Rehabilitation after sandmining at Eneabba, Western Australia.

A preliminary report on the results of the Allied Eneabba Ltd. South East Factorial Experiment prepared by E.A. Griffin and A.J.M. Hopkins using data collected by J. Elkington under the guidance of R. Black.

August 1982

INTRODUCTION

Allied Eneabba Ltd began mining mineral sands at a site south of Eneabba in early 1976. The mining operation was subject to an Agreement between the Company and the State which included provisions for environmental controls. Because much of the mining was to be on a Nature Reserve, the objective for post-mining rehabilitation was stipulated to be a return to a stable cover of native vegetation. Very little was known of methods of achieving this objective in the complex kwongan vegetation of the Eneabba so the Environmental Management Programme (EMP) included a proposal for assessing the roles of various factors (season of rehabilitation, storage of topsoil, use of fertilizers, use of cover crops, use of irrigation) in rehabilitation.

The following report outlines the experiment which was established at the Allied Eneabba Ltd minesite and the results from the first four years of monitoring. The experiment was designed by Ekomin in consultation with members of the Mineral Sands Rehabilitation Coordinating Committee and under contract to Allied Eneabba Ltd. Ekomin were also contracted to set up and monitor the experiment. Results were analysed by E.A. Griffin under contract to the Department of Fisheries and Wildlife using the Department of Agriculture computing facilities.

METHODS

A. Experimental Design and Treatment Application

The experiment was an Hierarchical Factorial Design for the convenience of treatment application (Fig.1) The treatments in descending order of hierarchy were:

1. Time of Placement of Topsoil (referred to hereafter as BLOCKS). The experiment was repeated at four times of the year: Block 1 - May 1977, Block 2 - July 1977, Block 3 - September 1977 and Block 4 - December 1977. Topsoil to a depth of about 15 cm, including intact vegetation, was removed by a scraper and dumped on the experimental site. A swamp-dozer spread the topsoil to approximately the same depth.

2. Cover crop of Cereal Rye (*Secale cereale*) (COVER CROP). This was applied at two levels: Cover 1 - no cereal rye, Cover 2 - cereal rye. The seed was hand broadcast at about the rate normally used in areas drill-seeded (*ca.* 14 kg/ha) and was left to germinate on the surface. The application was made soon after placement of the topsoil.

3. Storage of Topsoil (STORAGE). For each Block there were two levels of Storage: Storage 1 - stored, Storage 2 - fresh. The topsoil was stored in heaps

constructed by scrapers. Storage time varied, with the length of storage for each Block being, Block 1 - 12 months, Block 2 - 4 months, Block 3 - 5 months and Block 4 - 37 months.

4. Mulch of Native Vegetation (MULCH). Two levels of Mulch were used: Mulch 1 - no mulch and Mulch 2 - with Mulch. Mulch was removed from one source by a Grasslands 600 forage harvester (see Griffin & Hopkins 1981) as coarse unchipped material. The mulch was removed from an area where the vegetation type would probably have been Heath 2 and floristic type Group 3 of Hnatiuk and Hopkins (1982). It was hand spread soon after harvest in October 1979. The rate was about 3 kg/m^2 or 4 times 12 year old post fire standing crop. This rate is about 1.5 times that currently used (R. Black pers. comm. 1982). Note, the Mulch was applied at least 22 months after topsoil was placed.

5. Inorganic Fertilizer (FERTILIZER). Five levels of fertilizer were planned: Fertilizer 1 - no fertilizer (control) Fertilizer 2 - Osmocote 104 kg/ha, Fertilizer 3 - Osmocote 208 kg/ha, Fertilizer 4 - Osmocote 416 kg/ha, Fertilizer 5 - Nitrogen (this treatment had not been applied up to the period of this assessment and is therefore equal to Fertilizer 1). The level of macro-nutrients added are shown in Table 1.

The experiment comprised 160 (ie 4x2x2x2x5) 5m x 4m quadrats. There was no replication.

B. Observations

For all species in each quadrat, density was determined and percentage cover estimated. Insignificant cover was recorded as 0.1%. Four observations were made: Observation 1 - April/May 1979, Observation 2 - September/October 1979, Observation 3 - November 1980, Observation 4 - September 1981. As Observations 1 and 2 were made before the Mulch was applied, the quadrats assigned to the Mulch 2 treatment for these observations can be considered as replicates of Mulch 1.

C. Data Summary and Analysis

The data were summarised both by quadrats and by species.

1) Quadrats

"Natural" groupings of species (Proteaceae, Native, Alien and Total) were used as the basis for the quadrat summaries. For each quadrat, the variables "number of species", "density" and "sum of cover estimates" were determined for each of the "natural" groups.

As cereal rye was a treatment, it was not included in the summaries, but its density and cover were recorded separately.

Summary totals of the main effects and first order interactions of the treatments were generated for each Observation. (A preliminary analysis showed very little contribution from higher order interactions). These summaries highlighted inconsistencies in the Block x Storage response for most of the variables summarised. This was traced to external factors which had unevenly influenced the experiment. Block 3 x Storage 2 was partially waterlogged and Block 1 x Storage 1 had a high proportion of slime tailings mixed with the topsoil. Quadrats on these treatment combinations had very low numbers of species regenerating. For these reasons, Blocks 1 and 3 were excluded from the factorial analysis of Quadrats as they would contribute variation unrelated to the experiment.

For each species group variable the differences between the treatment level effects were tested using an Analysis of Variance Program (GENSTATV, Rothemsted Experimental Station). Main effects, first order interactions and the linear and quadratic responses to Fertilizer level were partitioned. Observation would normally be included as a factor in the statistical analysis, i.e. a split-plot analysis, but as all treatment (i.e. Mulch) had not been applied from the start, this approach was not possible.

As Observation 1 contained many zero values treatment differences were not analysed statistically. In Observations 3 and 4 a very high contribution (up to 2/3 in some quadrats) to density was made by a relatively insignificant Geophyte (*Drosera paleacea*). This variable, "Density of *Drosera paleacea*", and the variable "Density Natives minus Density of *Drosera paleacea*" were also analysed in Observations 3 and 4.

An attempt to analyse for the influence of elapsed time was made by analysing the differences between Observations 3 and 4,

A summary table was made of the Analyses of Variance tables. This showed that the probability at which the treatment affects partitioned were statistically significantly different.

After completing the statistical analysis and data summaries, the significance of Bradysporous species became evident. Ideally "Bradysporous" species and species with "Soil Storage of seed" should have been analysed as "Natives", "Proteaceae" and "Aliens" were. The total number and total density of Bradysporous species for each of the four combinations of Mulch x Storage were determined.

2) Species Richness and Individual Species' Responses

The above analysis provides the "average number of species per quadrat". This does not indicate the total number of species occurring in each treatment. For direct comparison with the quadrat data, the number of species in Blocks 2 and 4 in Observation 4 were determined for each level of the main treatments (Mulch x Fertilizer, Storage x Fertilizer, Fertilizer) and for all treatments combined.

Although Blocks 1 and 3 were excluded from the above summary and the statistical analysis, it was considered that useful species' response data would still be available from these blocks. In Blocks 2 and 4, the average number of species per quadrat was only about one quarter of the total number of species encountered. It was therefore considered that meaningful species richness data would come from the amalgamation of some quadrats from all Blocks. This was done by considering the Cover treatment levels (2 of) as replicates, and reducing the Fertilizer treatments to two levels: absent (2 of) and present (3 of). On this basis the quadrat frequency of each species, for Observation 4, in all combinations of

Blocks x Storage x Mulch x Fertilizer were determined. The number of species occurring in each of these treatment combinations were summarised into "natural" groups and major families. Chi^2 tests (Ho = species quadrat frequency of treatment levels are proportional to the number of quadrats in each level) were used to determine the species with statistically ($p<.05$) significant responses to the levels of the treatments Storage, Mulch, Fertilizer and Blocks (4vs2only). The statistical significance of differences due to the interaction of Storage x Fertilizer, Storage x Mulch, Storage x Blocks (4 + 2 only) and Mulch x Fertilizer were tested using a 2 x 2 contingency table, Chi^2 test with the significance level set at $p<.05$. The species favouring any level of the treatments were summarised for each "natural group" and major family combination.

The possibility of the species response to a treatment being a change in density or cover and not quadrat frequency was examined. Data from Blocks 2 and 4 only were used. The main effects of Mulch and Storage on each species was examined and species with significant differences in level totals (Chi^2 test, $p<.05$, 1 df) were noted. For each species a response curve to added fertilizer level was generated using separate totals of density and cover. These response curves were classified subjectively according to a range of response curve types arbitrarily defined in Figure 2.

The number of species in each response curve type were summarised for each "natural" group and major plant family.

The most abundant species (density and cover separately) in each fertilizer level was determined from the species summary.

The differences between species occurring in this regeneration experiment and a composite list for the undisturbed vegetation (Allied Eneabba 1979, unpublished) were noted.

Changes in species composition with Observations were noted only in terms of overall presence or absence.

RESULTS

The raw data and the tables of means of the variables for Treatment effects, and the Analyses of Variance Tables for the quadrat data in Blocks 2 and 4 are not presented here. A summary table of the significance levels of the Treatment effects for the variables from the most recent Observation (No. 4) are presented in Appendix 1. The results from this observation were generally the same as those from earlier observations. Figures 3 (a-i) shows the number, density and cover of Native and Proteaceae species for each Observation time, with the effects of Blocks, Mulch and

Storage presented separately, each related to Fertilizer level.

The most important Treatment influencing the presence of Native species, and Proteaceae when considered separately, was Blocks (i.e. Placement Time). Block 4 (December Placement) produced higher values of all Native and Proteaceae variables (number of species, sum of density and sum of cover) than Block 2 (July). Topsoil storage generally depressed the values of most Native variables (excluding Density of Drosera paleacea) compared to fresh topsoil. The addition of Mulch increased their values compared to without Mulch. Inorganic fertilizer addition generally depressed the number and density of Native species but few of these differences were statistically significant. In Observations 2 and 3, but not 4, the addition of Fertilizer gave a statistically significantly higher cover of Native species. The addition of the cereal rye Cover Crop had little influence on Native species. For example at Observation 2, cereal rye was present in both of the Cover Crop treatments - only slightly more abundant where cereal rye had been deliberately added (Appendix 2).

The major interaction term with statistically significant influences on the variables for Native species was Blocks x Storage. Most variables in Block 4 Stored topsoil were generally lower than the main effects of Blocks and Storage would predict. Block 4 Stored topsoil was 37 months old/

when placed, while Block 2 Stored topsoil was only 4 months old. This data suggests that an increased Storage time in Block 4 magnified the depression which Storage caused to the number, density and cover of Native species returning. The Storage x Mulch interactions were minor though fairly consistent. While Fresh topsoil generally had more Native and Proteaceae species present, and at higher densities than Stored topsoil, the addition of Mulch diminished these differences substantially.

