Agricultural Research and Development Paper
Number 51

[illegible]

[illegible]

INTRODUCTION

It has been stated on a number of occasions (e.g. Nature Conservancy 1971) that hedgerows may act as "corridors" for wildlife, linking areas of woodland and other semi-natural habitats and preventing them from becoming isolated, but little direct evidence has been advanced in support of this concept. An examination of data on bird populations in some 60 wooded sites in south-east England (Helliwell 1973) indicated that, in these particular sites, the degree of isolation of a woodland had little effect on the bird population to be found in it; and the same may be true for many of the more mobile animals.

As far as plants are concerned, it is known that some species, such as Paris quadrifolia L., Anemone nemorosa L., and Primula vulgaris Huds. (Peterken, 1973) are slow to colonize new areas of woodland, yet some, at least, of these species can be found in hedgerows. Is it possible that hedgerows may act as a "corridor" for the passage of such plants? Recent work by Pollard (1973) in Huntingdonshire indicates that many woodland plant species do not readily colonize new hedgerows, which appears to show that any "corridor"effect is, at the most, not very strong.

Pollard commenced his study by a detailed examination of one hedgerow containing sections of different ages, and then expanded his investigation to cover a number of selected hedgerows of different ages throughout the county. A different approach was used in the present study, in that hedgerows were selected at random within an area of fairly uniform farming type covering only 200 square kilometres.

It was decided, in the first instance, that it might be useful to examine the number of species to be found in different lengths of hedgerow, in addition to the recording and analysis of the species present. A number of workers (e.g. Brown 1971, Darlington 1957, and Preston 1962) have examined the relationship between the size of a sample area, the number of species of plants or animals to be found within it, and the isolation of the sample area. The relationship has been expressed as $N = n A^{C}$

where N = no. of spp. in sample area
n = no. of spp. in a unit area
and A = area of sample

The value of c is related to the degree of isolation of the sample, and is normally between 0.12 and 0.25 if the samples are part of a continuous population, and between 0.30 and 0.40, if the samples are isolated oceanic islands or mountain tops. It may, therefore, provide a useful means of assessing the degree of isolation of one area of habitat from another, or for assessing the degree of "internal isolation" within continuous areas. If, for example, a continuous area of 100 hectares contained 100 species and a 1 hectare sample of this contained 20 species an isolated area of 1 hectare may be expected to contain fewer than 20 species, giving a higher value for c in the above formula. Similarly, if there is "internal isolation" or discontinuity between one part of a hedgerow and another, a small quadrat may be expected, other things being equal, to contain fewer species than might be expected from an examination of the total number of species in a longer length of hedgerow.

SELECTION OF STUDY AREA AND SAMPLE SITES

An area in west Shropshire was selected, being an area of predominantly grassland farming with numerous hedgerows and comparatively little recent change in agricultural usage or methods. There were a number of small woodland areas, most of which had been wooded for at least 100 years. The study area was taken as the two 10 x 10 km. National Grid squares, reference SJ 30 and SJ 40.

All the hedgerows sampled were roadside hedgerows on class C roads. This simplified the survey work, as there was no problem of gaining access to the sample sites; and it was also thought that there was likely to be a greater degree of uniformity of management of these hedges than of hedges bounded on both sides by fields. Sample sites were selected by driving along a class C road until a length of 256 metres or more was located which was not interrupted by any obvious change in hedge type or

by the occurrence of a roadside farm or house. Where there was any choice, hedges were sampled on alternate sides of the road. After sampling one hedgerow, the surveyor proceded to the next road junction before looking for another sample site.

SAMPLING PROCEDURE

The approximate centre of the sample length of hedgerow was located and the first point for recording was then determined by taking a further 20 paces in the direction from which the site had been approached. At this point, the approximate width of the roadside verge, the width of the hedge, the height of the hedge, and the aspect of the hedge were recorded. Vascular plant species present in the roadside verge and hedge in the next two metres were then listed; and then additional species in the subsequent, 2, 4, 8, 16, 32 and 64 metres, and, finally, in the 128 metres preceding the starting point, giving a surveyed length of 256 metres.

The number of trees (other than saplings) in the 256 metre length was also recorded, and the number of shrub species in the first 27 metres (to conform to Hooper's 30 yard length for estimating the age of a hedge (Hooper 1970a)). The distance to the nearest woodland, the number of hectares of woodland in the surrounding 100 hectares, and the total length of hedgerow in the surrounding 100 hectares were read from the 1:25,000 Ordnance Survey map, adjusted for any alterations to woodland area which had occurred since the map was made in 1949. (There were, in fact, very few such alterations.)

Any plant species growing on the field side of the hedge were ignored.

50 hedgerows were sampled.

