

EXPERIMENTAL TAXONOMY OF STELLARIA SPECIES

A thesis presented in part fulfilment of the requirements
for the degree of Doctor of Philosophy in the Faculty
of Science in the University of London

by

RAM PUJAN SINHA M.Sc.(Patna)

Department of Botany & Plant Technology,
(Experimental Taxonomy)
Imperial College of Science & Technology,
London S.W. 7.

April ,1965

ACKNOWLEDGEMENTS

I have the pleasure to thank Dr.F.H.Whitehead M.A.,D.Phil. , for stimulating my interest in the topic of the present investigation, ^{and for} having acted as my supervisor / helpful suggestions during the period of experimentation and presentation of this thesis.I am thankful to Prof.W.O.James , F.R.S. ,for allowing to work in the Dept. of Botany & Plant Technology(Experimental Taxonomy) and to Prof.O.W.Richards, F.R.S. , for permitting me to use the facilities at Silwood Park, the college's Field Station ,where the work was mainly done.I am grateful to Prof.R.P.Roy,Ph.D.(Cantab.),for encouragement during the pursuit of this course and to the authorities of the Patna University for granting necessary leave .

Thanks are due to Dr.E.F.Warburg,Botany School, Oxford , and to Dr. S.M.Walters and Mr.P.D.Sell of Botany School ,Cambridge ,for lending the herbarium specimens used in the taximetric investigations. Thanks are also due to Mr. J.N.R. Jeffers,Forestry Commission,Farnham,Surrey, for having permitted to use the ICT-Sirius computer for computational work and also for necessary help in canonical variance statistic.

I am thankful to Mr.J.W.Siddorn for help in photomicrography and to Mr.A.Horne for general photography.I am thankful to to Mr.J.S.R.Hood and Mr. L.J.Bunning of the Experimental Taxonomy Laboratory for help in several ways.I am also thankful to some of my friends who have in several ways contributed to the successful completion of this work.

ABSTRACT

Stellaria media (L.) Vill. and the related species S. pallida (Dumort.) Piré and S. neglecta Weihe were studied in terms of their cytological features, morphometrical variation in herbarium specimens, growth behaviour and morphogenetic patterns. The number, general morphology and pairing behaviour of chromosomes at the prophase I of dividing PMCs and somatic metaphase were studied in different populations and found to be fairly uniform for each species.

S. neglecta and S. pallida had $2n = 22$ each whereas S. media had $2n=44$. Somatic chromosomes as well as meiotic ones at diplotene and diakinesis in S. media were dimorphic. Pairing behaviour in all the three species was found to be normal, S. pallida and S. neglecta had eleven bivalents each and S. media had twenty-two. Base number for the group is suggested to be eleven as against ten and/or eleven in previous reports and it is inferred that wider tolerance and hence plasticity, extended distribution, ubiquity and earlier sexual maturity of S. media are all probably due to enhanced vigour released as a result of hybridisation followed by polyploidy. Possibility of S. media being an allotetraploid with S. neglecta and S. pallida as putative ancestors has been considered probable.

These conclusions have been found to have corroborated the results of comparative culture and taximetical studies. At varying light regimes and concentrations of nitrogen and/or phosphorus S. media was found to have higher values of α , mean unit leaf rate and

and decreasing values of leaf area ratio all indicative of its higher efficiency in terms/parameters of growth and morphogenesis. It also has higher capability to exploit N , P and K. In terms of dry weight gain S.media and S. neglecta were found to be clearly separable from S.pallida . Enhanced morphogenetic activity, however, even under most depauperate conditions of growth was found to have conferred adaptative and survival advantages to S.media over the other two species.