Overall, there were more Bradysporous species where Mulch had been added compared to not. The total density of these species was very clearly dependant on Mulch addition (Table 2). In the absence of applied Mulch, the Storage of topsoil appeared to reduce the number and density of these species.

The variables for Alien species were very significantly increased by the addition of inorganic Fertilizer. Also Block 2 had a higher density and cover of Aliens than Block 4, which is the converse of the situation for Native species. Storage, Cover Crop and Mulch each had no statistically significant influences on Alien Species in Observation 4. The addition of Mulch depressed the density of alien Species in Observation 3.

Alien species were more influenced by the interactions between Treatments than were the Native species. The most consistent ones were Storage x Fertilizer and Blocks x Fertilizer. Most of the interaction do not lend themselves to easy interpretation. Interactions involving Cover Crop had some influence on Alien Species but little or no influence on the Native species for Observation 4.

An analysis of the total number of species occurring in the treatments Mulch x Fertilizer, Storage x Fertilizer, Fertilizer, and Overall (Figure 4) suggests that more Native species and fewer Proteaceae respectively occured in fertilized quadrats than in unfertilized quadrats. However, the average per quadrat suggested a reduction for both Native and Proteaceae species with added Fertilizer. The apparent difference between these data for the Native species could be reconciled by suggesting that Fertilizer causes a reduction in species richness rather than a loss of species per se. The data for number of species per quadrat should therefore be treated with caution as, for Proteaceae it is only 11% of the total Proteaceae in the 80 quadrats in Blocks 2 plus 4, 26% for Native and 52% for Alien species respectively. On a species-area basis the $20m^2$ quadrats would not be an adequate sized sample for Native and Proteaceae species for these rehabilitation experiments. It is not possible to estimate an adequate area from these data. Less than the $100m^2$ reported as a minimum area required for undisturbed kwongan in the Eneabba region (Hnatiuk & Hopkins 1982) is unlikely to be adequate for rehabilitation studies aimed at analysing species richness.

In an attempt to overcome sample area deficiencies, the number of treatments considered were effectively reduced by not considering the cover crop treatments and reducing the levels of Fertilizer to two (present/absent). A summary of the number of species (Native, Proteaceae and Alien) in each possible combination of Blocks (all 4) x Topsoil (Fresh, Stored) x Mulch (+/-) x Fertilizer (+/-) is shown in Appendix 3. Note that as there were more quadrats with Fertilizer present than absent (ratio 1.4:1 respectively), more species could have been expected in the Fertilizer level "present" than "absent". Fresh Topsoil with the addition of Mulch and Fertilizer had more species than their respective alternate levels and this combination appeared to have had more species than any other combination of treatments. In terms of the number of Native species, the depression due to Storage of Topsoil was greater than the increase due to addition of Fertilizer which in turn was greater than the increase due to addition of Mulch. For Proteaceae, the number of species resulting from Mulch addition was greater than from Fertilizer addition which was greater than the Topsoil Storage reductions. The addition of Mulch was clearly necessary to achieve the maximum number of Bradysporous species. In the absence of Mulch, Storage of topsoil reduced the number of these species. Fertilizer addition seemed to have had little influence of their return.

Appendix 4 lists the species which showed a statistically significant Chi^2 value for the differences between the quadrat frequencies of the respective levels of the Block, Mulch and Fertilizer treatments and their first order interactions. Table 3 is a summary of the species which had statistically significantly different quadrat frequency between the respective treatment levels. Using major species groups, these were tabulated under the treatment with the higher quadrat frequency. 35 species were more abundant in Fresh than in Stored topsoil and much fewer (9) more abundant in Stored than in Fresh. These species were from most groups and families, but there appeared to be a high proportion of species with Soil Storage of seed which had high quadrat frequencies on Fresh topsoil, but a low proportion of Bradysporous species. Most of the 25 species which were more abundant in Mulched areas were Bradysporous species from the Families Proteaceae and Myrtaceae but also notable were the species which have Soil Storage of seed but were enhanced by the addition of Mulch. No species were statistically more abundant in non-Fertilized quadrats. A high proportion of the species enhanced by the addition of fertilizer were Alien species. Four times as many species had a higher quadrat frequency in Block 4 than in Block 2. Notable of the species with higher frequencies in Block 4 were those with Soil Storage of seed, and in particular, the Liliaceae, Epacridaceae and Restionaceae. The most significant interaction was Blocks x Storage. For the eight species with a statistically significant Block x

Storage interaction, topsoil storage apparently enhanced the quadrat frequency for Block 2 but depressed or had no effect for Block 4. The Storage x Mulch interaction revealed some species for which the addition of Mulch, enhanced the quadrat frequency on Stored topsoil but not on fresh topsoil. Only one species (a Native) showed any significant interactions between Fertilizer and other treatments.

Comparisons between the levels of Mulch and Storage based on density were very similar for most species. Notable differences were that many of the abundant species had significantly different densities but the quadrat frequencies were not different. This applied to both Native and Alien species. Amongst these species, more were more abundant in Fresh vs Stored topsoil and Mulched vs non-Mulched areas respectively.

These data suggest that few species, especially natives, are affected by the addition of inorganic Fertilizer. However, this evaluation is only from the simplified quadrat frequency for presence or absence of Fertilizer. A more detailed evaluation involved using the sum of the density and the sum of the cover values as measures of reponse to Fertilizer level. The data from Blocks 2 and 4 only were used. The separate classifications using density and cover produced very similar evaluations. Much of this is attributable to the very low cover and density values of many species, in which cases density and cover were linearly proportional. Thus, density was considered the more reliable value for use here. Appendix 5 shows examples of species which were classified into each response type. Table 4 is a summary of the number of species in each response curve type broken down by major species groups and plant families. There were a large number of species which were classified as not responding to fertilizer, but the abundance of most of these was too low to classify. A larger data base would reduce the number in this group.

The response curves can be simplified into two groups of two:

1a positive or no response, compared to the control, to low levels of Fertilizer added (Types 1-5 inc. Fig. 2) (For density 25 Native species).

1b negative response to same (Types 6 and 7) (22 Native species).

2a positive or no response to high levels of fertilizer (Types 1-4 inc) (20 Native species)

2b negative response to same (Types 5-7 inc). (27 Native species)

Twenty-two native species had a depression in density at low levels of Fertilizer and an additional 5 species were depressed at high levels. These species, which could probably be classified as sensitive to Fertilizer, belong to a range of groups and families. Cyperaceae and Haemodoraceae seem to have a higher proportion of these species than average and Epacridaceae a lower proportion. Notable in this sensitive group of species are some which are relatively abundant in the revegetated areas - *Caustis dioica*. *Conostylis aculeata*, *C.* "*dielsii*", *Eremaea beaufortioides*. *Eucalyptus tetragona*, *Gastrolobium obovatum*, *Johnsonia pubescens*. *Lepidosperma tenue*, *Melaleuca acerosa*, *Mesomelaena stygia* and *Stylidium crossocephalium*.

The density of 25 Native species was increased at low levels of fertilizer. For nine of these, higher levels of fertilizer gave densities close to those of the control and for a further 5 it gave densities below the control. Some of the species which were increased by the addition of Fertilizer were *Ptilotus* sp., *Hibbertia hypericoides*, *Baeckea grandiflora*. *Darwinia neildiana* and *D. speciosa*. The number of Bradysporous, Proteaceae and Leguminosae species which responded positively to Fertilizer addition, seemed to be lower than their proportion of the total number of species in Blocks 2 and 4 would predict.

A total of 177 Native species were recorded in the 4 Blocks

(Appendix 3). (This is a slight under-estimate of the total number encountered because there were several unidentified monocots recorded as one species. Similarly several species were combined under each of *Thysanotus* spp. and *Banksia sphaerocarpa*). This total compares with 239 species (Lamont 1976) and 429 species (Hnatiuk and Hopkins 1982) recorded in undisturbed kwongan of this area. From the numbers of species present, it would appear that some species are not returning. However, without a detailed knowledge of the species which were present in areas from which the Topsoil and Mulch were taken, it is not possible to determine confidently whether any species have returned.

In terms of proportion of the total number of species present, the 4 most important families were in the same ranking, and of very similar proportions of the total as in the undistrubed kwongan (Hnatiuk and Hopkins 1982): Proteaceae 14.6% in regenerating area, 16.6% in undisturbed; Myrtaceae 12.4%, 12.8%; Leguminosae 8.5%, 7.9%; and Liliaceae 7.3% and 7.2%. Proteaceae might be considered to be slightly under-represented.

A composite list of species present (Allied Eneabba 1980, unpublished) was used in an attempt to establish what species may not be returning and to give an indication of changes in relative importance. Appendix 6 is a list of 39 species present in this undisturbed kwongan but not recorded in Observation 4 of this experiment. A few species were recorded at earlier Observations but not since. Others have been recorded in other regenerating areas and some were actively planted in rehabilitation programmes. The most significant and notable absences were those which were very important in the undisturbed kwongan (e.g. *Banksia candolleana*, *Calothamnus sanguineus*, *Eucalyptus macrocarpa*, *E. johnsoniana* and *Xanthorrhoea reflexa*.

Most of the species of the undisturbed kwongan which have high cover values, were of low abundance in the regenerating areas compared to other species (Appendix 7). Of the 22 species with highest cover values in the undisturbed kwongan only *Conospermum triplinervium*, *Hibbertia hypericoides*, *H. crassifolia*, *Jacksonia floribunda* and *Mesomelaena stygia* appeared to be relatively important in the rehabilitation areas.

For each level of Fertilizer, Appendix 8 shows an assessment of the most important species, both in terms of density and cover. In terms of sum of density, the level of Fertilizer changed the ranking of these species little. Only *Podotheca gnaphalioides* gained substantially in rank. The actual density of most of these important species was decreased by added fertilizer (e.g. *Drosera paleacea*), or was not affected (e.g. *Astroloma prostratum*). Only *Ptilotus* sp. increased in density. Of these species only *Hibbertia crassifolia*, *Melaleuca acerosa* and *Mesomelaena* stygia were present at high cover values in the undisturbed kwongan (Appendix 7).

The ranking of species in terms of sum of cover for the levels of Fertilizer addition was less consistent than that based on density. Of the 6 species highest in cover, Astroloma prostratum, Conospermum triplinervium and Adenanthos cygnorum generally maintained their ranking but Mesomelaena stygia and Conostylis aculeata ranked lower and Thysanotus spp. higher. Scholtzia capitata, Baeckea grandiflora and Ptilotus sp., which were relatively unimportant in the control quadrats, were very much increased in cover with the addition of Fertilizer. Two species (Adenanthos cygnorum and Conospermum triplinervium) which were conspicuous in this ranking contribute 60-70% to the total cover of Proteaceae in the quadrats.