RESULTS

The mean numbers of plant species in successive lengths of hedgerows were:-

2 metres	17.2 species
4 metres	20.9 species
8 metres	24.5 species
16 metres	29.0 species
32 metres	34.6 species
64 metres	41.4 species
128 metres	49.0 species
256 metres	57.2 species

which gives a value of 0.25 for c in the formula $N = n A^c$. These numbers are plotted in Figure 1, and, as can be seen, conform very closely to the values given by the formula:

$$\text{No. of species} = 17.2 \times \text{length of hedgerow}^{0.25}$$

The numbers of plant species in successive lengths were also plotted for each individual site and a smooth curve drawn through by eye. The value of c was then calculated for each site and correlated again the other factors which had been recorded. The correlation matrix is given in Table 1.

As can be seen, the value of c is correlated with the total number of plant species and the conservation "value" of these species, but has no other significant correlations at the 5% probability level. It has a negative correlation of 0.23 with the distance to the nearest wood, but this is not enough to reach significance.

The width of the verge is negatively correlated with the number of shrub species in the hedge, reflecting the fact that where the road has been widened the hedge is usually much younger and contains fewer shrub species. The remaining correlations between variables are shown in Figure 2.

The number of "woodland" species referred to was derived by examining the list of plant species and noting those which were thought most likely to be associated with woodland conditions. Out of a total of 194 plant species 13 were considered most likely to come into this category.

These were:-

Arum maculatum L.
Endymion non-scriptus L.
Galium odoratum L.
Lysimachia nummularia L.
Melica uniflora Retz.
Mercurialis perennis L.
Oxalis acetosella L.
Polypodium vulgare L.
Primula vulgaris Huds.
Sanicula europaea L.
Teucrium scorodonia L.
Veronica montana L.
Viola riviniana Reichb.

The floristic data were also subjected to an association analysis (Figure 3), which gave 11 groups at a chi-square level of 3.84 (significant at the 5% probability level). At a chi-square level of 10.0 there were six groups (Figure 3), which correspond fairly closely to the presence of "woodland" species referred to above. Sites in group 1 contain an average of 4.1 "woodland" species, sites in group 2 an average of 2.1, sites in group 3 an average of 1.7, and sites in groups 4 to 6 an average of 1 or less.

If one examines the other variables which showed significant correlations (see Figure 2) there are differences between the groups in the association analysis, but these are not large enough to be statistically significant. Taking groups 1 and 6 as representing the greatest differences in vegetation, those variables are:-

Variable	Group 1	Group 6
Value of c	0.255 ± 0.014	0.217 ± 0.008
Area of woods in 1 sq km (hectares)	5.2 ± 1.98	2.11 ± 0.98
Distance to nearest wood (metres)	232 ± 42.2	516 ± 83.2
Total number of plant species	67.3 ± 1.90	52.3 ± 1.40
Number of hedgerow trees	2.1 ± 0.57	1.4 ± 0.35
Number of shrub species in 27 metres	7.4 ± 0.54	5.9 ± 0.40
Length of hedgerows in 1 sq km (kilometres)	14.3 ± 0.85	13.7 ± 0.46

A polythetic association analysis (i.e. dividing on more than one feature) of the floristic data was also carried out (Figure 4). This method (Hill, no yet published) gives 4 main groups, which were found to correspond closely with the groupings given by the monothetic analysis. It is a method which is less likely to give spurious classifications of any individual site and, in this case, the groups were more easily interpretable. The first division was between "base rich" sites and a smaller number of more acidic sites. Each of these two categories was then divided into those with several (mean values of 5.7 and 3.2 respectively) "woodland" species and those with few (0.9 and 0.8 respectively).

The first two axes of an ordination (Hill, 1973) of the species data were plotted and the 13 selected "woodland" species marked. These occurred in one quadrant of the ordination, and a line could be drawn which included most of these species together with a number of others. Arum maculatum, Lysimachia nummularia, and Mercurialis perennis were some small distance outside this line and 27 additional species were inside it, in addition to the 10 other pre-selected species. The species included were:-

Ajuga reptans L.
Alnus glutinosa (L.) Gaertn.
Angelica sylvestris L.
Brachypodium sylvaticum (Huds.) Beauv.
Bromus ramosus Huds.
Betonica officinalis L.
Clinopodium vulgare L.
Cornus sanguinea L.
Deschampsia flexuosa (L.) Trin.
Dryopteris filix-mas
Epilobium hirsutum L.
Epilobium montanum L.
Endymion non-scriptus L.
Fragaria vesca L.
Galium odoratum L.
Geranium robertianum L.
Geum urbanum L.
Glyceria fluitans (L.) R. Br.
Hieracium sp.
Hypericum pulchrum L.
Juncus effusus L.
Melica uniflora Retz.
Oxalis acetosella L.
Pilosella officinarum C. H. and F. W. Schultz.
Polypodium vulgare L.
Primula vulgaris Huds.
Prunella vulgaris L.
Prunus avium (L.) L.
Sanicula europaea L.
Senecio jacobea L.
Sieglingia decumbens (L.) Bernh.
Teucrium scorodonia L.
Trisetum flavescens (L.) Beauv.
Veronica chamaedrys L.
Veronica montana L.
Vicia sepium L.
Viola riviniana Reichb.

