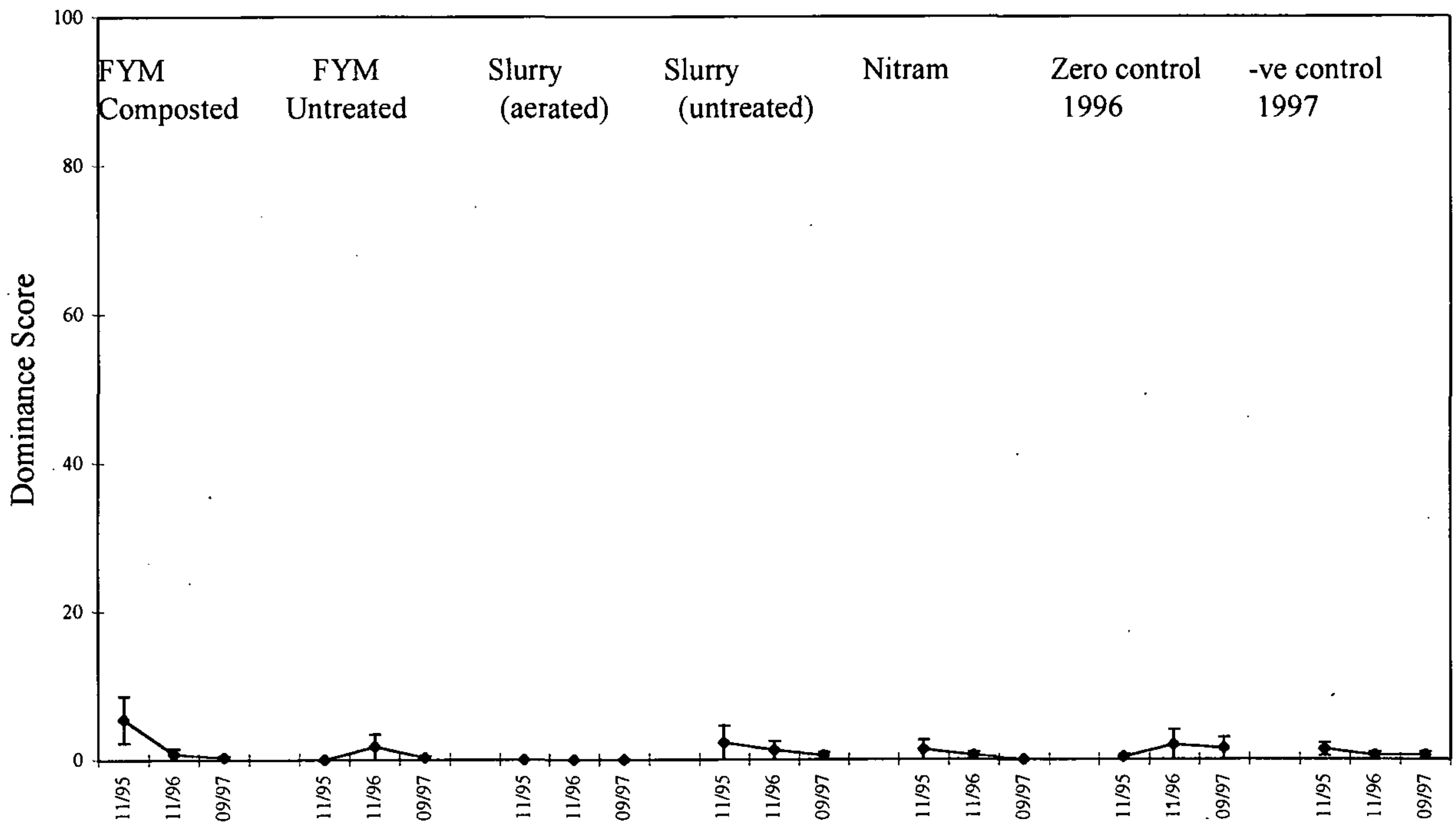


Figure 28. Procedure for classification of field samples