Generally, most species recorded in one Observation were also recorded in the following one. Some species, however, were recorded in early Observations but have not been recorded in Observation 4 (e.g. Appendix 6). Those so noted were Acacia latipes, Banksia candolleana, Calothamnus sanguineus, Calytrix simplex, Comesperma acerosum, Diplolaena ferruginea, Gompholobium tomentosum, Grevillea thrysoideus, Tetratheca confertifolia and T. efoliolata. Other species have demonstrated obvious mortality (e.g. Conothamnus trinervis, Dryandra tridentata, Lambertia multiflora and Verticordia grandis). The data collected in this study does not permit a reasonable assessment of the levels of germination and mortality, mainly because of the long time intervals between Observations and the absence of tracing of specific individuals.

The month at which the Observations were made had a noticeable influence on the species recorded, particularly for a few of the Geophytes and Therophytes. Much of the differences noted between Observations 3 and 4 (e.g. Figure 3) were probably due to the Observations being made in November and September respectively. The Geophytes (e.g. *Drosera drummondii* and *Burchardia umbellata*) were absent or of lower density in November than September while the Therophytes (e.g. weeds) had a lower density and higher cover respectively. Differences between years in the level and effectiveness of seasonal rainfall may also be an influencing factor.

DISCUSSION

Generally, for Native species, Blocks, Topsoil Storage and Mulch were the most important treatments. The levels Block 4, Fresh Topsoil and Added Mulch in this order gave higher quadrat averages for the number, density and cover of native species as well as species preferences and total number occurring. Mulch had the greatest influence on Bradysporous species of all treatments. The Fertilizer and Cover Crop treatments had little general effect on Native species. Alien species were strongly enhanced by Fertilizer addition but other treatments were relatively unimportant for these species.

Block 4 quadrats had a higher number, total density and total cover of Native and Proteaceae species than Block 2 but a lower total density and total cover of Alien species. About 20% of the species had a significant "preference" in terms of quadrat frequency for Block 4 compared to Block 2 but only about 5% had the reverse "preference". Some of this difference may be due to the different origins of the topsoil but this is unlikely as the Fresh and Stored topsoil in each Block were not necessarily from the same source. The differences between Blocks are general for both Fresh or Stored topsoil but the depression due to Storage is greater in Block 4 than Block 2. This accords with the length of Storage time being important as the Stored topsoil in Block 4 was 37 month old on placement while that in Block 2 only 4 months.

All species do not respond the same way to Storage or Blocks. Although there is a general depression in the regeneration variables measured for stored topsoil, the presence of some species actually appear to be enhanced by storage. For some species, the influence of storage was inconsistent for the two Blocks analysed statistically. The respective differences in topsoil source could contribute to this inconsistency. However, most of the species with a significant Blocks x Storage interaction are relatively commonly occurring and therefore source differences may be expected to be unimportant. Half these species show a depression of quadrat frequency in Block 2 due to storage but no such depression in Block 4. This suggests the environment of Block 4 may be better than Block 2. As there are differences in the season of harvest (Block 4 Fresh - December, Stored - November and Block 2 July and March respectively) harvest time (or initial propagule supply) cannot be ruled out as important in this case. Eight species showed an enhancement in quadrat frequency due to storage in Block 2 but a depression in Block 4. This is interpreted as meaning a short period of storage may enhance some species' regeneration but a longer one can depress it.

It may be argued that the differences in performances between Blocks 2 and 4 are due to differences in placement time. A winter (July) placement (Block 2) may not allow enought time for release of seed, germination and establishment before the dry summer onset. A December placement could have a full winter and spring for establishment before the next dry summer.

The data accumulated in this trial do not allow the discrimination between the effects of Placement time or the possibility that the environmental conditions of Block 4 are better than Block 2. More detailed observations on germination and mortality during the first year would be necessary. Not withstanding this, the following general observations suggest the environment to be more important.

In both Fresh and Stored topsoils of Block 4 a quantity of gravel with size, colour and shape characteristics inconsistent with surface gravel of the area was present. This gravel was not present in Block 2. As there were difficulties in placing some of the topsoils due to a wet tailings surface, the presence of the gravel is consistent with an attempt to overcome these problems. This gravel may have significantly altered soil structure/drainage conditions which could be important, as serious waterlogging was the reason for our omitting the data from Block 1. Therefore, it is possible that winter wet conditions are as important an influence as summer dry could be expected to be. R. Black (pers. comm. 1982) suggests that wet winters retard the rehabilitation growth.

While Blocks (Topsoil Placement) had a strong influence on performance, we believe that this was probably not due to intrinsic propagule supply differences. Conversely, the main effects due to Topsoil Storage and Mulch most likely were due to differences in propagule supply at the time of application of the treatments. Most of the species which prefer either Fresh or Stored topsoil are species which normally have their propagule supply in the soil. Few Bradysporous species showed these clear preferences, though this may partly be due to the confounding affect of Mulch addition. Where no Mulch was applied some Bradysporous species showed a significant reduction due to Storage.

Most of the species with significant differences in quadrat frequency between Mulch treatments are Bradysporous. In fact almost all Bradysporous species are enhanced by added Mulch and this enhancement was statistically significant for 2/3 of them. Mulch is the major source of Bradysporous seeds, but not the exclusive source as the topsoil has above ground vegetation incorporated. Quadrats with Mulch added potentially had about three times more Bradysporous seeds present than those without Mulch. Although the differences may be due to this, 12 of these Bradysporous species show significantly higher quadrat frequency than could be accounted for by the 3 : 1 ratio for Mulch : No Mulch. This suggests that Bradysporous seeds are better applied in Mulch than incorporated in topsoil. This may be explained recognising that topsoil incorporation results in a significant proportions of the seed being placed at depths up to 15 cm from which successful seedling germination and establishment is not likely. Compare Horticultural practice of covering the seed with no more than its own thickness (W.A. Wildlflower Society, 1979).

Notable however is the enhancement provided by added Mulch to species with a Soil Storage of seed. For these species it is probable that the Mulch improves the environment for establishment. Some of these species only show an improvement for Stored topsoil in which case the Mulch may be providing nutrients which may have been lost in storage.

The Cereal Rye Cover Crop as applied in this experiment made very little difference to the growth of either Native or Alien species. Its only statistically significant influence was its separate interaction with Fertilizer and Blocks on the number of Alien species and with Mulch on the Density of Alien species. The lack of statistically significant results should not be taken to represent the performance on the larger scale because:

1. Hand broadcasting of cereal rye does not produce as consistent or reliable an establishment of cereal rye as does the drilling method used on the Field scale,

2. Cereal Rye being a winter crop is not suited to growing in summer, even in the presence of irrigation, in which case an uneven effect of the Cover Crop can be expected due to the time of sowing, and

3. The significant volunteering of the cereal rye (and any cohort weed species) into areas not treated with cereal rye suggests that the Cover Crop treatments were physically too close and the real differences between the Cover Crop levels were much less than might be expected from the original applications.

In general terms, a Cover Crop is added to stablize the soil surface and create a favourable environment for the establishment of "desirable species". A Cover Crop can however lead to a depression of the "desirable species" due to competition (R. Black 1982 pers. comm.). The reverse responses of Aliens and Natives to fertilizer, for example, may have been a direct result of competition between these species types.

Fertilizer addition had more influence on the Alien species than other treatments. The variables which were analysed showed highly significant positive and generally linear responses to the level of Fertilizer added. Alien species as a whole actually responded little to the main effects of other treatments (e.g. Mulch and Storage) probably as species responses were opposing. Where they did respond (e.g. Blocks and Storage for density of Aliens and Blocks for Cover of Aliens), the treatment levels with the highest value of variables were the reverse of those for Native species. This may indicate that competition occurred between Native and Alien species. No interpretation can be suggested for significant interaction terms (particularly the consistent Blocks x Fertilizer). As the growth of cereal rye is dependent on fertility levels and its full potential would only be achieved at high levels of added fertilizer, it is surprising that there was little interaction between the Cover Crop and Fertilizer treatments. The slow release nature of the fertilizer may have meant that only low levels of nutrients were available at the critical time for the cereal rye growth, but the broadcasting of the Cover Crop may have been the responsible factor.

The quadrat averages (species number, density and cover) are barely affected by fertilizer, but there were trends especially in the number of Proteaceae (Fig.3) which suggest that high fertilizer levels decreased the number and density but increased the cover of Native species. This could correspond to the data of Specht (   ) which showed an increase in size of mature plants but an increased mortality of seedlings in response to fertilizing.

The total number of species in the fertilized quadrats was greater than the non-fertilized quadrats. This is probably mainly due to the differences in the relative number of quadrats (3 : 1 respectively), but a slight enhancement due to added fertilizer seems real (Fig.4, Table 2). While seeming to conflict with the average quadrat data, what it really suggests is that Fertilizer, at the levels used, seemed not to eliminate any species but it reduced the density of some which, because of the small quadrat size, is reflected in relatively low quadrat species numbers. A few species are actually advantaged by the addition of Fertilizer as detailed evaluation of each species' density and cover response curves to fertilizer level confirm. Only half the species could be evaluated with any confidence but a substantial number were adversely affected by even low levels of fertilizer. It is difficult to make generalisations about the effect of Fertilizer level on the plant families as the data base is rather limited. Proteaceae have been reported to not favour high levels of phosphate fertilizer (   ) but to be less affected when more balanced NPK fertilizer is added (   ). Half of the Proteaceae for which enough density data is available for trends to be seen, are depressed by even low levels of fertilizer.

Although 50-70% of the species of the region are recorded in the regeneration many of the more important (cover-abundance) species in the undisturbed vegetation are either of low abundance or are absent in the regenerating area. As these species generally have large individuals, their importance in the regenerating areas may change as they grow. Many of the large species are Bradysporous and often have very little seed available. If the above ground vegetation is not used as Mulch, this scarce seed resource will be lost and the rehabilitated areas will contain low amounts of these important species.

TABLE 1 D·9¼ ⊗r ?

Table 1. Macro-nutrients added to Treatments

Fertilizer level	Nutrients added (Kg/ha)			
	P	N	K	S
1	0	0	0	0
2	5	19	8.6	3.5
3	10	37	17.3	7.1
4	20	74	34.5	14.1
5	0	0	0	0

Table 2. Total Number and Density of Bradysporous Species in Mulch x Storage treatments, Observation 4.

	Total Number		
	No Mulch	Mulch	Total
Stored	5	23	23
Fresh	12	21	23
Total	15	25	25

	Total Density		
	No Mulch	Mulch	Total
Stored	5	687	692
Fresh	23	584	607
Total	28	1271	1299

Table 3. GROUP AND MAJOR FAMILY SUMMARY OF SPECIES' RESPONSE TO TOPSOIL STORAGE, MULCH AND FERTILIZER (ALL BLOCKS) AND BLOCKS (4 & 2 ONLY): Number of Species with significant difference in quadrat frequency between levels of treatments (Chi^2 test, 1 df). (Species summed under level giving highest quadrat frequency).