Some of these species occurred only once or twice in the survey and may be included in this list more by accident than by any real affinity with the other species, but the majority can be recognised as having woodland affinities.

The conservation "value" of the plant species (see Hellwell 1973b) was calculated using the method described in Merlewood R and D Paper No. 39 (Hellwell, 1973a). As can be seen in Table 1, this was closely correlated with the total number of plant species present.

DISCUSSION

The amount of variation within the hedgerows sampled was fairly small in respect of many of the variables measured. This was to be expected in an area of fairly similar history and current land use, and was useful in permitting the closer study of the remaining variables. It may, however, limit the relevance of the results of this study to other situations. The mean, minimum, maximum and standard deviation of each variable is listed below, together with the coefficient of variation:-

	Mean	Min.	Max.	S.D.	Coeff. of Var.
1. Width of verge (metres)	1.42	0.25	5	0.84	0.59
2. Width of hedge (metres)	1.33	1	4	0.47	0.35
3. Width of hedgerow (metres)	3.22	1.5	7	1.00	0.31
4. Height of hedge (metres)	1.76	1	4	0.61	0.35
5. Number of trees in 256 m.	1.40	0	5	1.63	1.16
6. Hedges per sq km (kilometres)	13.71	11	20	1.89	0.14
7. Woods per sq. km (hectares)	4.33	0	20	5.43	1.25
8. Distance to nearest wood (metres)	345	0	1200	276	0.80
9. No. of shrub spp. in 27 metres	5.98	2	10	1.81	0.30
10. No. of shrub spp. in 256 metres	9.04	2	13	2.13	0.24
11. Total no. of plant spp.	57.2	41	84	10.3	0.18
12. Value of c	0.246	0.15	.51	0.057	0.23
13. Total "value" of species	268	122	462	80	0.30
14. No. of "woodland" spp.	1.86	0	8	1.93	1.04

Variables 5, 7, 8, and 14 are the most variable, and these are the ones with which the study was most concerned. The results are, therefore, satisfactory from this point of view, The fact that the value of c does not show a corresponding amount of variation would appear to indicate that it is not a very sensitive parameter to use to measure the degree of isolation of one part of a hedgerow from other parts of the same hedgerow, although it may be of use for other purposes. The mean value of approximately 0.25 is fairly high, but is similar to values obtained by Hopkins (1955) in Rannoch Wood and a Chiltern beechwood, using quadrats from 1 to 400 sq metres, and by Kilburn (1966) in wooded areas in North America (using his figures for quadrats from 1 to 90 sq metres). This value is higher than values recorded from wooded sites in the English Lake District (Helliwell, 1973) or south-west Scotland (Helliwell, 1971), or from non-wooded sites in a whole range of localities (e.g. Dony 1963, Hopkins 1955, Helliwell 1971 and 1973).

The fact that the association analyses separate groups of hedgerows which contain a high proportion of "woodland" species would appear to indicate that these hedgerows are to some extent "special", and that such woodland species do not occur generally in all hedgerows; and, as there is no great difference in the age of most of the hedges (as judged by the number of woody species in a 27 m length) it seems logical to conclude that these species do not readily travel along hedgerows, though they may sometimes be found in hedgerows which are near to woods or which have, perhaps, been near to woods at some time in the past. As listed previously, the average distance to the nearest wood from sites in group 1 of the analysis is less than half that from sites in group 6, although there is considerable variation around the mean values.

The "values" given to the hedgerows (see above) ranged from 122 units for a relatively young hedge containing 44 plant species to 462 units for an older hedge containing 84 species (occupying areas of 1200 square metres and 750 square metres respectively). Using the same evaluation process, sites in the Lake District (Helliwell 1973) ranged from 9 units for 200 sq m of young conifer plantation to 1139 units for a similar area of sub-alpine vegetation. It is not strictly valid to make direct comparisons between linear samples and square or round samples (Helliwell 1974), but it is evident that the hedgerows examined contain a relatively large number of

plant species per unit length, although these are usually fairly common species, giving the hedge a reasonably high value, but never a very high value for wildlife conservation. This conclusion is supported by Hooper (1970) who states that, of the 300 rarest plants in Britain, only about 10 are hedgerow plants.