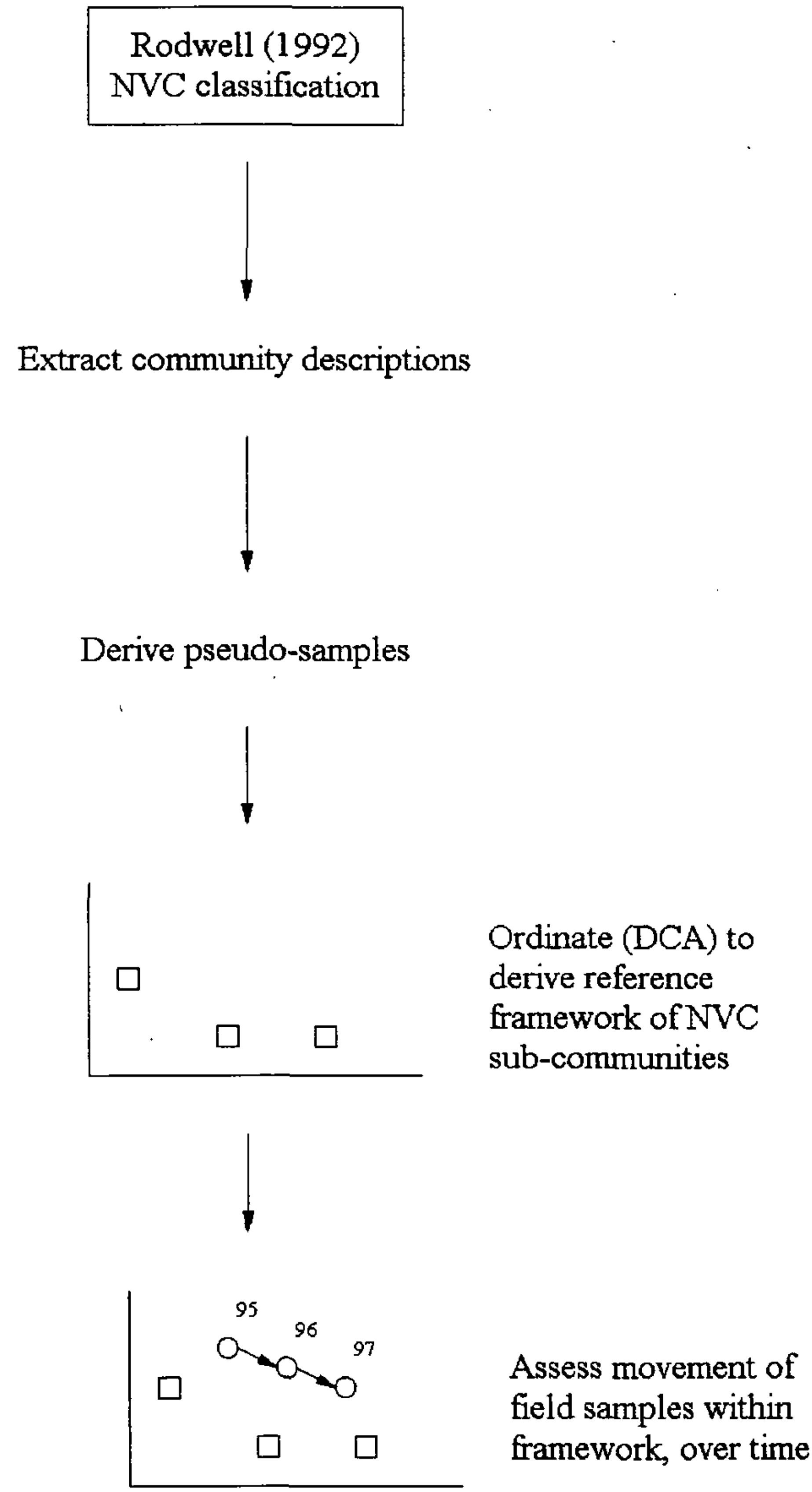


Figure 29. Distribution of community means. Axis 1 vs. Axis 2