GROUP	SPECIES TOTAL	TOPSOIL STORAGE (S) Fresh	Stored	MULCH (M) 0	+	FERTILIZER (F) 0	+	BLOCKS (B) 2	4	SxM (1)	MxF (2)	BxS (3)	(4)	BxM (5)
All Species	191	35	9	2	25	0	9	8	36	7	1	8	8	1
Weeds	14	2	0	0	0	0	4	2	1	0	0	0	0	1
Natives	177	33	9	2	25	0	5	6	35	7	1	8	8	0
Bradysporous Natives	27	1	0	0	18	0	2	1	0	2	0	0	0	0
Natives with Soil Seed Store	150	32	9	2	7	0	3	5	35	5	1	8	8	0
Proteaceae	26	2	0	0	10	0	2	2	2	0	0	0	0	0
Myrtaceae	22	4	0	0	8	0	0	0	1	3	0	0	1	0
Leguminosae	15	1	0	0	2	0	0	1	3	0	1	1	1	0
Liliaceae (inc. Xanthorrhoeaceae)	13	4	1	0	1	0	0	1	8	0	0	1	0	0
Epacridaceae	12	3	4	0	0	0	0	0	6	0	0	0	2	0
Cyperaceae	11	4	0	0	0	0	0	2	3	1	0	0	2	0
Haemodoraceae	7	1	1	0	0	0	0	0	1	0	0	2	0	0
Stylidiaceae	6	2	0	0	0	0	0	0	2	0	0	1	0	0
Goodeniaceae	5	2	1	1	0	0	0	0	0	1	0	0	1	0
Restionaceae	5	2	0	0	0	0	0	0	4	0	0	0	0	0
Other Native Families	55	8	2	1	4	0	3	0	6	2	0	3	1	0

Interactions:

(1) Greater positive response to mulch for stored topsoil compared to fresh topsoil
(2) greater positive response to fertilizer for non mulched compared to mulched areas
(3) Block 2 fresh topsoil and/or B4 stored much lower than B4 fresh or B2 stored respectively
(4) B4 stored approximately equal to B4 fresh but B2 stored much lower than B2 fresh
(5) Mulch addition depressed value for Block 4 not for Block 2.

Table 4. Summaries of Response Curve Types by Major Families and "Natural Groupings" (All Blocks)

		Response Curve Type Nos. 1	2	3	4	5	6	7	Group Total
All species	D*	119	11	5	14	5	21	2	177
	C*	129	12	7	12	3	9	5	
Weeds	D	4	2	3	5				14
	C	6	2	4	2				
Natives	D	115	9	2	9	5	21	2	163
	C	123	10	3	10	3	9	5	
Bradysporous	D	15	2			3	4	1	25
Natives	C	18	1			1	3	2	
Natives with	D	100	7	2	9	2	17	1	138
Soil Seed Store	C	105	9	3	10	2	6	3	
Proteaceae	D	19	1			1	4		25
	C	18	2		1	1	2	1	
Myrtaceae	D	11		2	1	2	2	1	19
	C	12	1	2	1		2	1	
Leguminosae	D	11					2	1	14
	C	12					1	1	
Liliaceae (inc.	D	10	1				2		13
Xanthorrhoeaceae)	C	11	1		1				
Cyperaceae	D	6					5		11
	C	9					2		
Epacridaceae	D	7			4				11
	C	8			3				
Haemodoraceae	D	1	1				4		6
	C	2	1		1		1	1	
Stylidiaceae	D	4	1				1		6
	C	5	1						
Goodeniaceae	D	4					1		5
	C	4				1			
Restionaceae	D	5							5
	C	5							
Other Native	D	37	5		4	2			48
Families	C	37	4	1	3	1	1	1	

D* = From Density data
C* = From Cover data

APPENDIX 1 SUMMARY OF VARIANCE ANALYSES: Probability levels where the differences between treatment levels are statistically significant: *** = p<0.001, ** = p<0.01, * = p<0.05. Treatment levels with highest values are indicated by the number before(0 = <1% difference). For Fertilizer, 1 = +ve response, 2 = -ve; linear component, 1 = +ve response, 2 = -ve.
Letters before Interaction terms are explained below table.

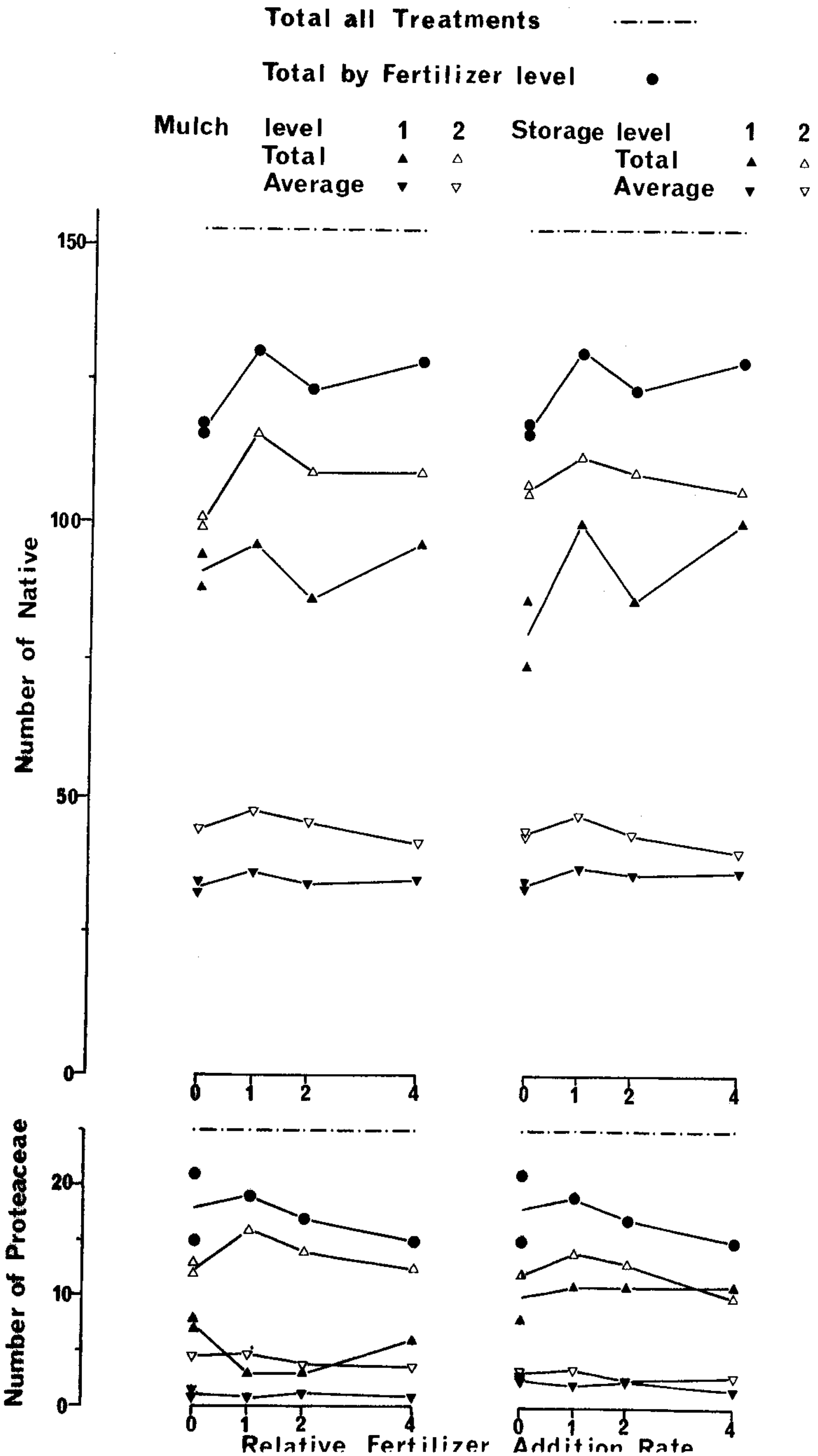
	NUMBER OF SPECIES				DENSITY						COVER			
	TNO	NOP	NON	NOA	TDEN	DENP	DENN	DEND	DENX	DENA	TCOV	COVP	COVN	COVA
BLOCKS (B)	4***	4***	4***	2	2	4***	4***	4*	4***	2**	4	4**	4***	2*
STORAGE (S)	2***	2***	2***	0	2	2	1	1***	2***	2	2***	2***	2***	2
B x S	a*	a*	a*		b***	a***	a*	a**		b**		a***	a***	
COVER CROP (C)	1	1	1	0	2	0	2	2	2	2	2	1	1	2
B x C				c**										
MULCH (M)	2***	2***	2***	1	1	2***	2	2	2***	1	2	2	2*	1
B x M														
FERTILIZER (F)	1	2	1	1**	1***	2	1	1	0	1***	1***	1	1	1***
LINEAR	2	2*	2	1*	1***	2	2	2	2	1***	1***	0	1	1***
QUADRATIC	*			**			*						*	
DEVIATIONS					*									
B x F				**	***					**			*	**
DEV. LIN.					***					***	*		*	***
DEV. QUAD.		*												
DEVIATIONS				**										
S x C														
S x M			d*			d*			d*					
S x F														
DEV. LIN.											*			*
DEV. QUAD.							*							
DEVIATIONS														
C x M					e*					e*				
C X F				*										
DEV. LIN.				*										
DEV. QUAD.														
DEVIATIONS							*							
M x F														
DEV. LIN.				*										
DEV. QUAD.					*									
DEVIATIONS														
RESIDUAL SS%	14	15	13	42	14	24	39	48	24	15	41	43	22	38
	TNO	NOP	NON	NOA	TDEN	DENP	DENN	DEND	DENX	DENA	TCOV	COVP	COVN	COVA
	NUMBER OF SPECIES				DENSITY						COVER			