Moore (1970) comes to a similar conclusion with regard to animals, stating that few or no animal species are entirely restricted to hedgerows, although an appreciable proportion (20% or more) of the population of some species is found in hedges; and Benson and Williamson (1972) found that some species of mainly woodland birds (wrens and robins) will breed in hedgerows when all the available woodland is fully stocked, but if there is a fall in breeding numbers the hedgerow sites are the first to be abandoned.

The general situation seems to be, therefore, that hedgerows contain a relatively larg number of our common plants, but are not seen to act as a "corridor" for the passage of species of plants which are typical of woodlands.

In order to check on this, a further visit was made to the study area and all roadside hedgerows of a suitably uniform nature were examined which bounded woodland marked as being present on the first edition of the Ordnance Survey maps, published in 1833. Sixteen hedgerows were covered in this way. 2 m sample lengths were examined adjacent to the woodland and at 25 m intervals from the edge of the wood. The results are summarised below:-

	Mean number of plant species, and standard error	Mean number of "woodland" species (from list of 37) and standard error
2 m sample adjacent to woodland	17.7 ± 1.03	2.12 ± 0.39
2 m sample 25 m from woodland	17.7 ± 0.74	1.19 ± 0.31
2 m sample 50 m from woodland	18.4 ± 1.02	1.00 ± 0.13
2 m sample 75 m from woodland	16.4 ± 0.98	1.06 ± 0.21
2 m sample 100 m from woodland	17.5 ± 1.29	1.25 ± 0.32

The hedgerows contained a mean number of 7.2 $\pm$ 0.45 woody species per 27 m length.

There is no significant difference between the total numbers of plant species recorded in 2 m samples of hedgerow adjacent to woodland and 2 m samples at varying distances from the nearest woodland, but the number of "woodland" species is significantly* greater in hedgerows adjacent to woodland.

These figures support the view that hedgerows do not act as efficient "corridors" for the passage of woodland plants.

CONCLUSIONS

It is concluded that, whilst the value of c in the formula $N = n.A^{c}$ does show some small degree of correlation with factors such as the proximity of a hedgerow to the nearest woodland, it is not likely to be sufficiently sensitive to form a very useful means of assessing the degree of isolation of sample hedgerows.

In spite of the lack of sensitivity of the above approach, association analysis of the floristic data divided the sample hedgerows fairly clearly into those with several pre-selected "woodland" species and those with few or none, indicating that such species do not readily spread throughout the hedgerow network. It is concluded, therefore, that hedgerows do not appear ao act as efficient "corridors" for the passage of most woodland plants, although they may act as "reservoirs" for some of our commoner woodland plants in some instances.

This confirms the recent findings of Pollard (1973) in Huntingdonshire.

* significant at the 1% probability level

ACKNOWLEDGEMENTS

Thanks are due to Steve Daggit for assistance with the survey work, to M. W. Shaw for carrying out the monothetic association analysis, and to M. O. Hill for carrying out the polythetic association analysis and an ordination analysis of sites and species by the method of "reciprocal averaging".

SUMMARY

A total of 66 samples of roadside hedgerow were examined in a 200 sq km area of Shropshire not far from the Welsh border.

The mean numbers of vascular plant species in samples of increasing length could be expressed as $17.2 \times \left(\frac{\text{length of hedgerow in metres}}{2}\right)^{0.25}$.

This equation varied somewhat between samples, but not greatly, and the correlation between this variation and the distance to the nearest wood was not significant at the 5% probability level.

Association analysis of the floristic data, did, however, provide a fairly clear division into hedgerows with some "woodland" species and hedgerows with few or no "woodland" species, and this difference was not accompanied by any corresponding difference in apparent age of the hedgerow.

It is concluded that these "woodland" species do not spread readily throughout the hedgerow network, and that hedgerows do not appear to act as efficient "corridors" for the passage of such plants.

BIBLIOGRAPHY

Benson, G. B. G. and Williamson, K. (1972). Breeding birds of a mixed farm in Suffolk. Bird study 19, 34-50.

Brown, J. H. (1971). Mammals on mountaintops: nonequilibrium insular biogeography. Am. Nat. 105, 467-478.

Darlington, P. J. (1957). Zoogeography: the geographical distribution of animals, John Wiley, New York.

Dony, J. G. (1963). The expectation of plant records from prescribed areas. Watsonia 5, 377-385.

Helliwell, D. R. (1971). Changes in flora and fauna associated with the afforestation of a Scottish moor - an evaluation. Merlewood R and D paper No. 29.

Helliwell, D. R. (1973a). A comparative study of wooded and non-wooded land in a part of the English Lake District. Merlewood R and D paper No. 39.

Helliwell, D. R. (1973b). Priorities and values in nature conservation. J. Environ. Manag. 1, 85-127.

Helliwell, D. R. (1973c). An examination of the effects of size and isolation on the wildlife conservation value of wooded sites. I. Birds. Merlewood R and D paper No. 49.