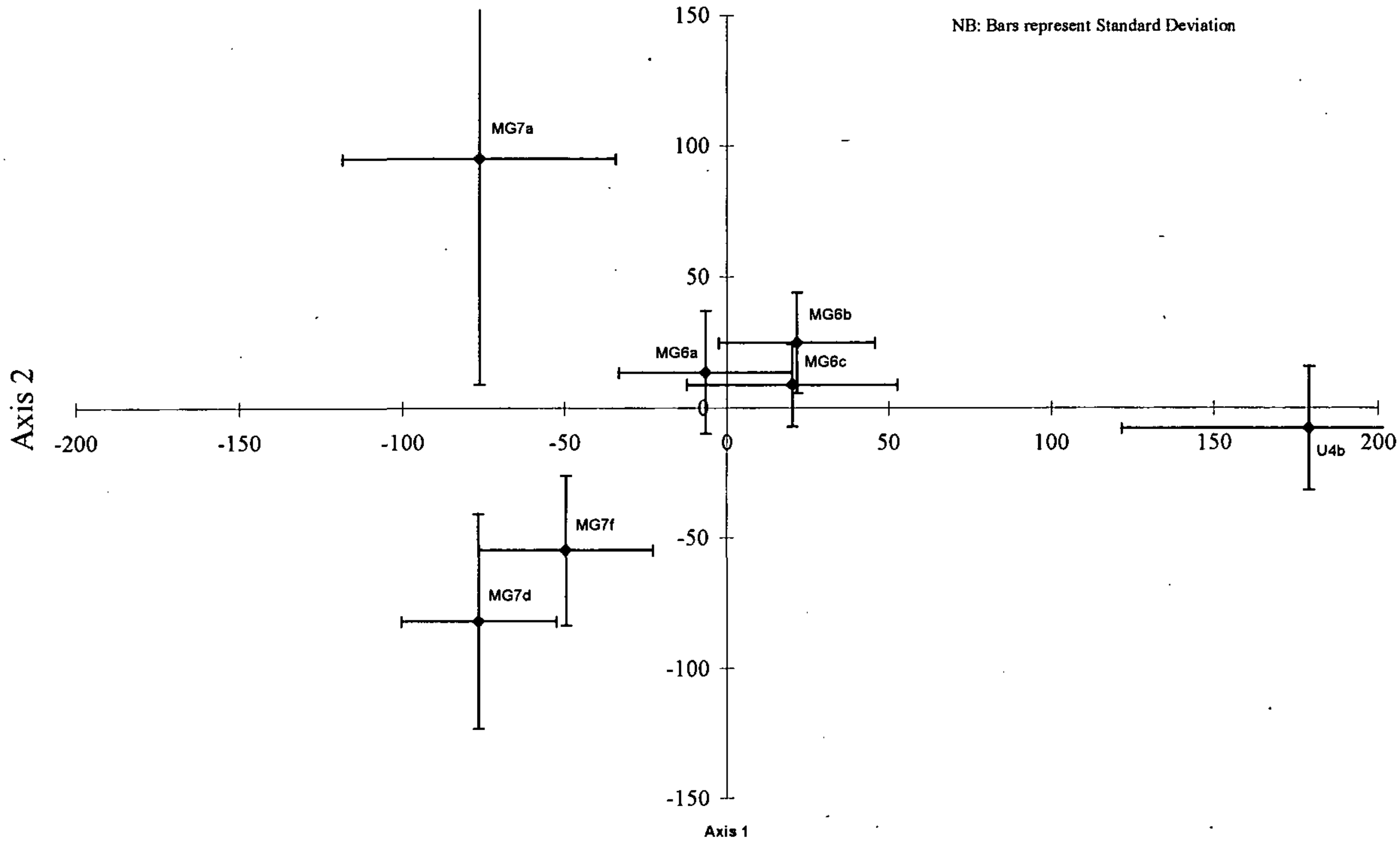


Figure 30. Distribution of improved hill sites in NVC ordination