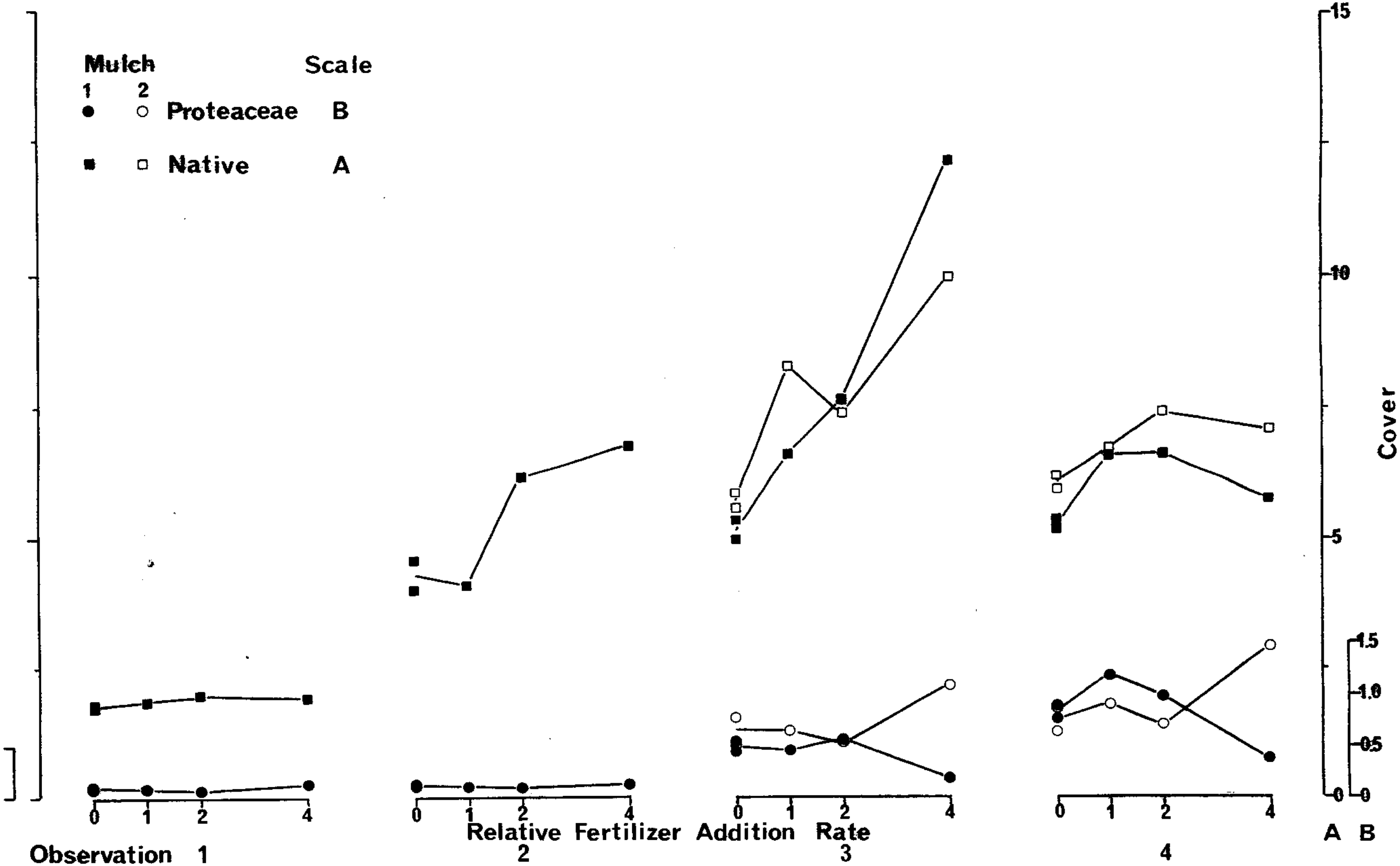
KEY TO VARIABLES ANALYSED:

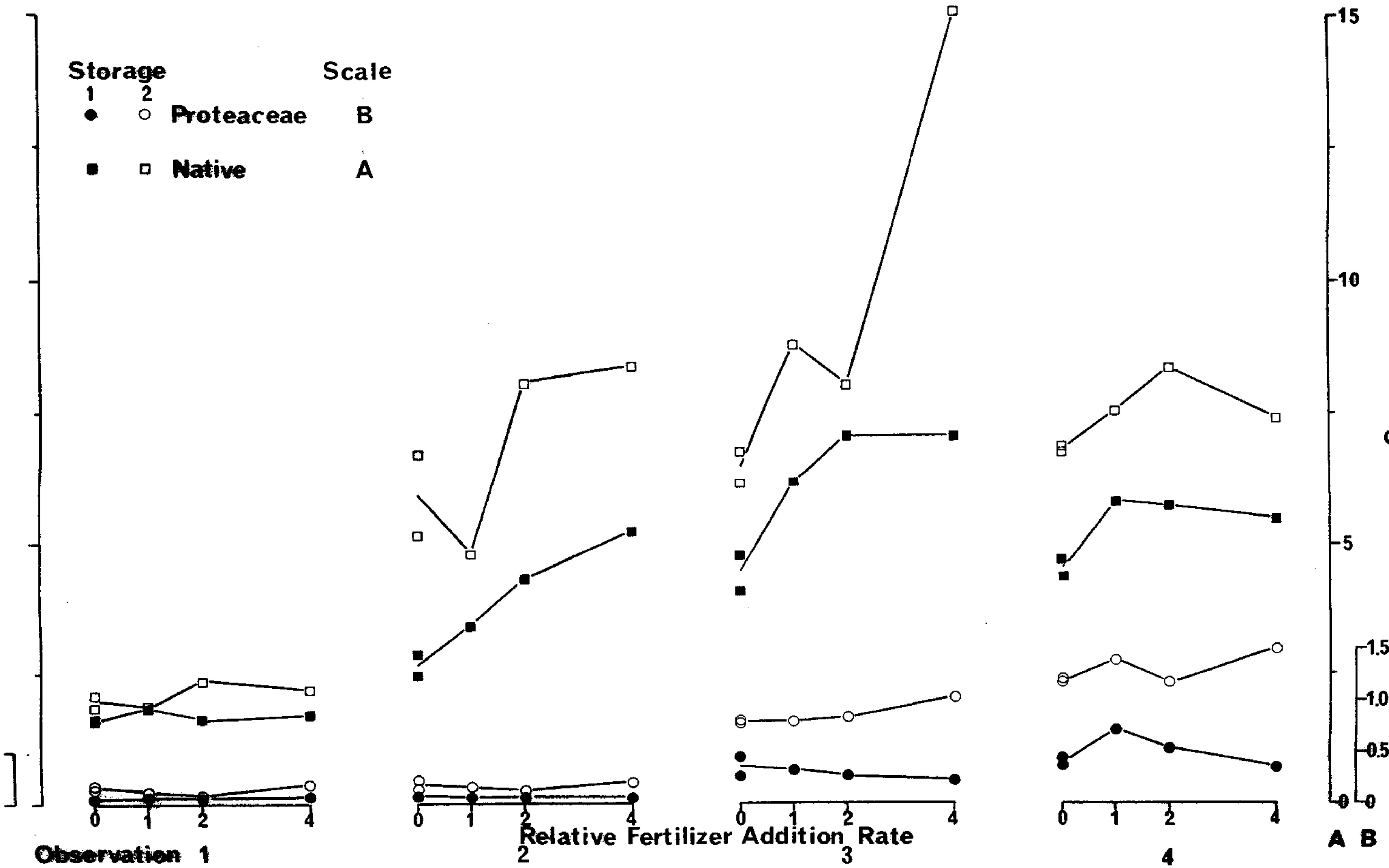
Number of Species TNO = Total, NOP = Proteaceae, NON = Native, NOA = Alien species
Density TDEN = Total, DENP = Proteaceae, DENN = Native, DENA = Alien, DEND = Drosera paleacea,
DENX = (DENN minus DEND)
Cover TCOV = Total, COVP = Proteaceae, COVN = Native, COVA = Alien species.

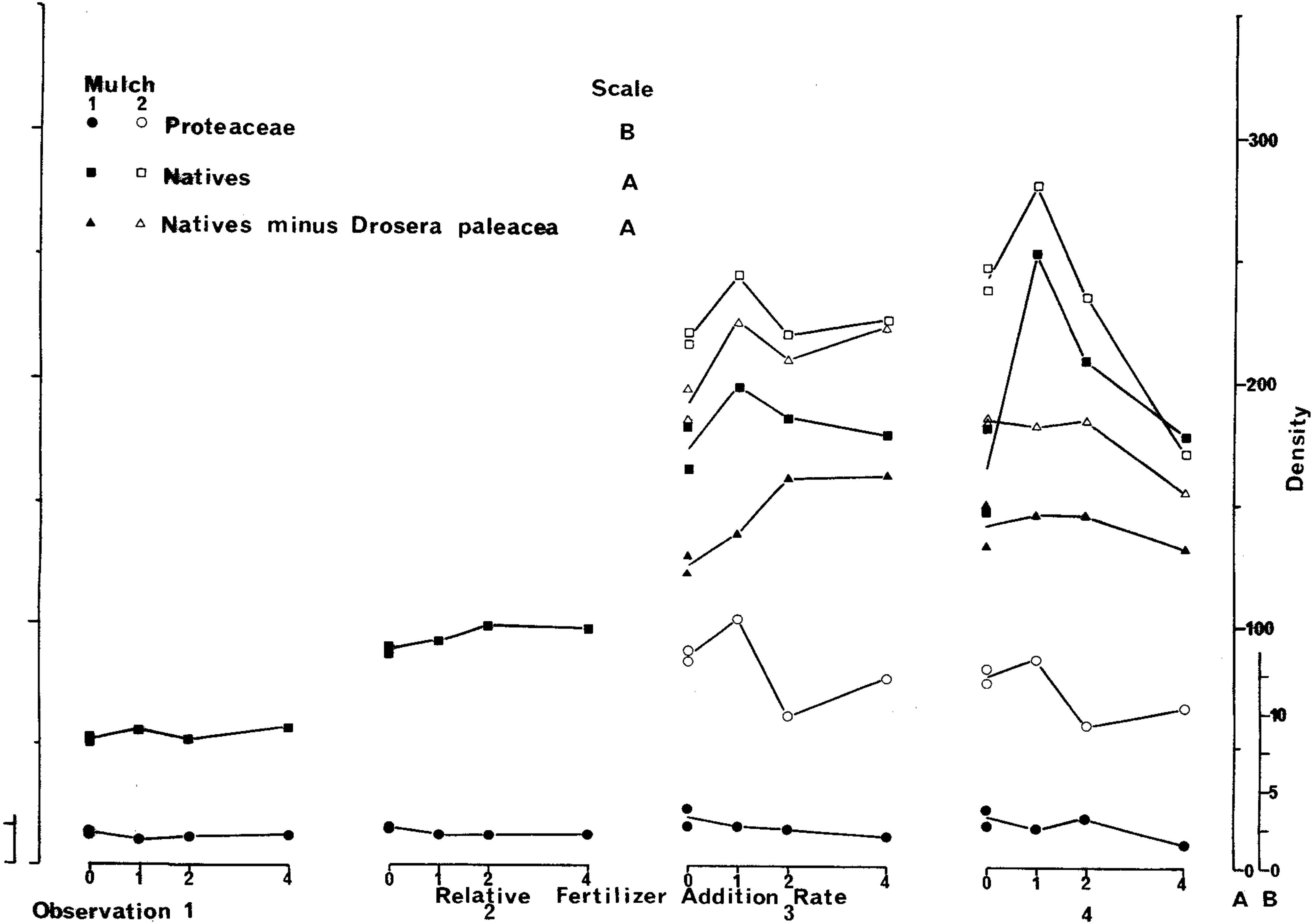
RESIDUAL SS% = Sum of Squares of Residual, as a percentage of Total Sum of Squares.