Helliwell, D. R. (1974). The value of vegetation for conservation. J. Environ. Manag. 2. (in press).

Hill, M. O. (1973). Reciprocal averaging: an eigenvector method of ordination. J. Ecol. 61, 237-249.

Hooper, M. D. (1970a). Hedges and history. New Scient. 48, 598-600.

Hooper, M. D. (1970b). The botanical importance of our hedgerows. in: The Flora of a Changing Britain, ed. F. Perring, Pendragon Press.

Hooper, M. D. (1971). The size and surroundings of nature reserves. in: The Scientific Management of Animal and Plant Communities for Conservation, ed. E. Duffey and A. S. Watt. Blackwell Scientific Publications, Oxford.

Hopkins, B. (1955). The species-area relations of plant communities. J. Ecol. 43, 409-426.

Johnson, M. P., Mason, L. G. and Raven, P. H. (1968). Ecological parameters and plant species diversity. Am. Nat. 102, 297-306.

Kilburn, P. D. (1966). Analysis of the species-area relation. Ecology, 47, 831-843.

MacArthur, R. H. and Wilson, E. O. (1963). An equilibrium theory of insular zoogeography. Evolution, 17, 373-387.

Moore, N. W., Hooper, M. D. and Davis, B. N. K. (1967). Hedges. I Introduction and reconnaissance studies. J. Appl. Ecol. 4, 201-220.

Moore, N. W. (1970). Wildlife conservation and the hedgerow habitat: conservation of animals. in: Hedges and Hedgerow Trees. Monks Wood Symposium No. 4, Nature Conservancy, Abbots Ripton, Huntingdon.

Nature Conservancy (1971). Nature Conservation in the Wye Valley Area of Outstanding Natural Beauty. Nature Conservancy, London.

Peterken, G. F. (1973). Personal communication.

Pollard, E. (1973). Hedges. VII. Woodland relic hedges in Huntingdon and Peterborough. J. Ecol. 61, 343-352.

Preston, F. W. (1962). The canonical distribution of commonness and rarity. Ecology, 43, 182-215 and 410-432.

Vuilleumier, F. (1970). Insular biogeography in continental regions. I The Northern Andes of South America. Am. Nat. 104, 373-388.