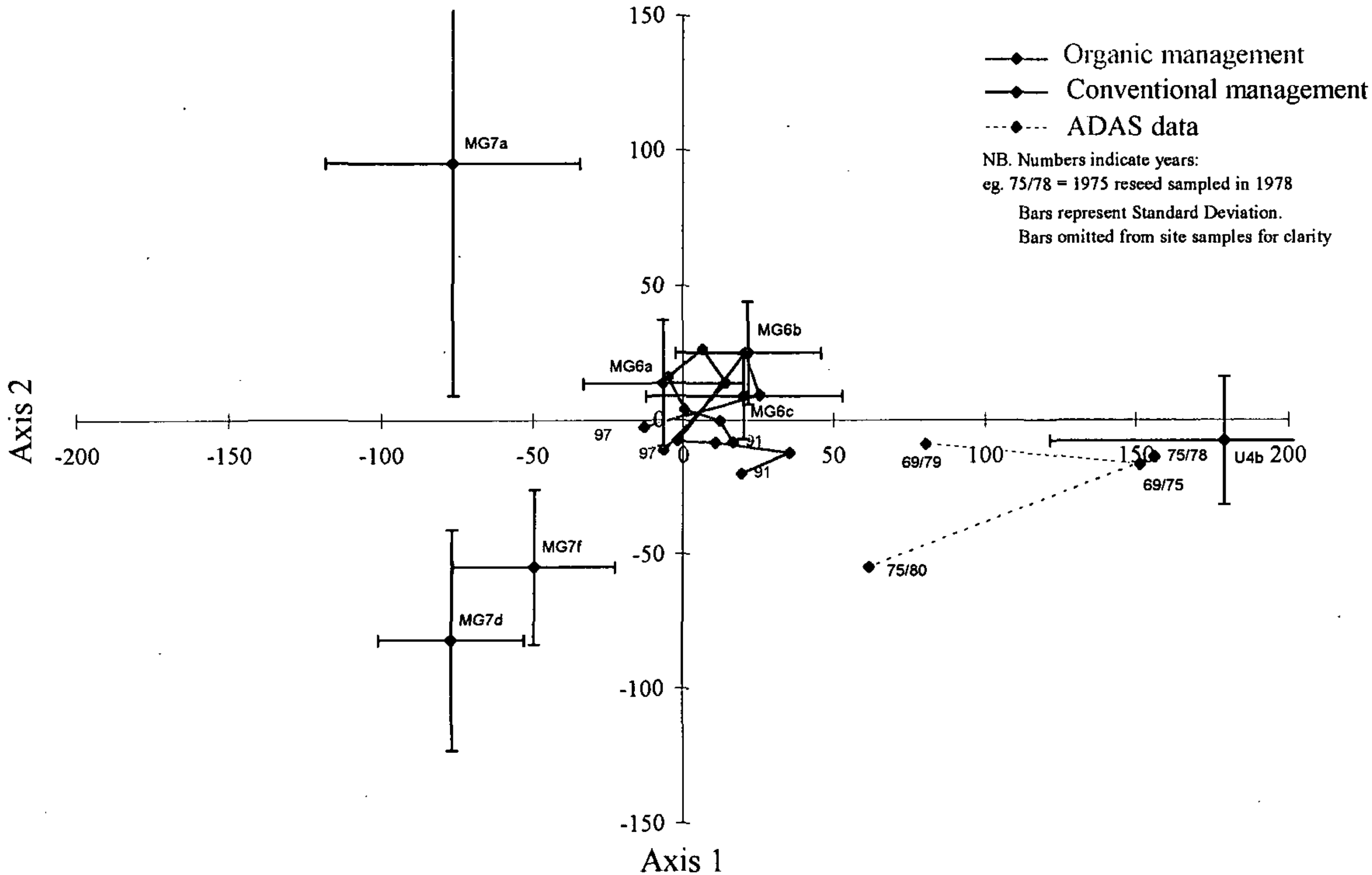


Figure 31. Distribution of in-bye sites in NVC ordination