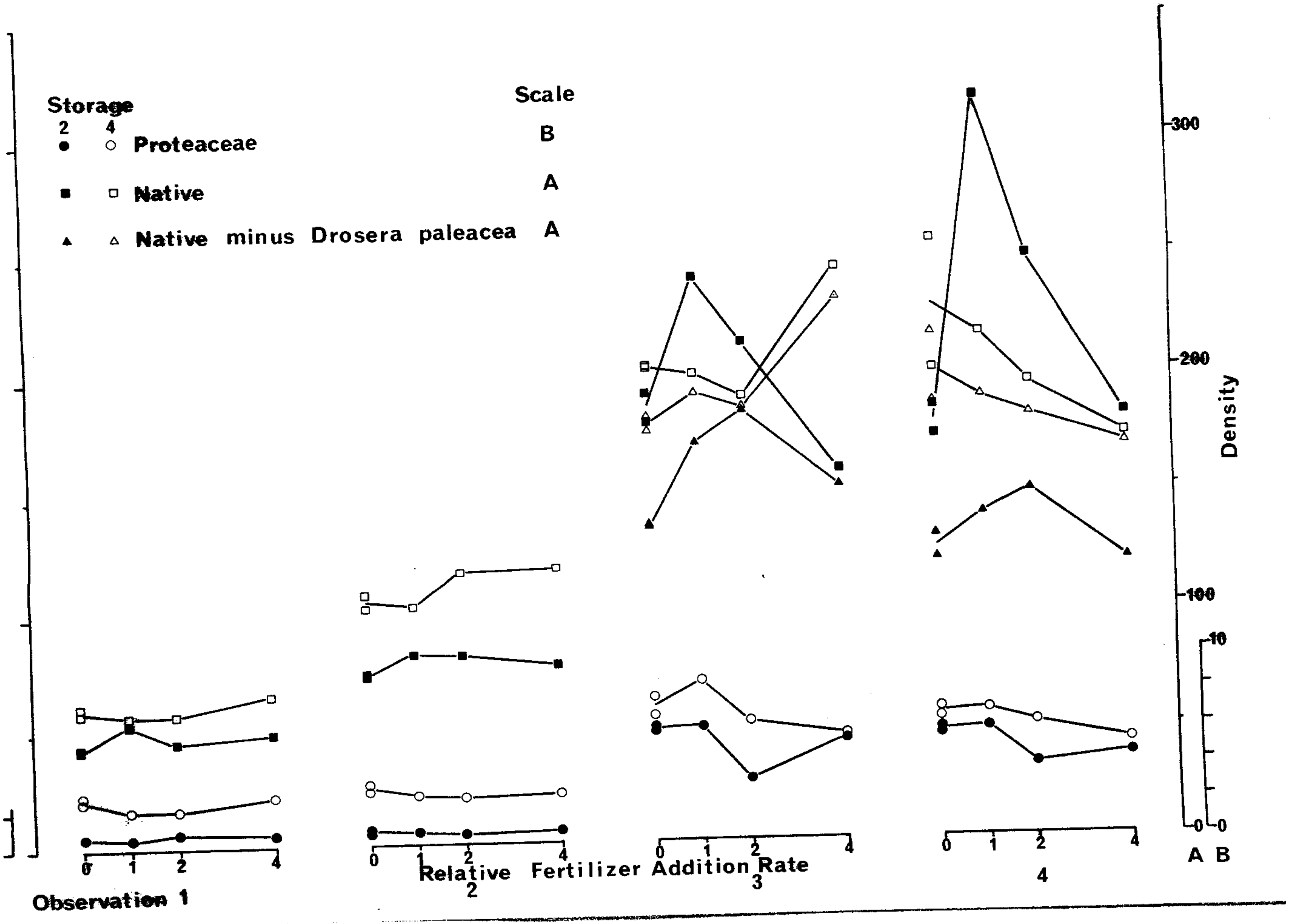
INTERACTIONS, terms which are increased (+) or decreased (-) proportionally more than expected from Treatment Main Effects.
a = B4S1(-), b = B4S1(+), c = B4C2(-), d = S1M1(-), e = C2M2(-).


Total all Treatments
Total by Fertilizer level
Mulch level 1 2
Total
Average
Storage level 1 2
Total
Average
150
100
50
0
Number of Native
0 1 2 4
0 1 2 4
20
10
0
Number of Proteaceae
0 1 2 4
0 1 2 4
Relative Fertilizer Addition Rate


Mulch
1 2
Proteaceae B
Native A
Scale
15
10
5
1.5
1.0
0.5
0
Cover
0 1 2 4
Relative Fertilizer Addition Rate
Observation 1
2
3
4
A B

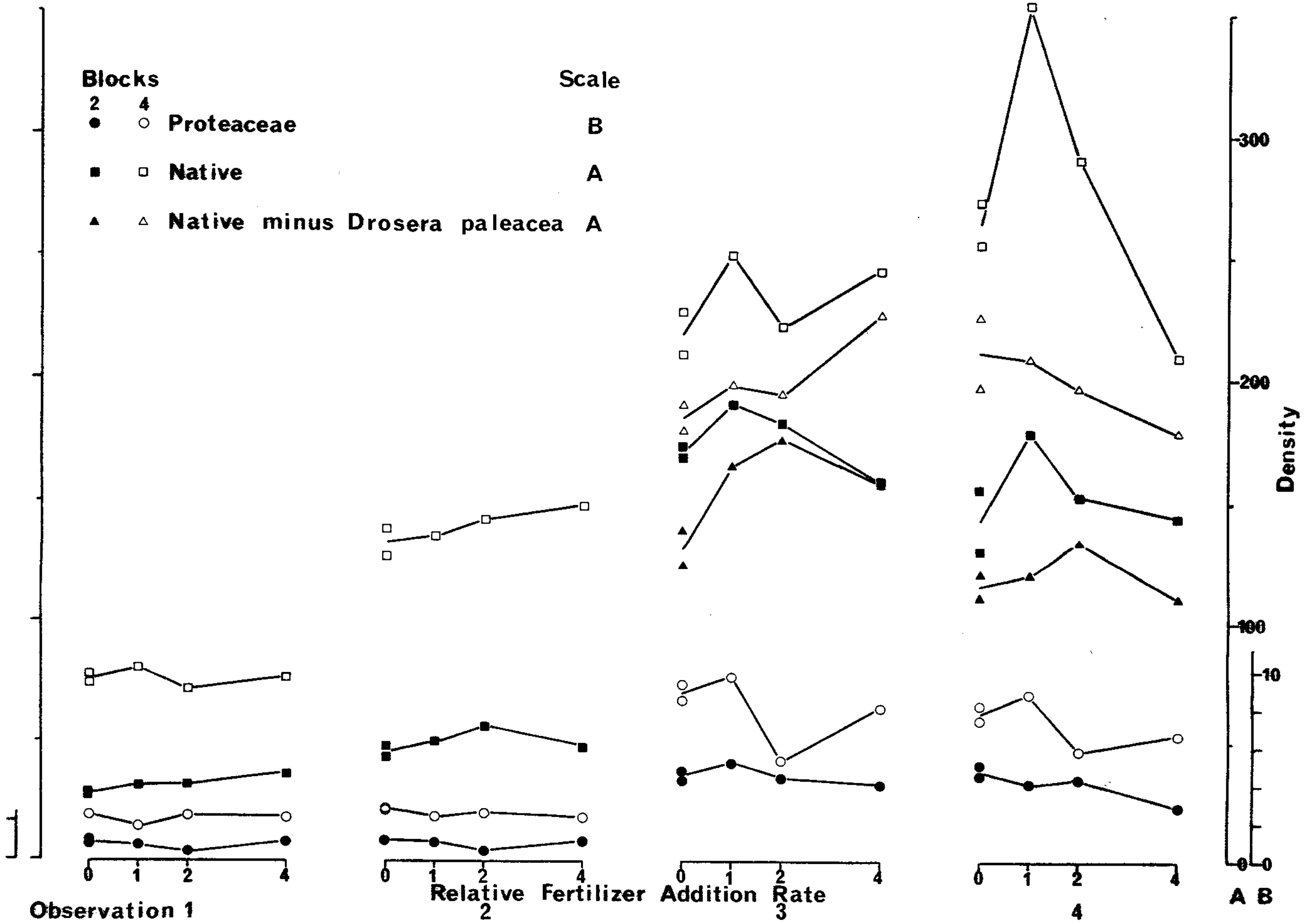

Storage
1 2
Proteaceae
Native
Scale
B
A
0
1
2
4
Observation 1
2
3
4
Relative Fertilizer Addition Rate
Cover
15
10
5
1.5
1.0
0.5
0
A B

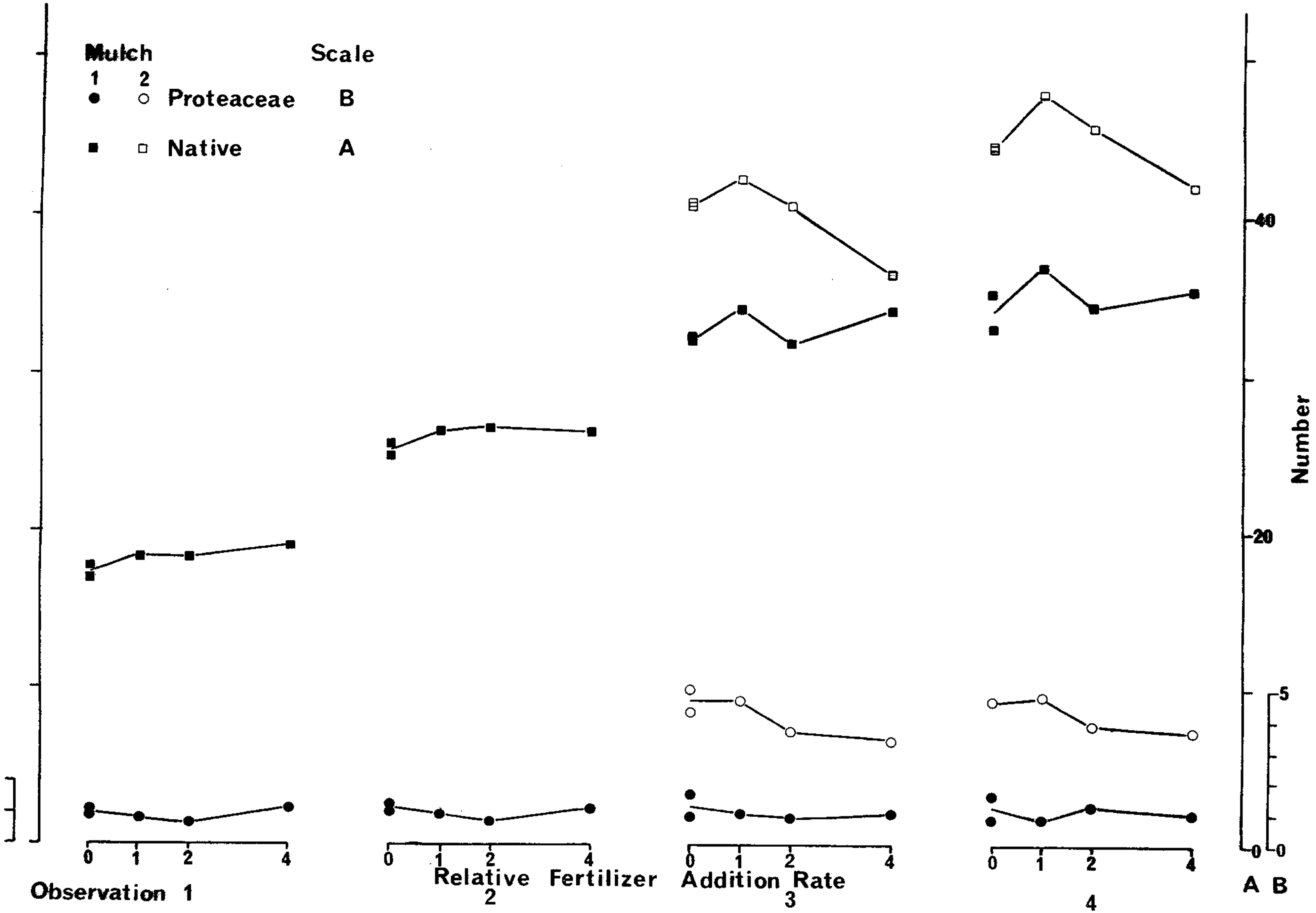

Mulch
1 2
Proteaceae B
Natives A
Natives minus Drosera paleacea A
Scale
300
200
100
10
5
0
Density
A B
0 1 2 4
Observation 1
2
3
4
Relative Fertilizer Addition Rate