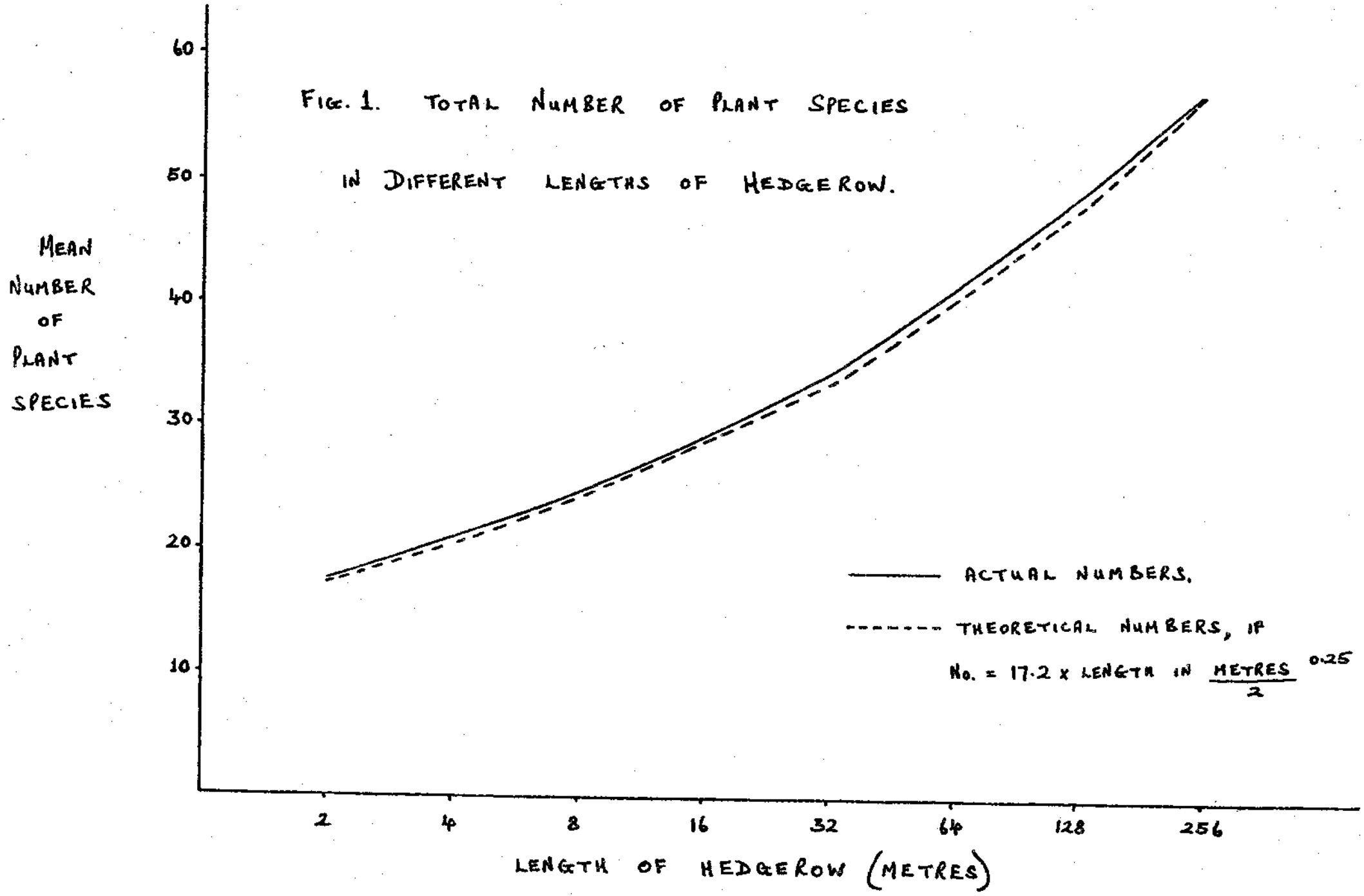
Table 1 CORRELATION OF VARIABLES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Width of roadside verge	1	-.02	.84**	.16	-.14	-.20	-.16	-.01	-.41**	-.52**	-.15	.07	-.25	-.34*
2. Width of hedge		1	.43**	.57**	-.04	.05	-.03	.16	.21	.01	-.04	-.05	-.08	.07
3. Width of hedgerow			1	.36**	-.17	-.08	-.21	.10	-.27	-.44**	-.25	.01	-.30*	-.25
4. Height of hedge				1	.12	.03	-.05	.14	.25	.17	.12	.05	.07	.19
5. Number of trees					1	.16	.02	-.21	.46**	.40**	.38**	.06	.35*	.12
6. Hedges per sq km						1	-.26	.11	.38**	.27	.09	.18	.03	.16
7. Woods per sq km							1	-.58**	.05	.12	.31*	-.01	.13	.34*
8. Distance to nearest wood								1	.00	-.08	-.35*	-.23	-.17	-.25
9. No. of shrub spp. in 27 m									1	.79**	.55**	-.01	.51**	.51**
10. No. of shrub spp. in 256 m										1	.49**	-.07	.51**	.36**
11. Total no. of plant spp.											1	.33*	.77**	.58**
12. Value of c												1	.30*	.03
13. Total "value" of species													1	.57**
14. No. of "woodland" species														1

* significant for 0.05 probability

** significant for 0.01 probability

FIG. 1. TOTAL NUMBER OF PLANT SPECIES IN DIFFERENT LENGTHS OF HEDGEROW.