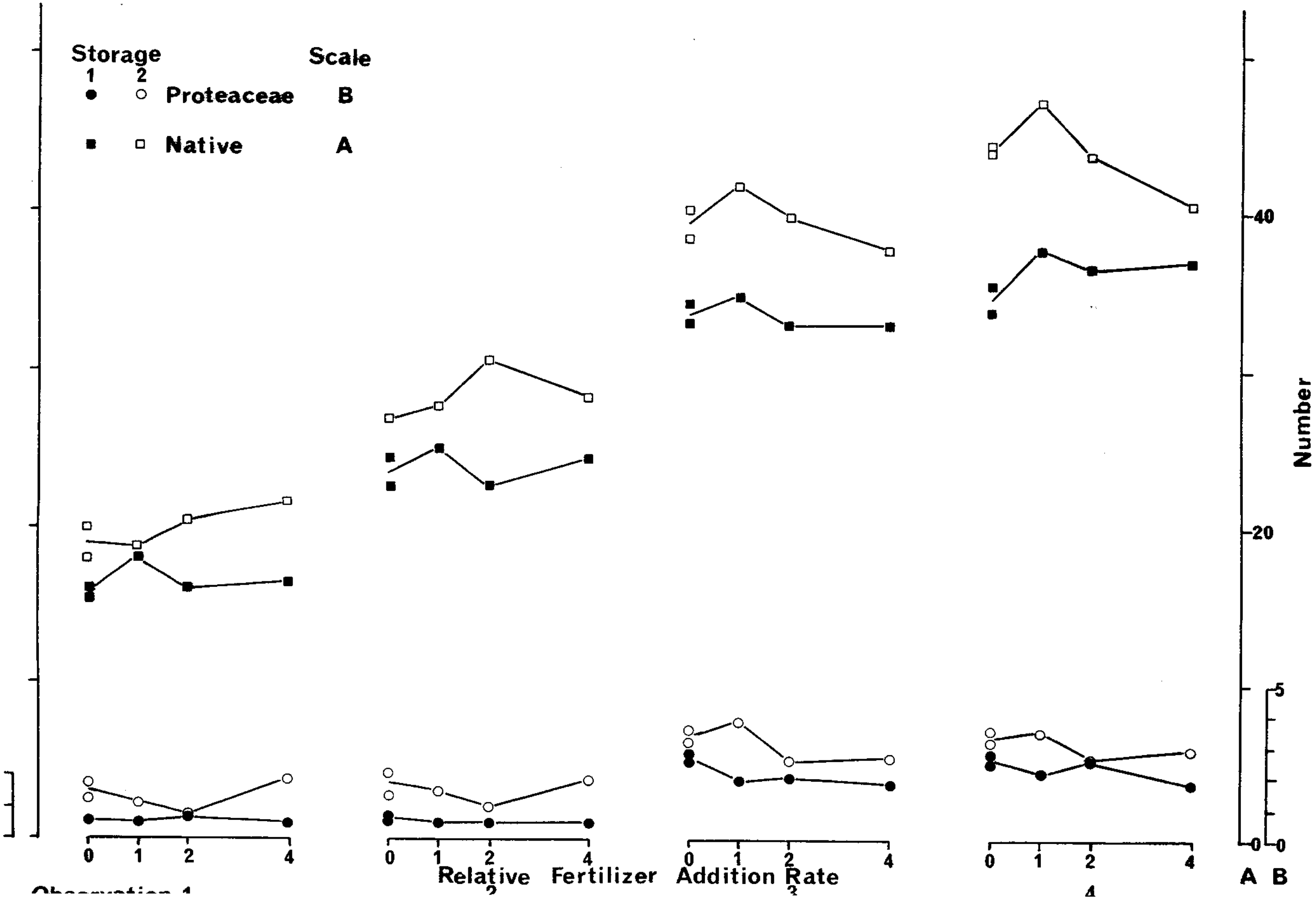
Storage
2 4
Proteaceae
Native
Native minus Drosera paleacea
Scale
B
A
A
300
200
100
10
0
0
Density
A B
0 1 2 4
0 1 2 4
0 1 2 4
0 1 2 4
Observation 1
2
3
4
Relative Fertilizer Addition Rate

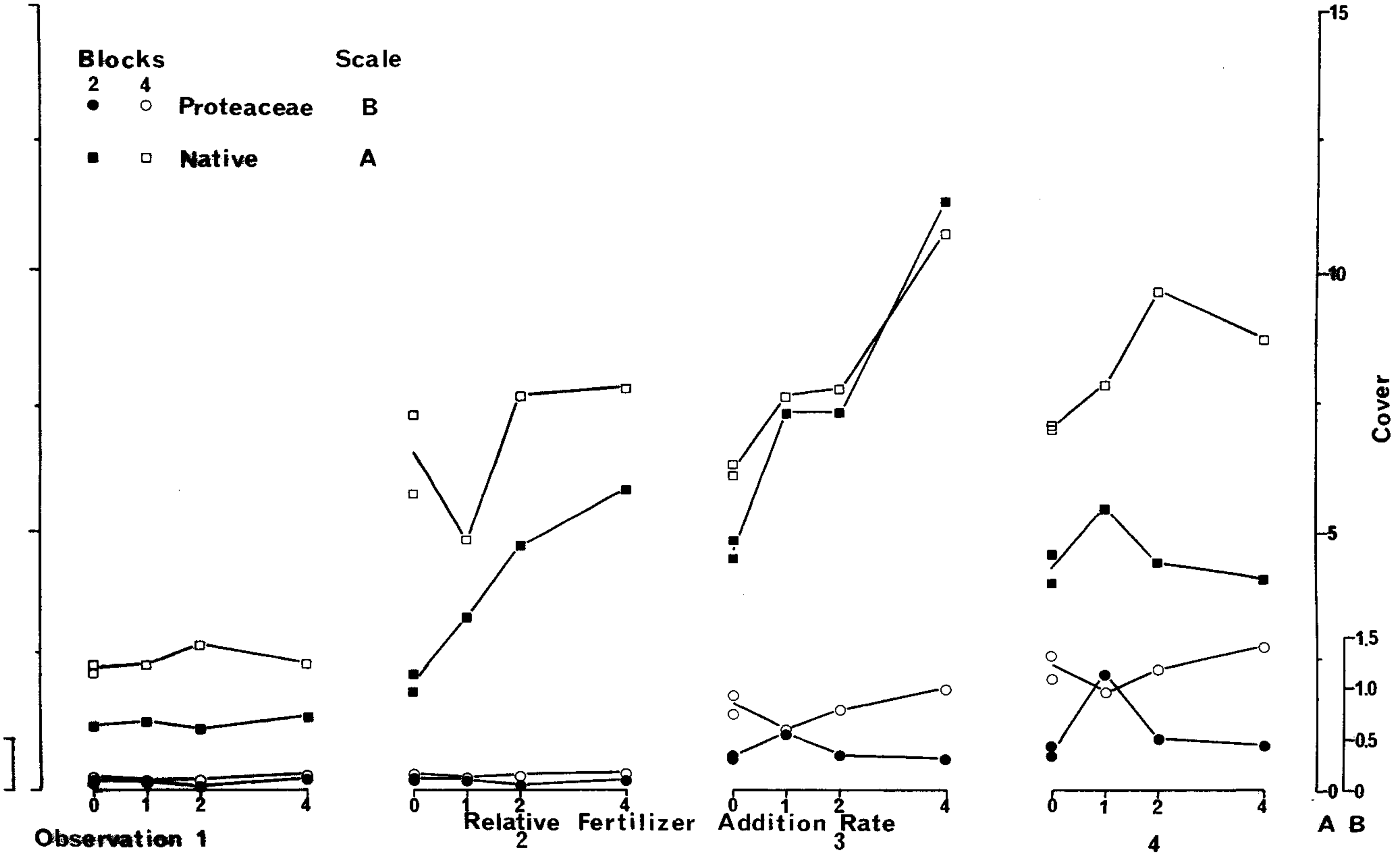
3d

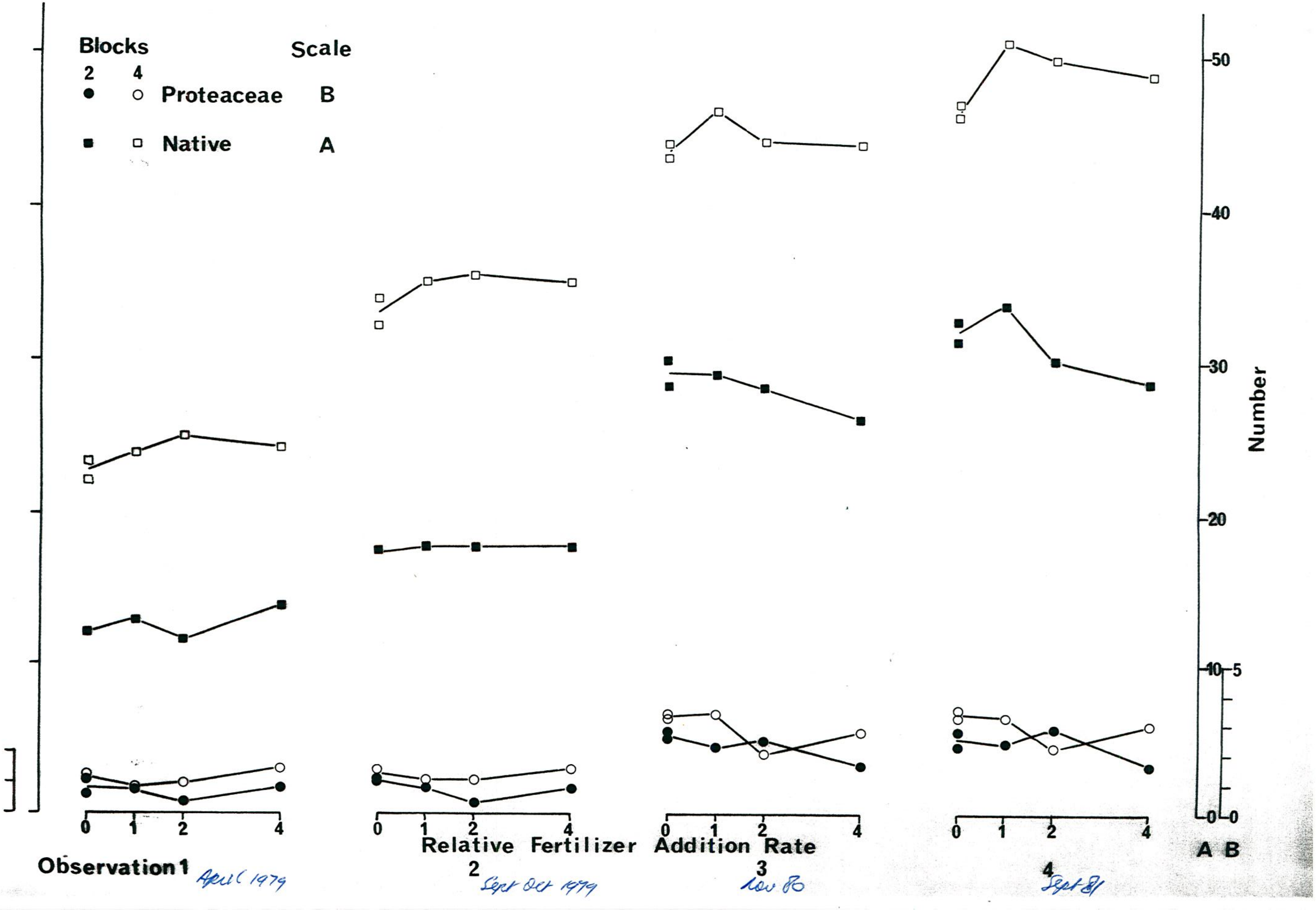

Blocks
2 4
Proteaceae B
Native A
Native minus Drosera paleacea A
Scale
300
200
100
10
0
0
Density
0 1 2 4
Observation 1
0 1 2 4
Relative Fertilizer Addition Rate
2
0 1 2 4
3
0 1 2 4
4
A B


Mulch
1 2
Proteaceae
Native
Scale
B
A
40
20
5
0
0
Number
A B
0 1 2 4
Observation 1
Relative Fertilizer Addition Rate
2
3
4

3k


Storage
1
2
Proteaceae
Native
Scale
B
A
Number
40
20
5
0
0
A
B
0
1
2
4
Relative Fertilizer Addition Rate
Observation 1
2
3
4


Blocks
2 4
Proteaceae B
Native A
Scale
Observation 1
2
3
4
Relative Fertilizer Addition Rate
0 1 2 4
Cover
15
10
5
0
1.5
1.0
0.5
0
A B


Blocks
2 4
Proteaceae
Native
Scale
B
A
50
40
30
20
10
5
0
0
Number
A B
0 1 2 4
Relative Fertilizer Addition Rate
Observation 1
2
3
4
April 1979
Sept Oct 1979
Nov 80
Sept 81

Type 1. no response

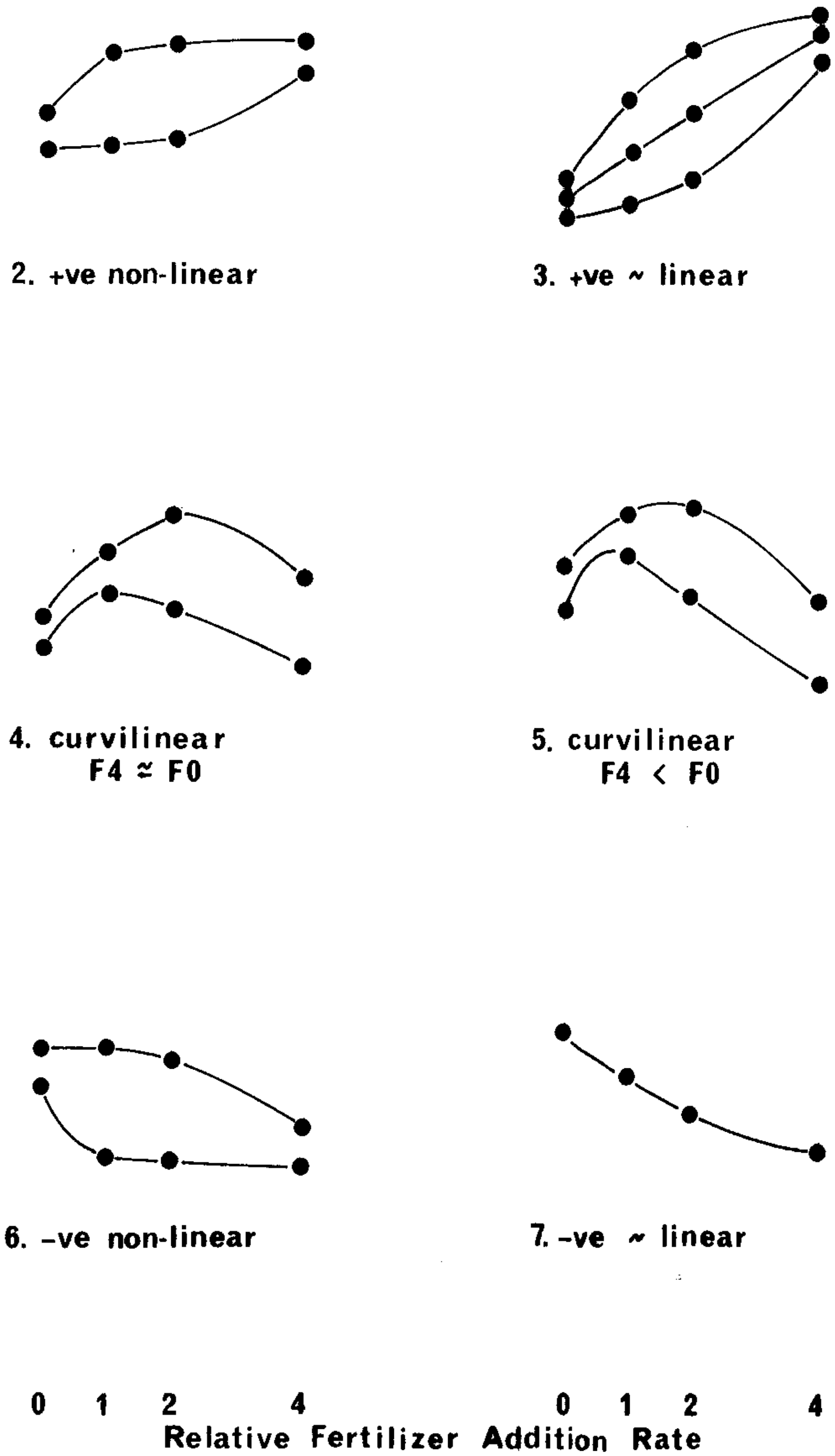
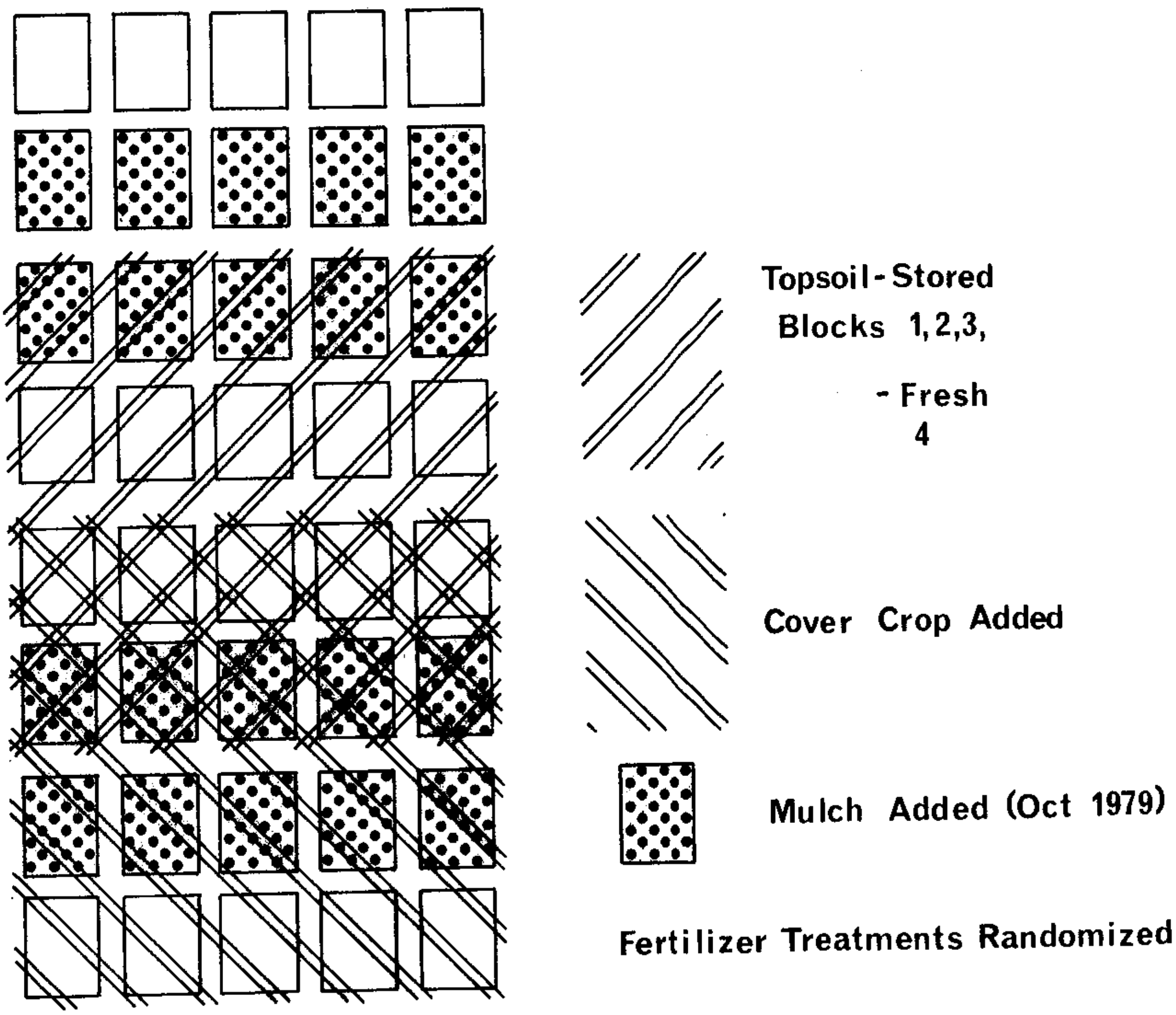


FIG 1

Arrangement within Blocks



Arrangement of Blocks