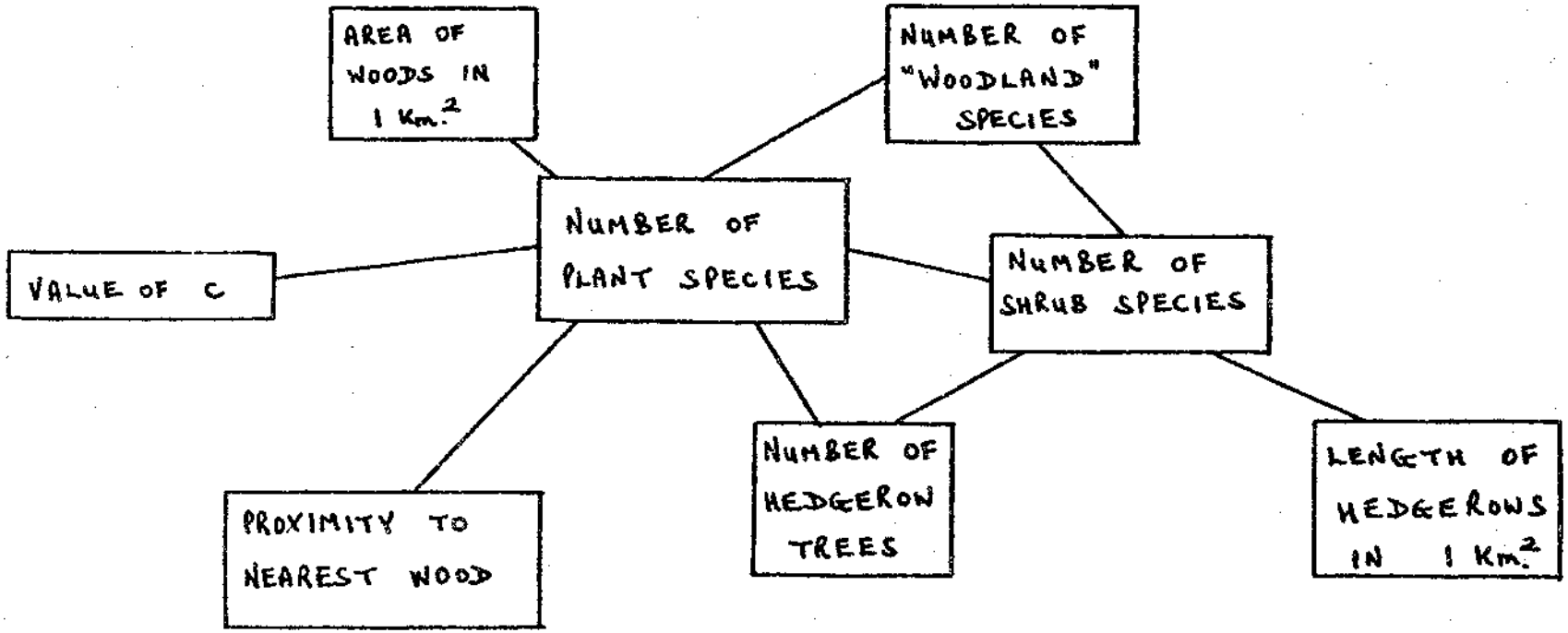


FIG. 2. MAIN CORRELATIONS BETWEEN VARIABLES.

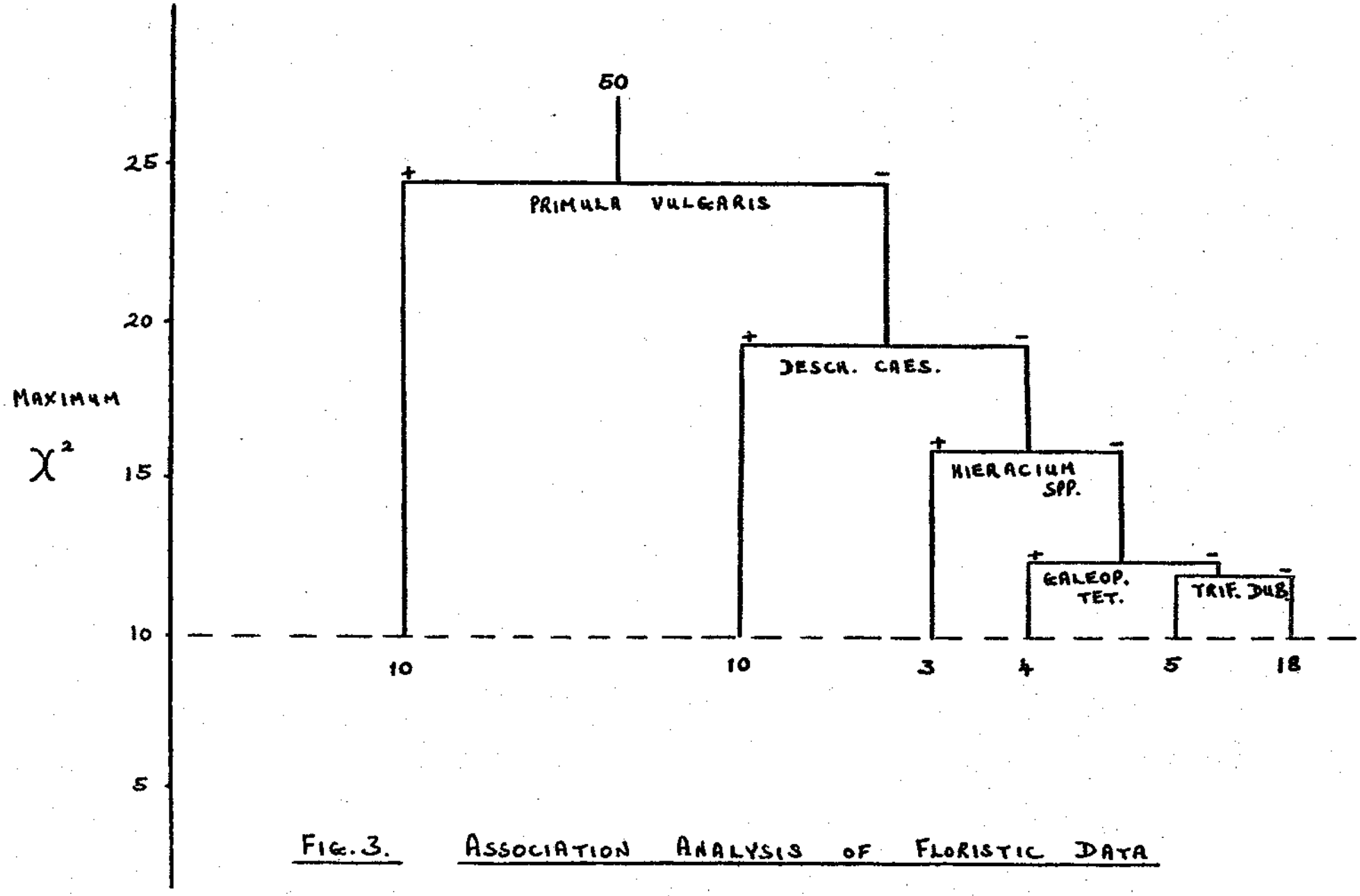


FIG. 3. ASSOCIATION ANALYSIS OF FLORISTIC DATA FROM 50 SITES.

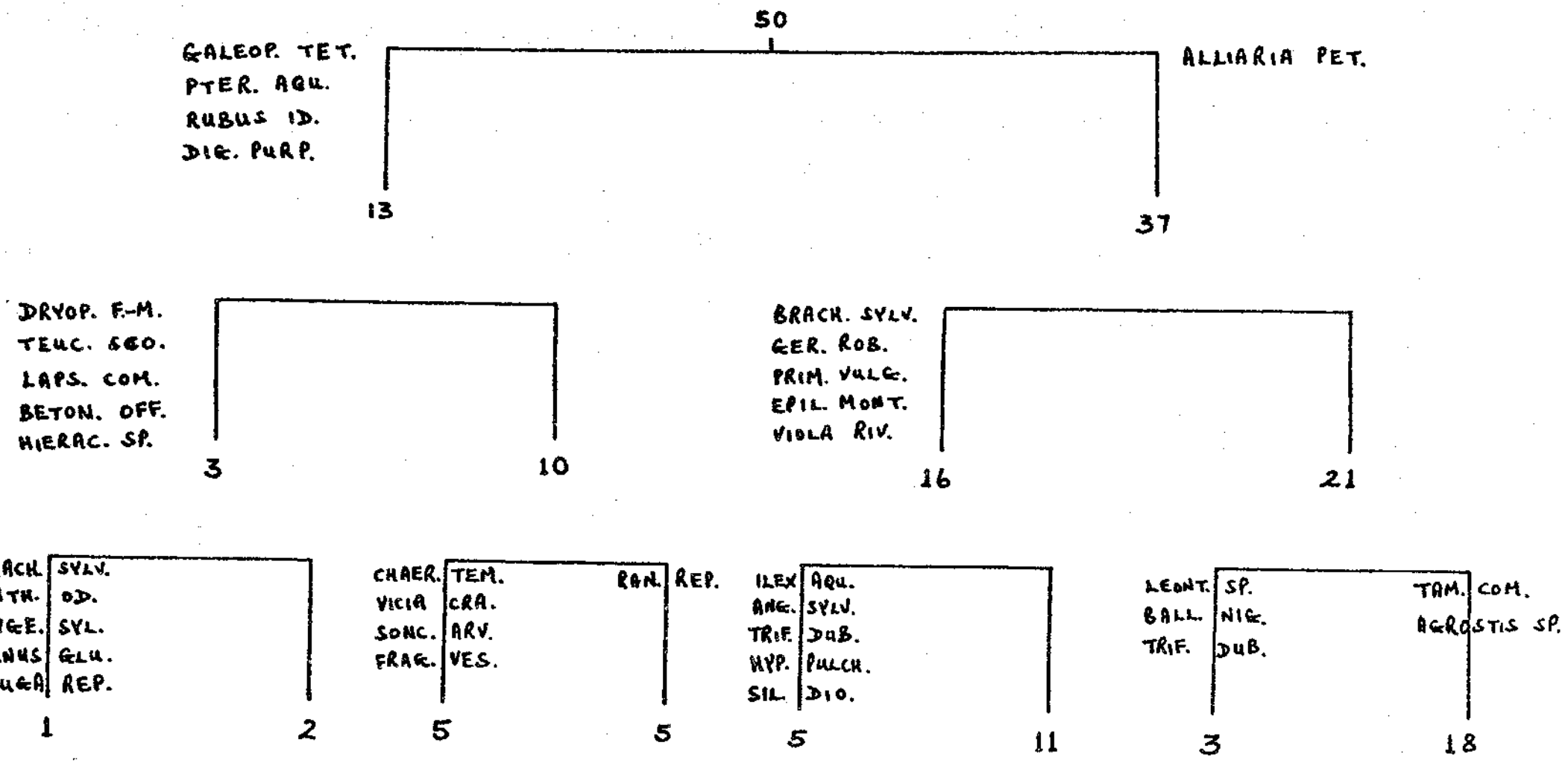


FIG. 4. POLYTHETIC ASSOCIATION ANALYSIS OF FLORISTIC DATA FROM 50 SITES.