Taximetical studies were based upon twelve variables all drawn from floral parts and canonical variances were derived from total variation calculated from determinantal matrix of in-between and within-taxa sum of squares. Using the methods of Rao and Bartlett , significance of some of the components was worked out. The three species analysis were found to be quite distinct. Principal component/ for the individual specimens was done which ensured the detection of mis-identification and reallocation to proper taxonomic position. This also indicated that morphometrically S.pallida is sharply distinguishable from both the other species. The tendency of the individual points for S.neglecta and S.media to form a cluster points towards the possible dominance of S.neglecta alleles in S.media.

C O N T E N T S

Title page, acknowledgements, abstract and contents.	Page 1
 <u>CHAPTER 1</u>	
Introduction.	
Boundaries between taxa, "Good" versus "Bad" characters.	9
Constitutive and non-constitutive characters.	10
Personal judgement in taxonomic delimitation.	11
Choice and concept of characters vis-a-vis purpose and procedure in taxonomy.	12
Concept of characters.	13
Canonical variance and weighting of characters.	14
Tolerance of objectivity of phenetic groups.	15
Electronic computers quicken the testing of validity of taxonomic discretion.	17
Phenetic grouping - an extension of Adansonian concept.	18
Marriage between concept and techniques.	20
Population versus individual in relation to quantitative measures of variability.	21
Material for experimentation.	25
 <u>CHAPTER II . Materials and methods.</u>	
Herbarium specimens and seeds.	27
Culture techniques.	29
Parameters used in the investigations.	39
Estimation of Nitrogen, Phosphorus and Potassium in the plant material.	42
 <u>CHAPTER III</u>	
Morphology and nomenclature of the species.	
<u>Stellaria media</u> .	48
A note on the treatment of <u>Stellaria media</u>	51
<u>S. pallida</u>	55
<u>S. neglecta</u>	60
Comparative diagnostic features	62
Distribution map of <u>Stellaria media</u> (L.) Vill.,	
<u>Stellaria neglecta</u> Weihe and <u>S. pallida</u> (Dumort.) Pire	64
 <u>CHAPTER IV</u>	
Cytological studies	
Chromosome number and morphology	67
Polyploidy	69
Cytology versus cryptic species	71
Mitotic studies	
Photographs of somatic plates	74

Table 1 showing various reports on the chromosome number of <u>S.media</u> (L.)Vill., <u>S.neglecta</u> Weihe and <u>S.pallida</u> (Dumort.)Pire Meiotic studies.	78
Photomicrographs of meiotic plates of prophase 1 of all the species .	
Fig. 7 early metaphase in <u>Stellaria pallida</u> .	81
Fig. 8. Diakinesis in <u>Stellaria media</u> .	82
Fig. 9. Early metaphase in <u>Stellaria neglecta</u> .	83
Fig. 10. Diplotene in <u>S.neglecta</u> .	84
Fig 11. Diplotene in <u>S.neglecta</u> showing euchromatic and heterochromatic zones .	85

CHAPTER V

Effects of artificial shading on the growth and morphology of the species .

Species in their habitats, and scope and purpose of the expt.	86
Experimental procedures .	88
Experimental results and derivations from them .	90
Graphs showing the values of α , Leaf area ratio and progress curves of dry weights .	97
Observations and discussions .	100

CHAPTER VI

Effect of various concentrations of N and P on the growth and morphology of the species .

Nitrogen .	107
Primary results and derived parameters from them .	111
Graphs of values of α , leaf area ratio and progress curves of dry weights and general discussion .	122
Photographs of plants grown at five different levels of Nitrogen .	
Phosphorus treatments, results and parameters derived from them .	128
Values of α at varying concentrations of P (Fig.21).	136
Progress curves of dry weights at different levels of P .	137

	7	
Progress curves of dry weights at varying levels of P(Fig.138).		138
Photographs of plants grown at varying levels of P.		139
Growth of <i>Stellaria media</i> at varying cons. of N and P both and their reciprocal combinations.		144
<u>CHAPTER VII</u>		
Uptake of P and K in culture solutions at varying levels of P and N.		145
Uptake of N,K, and P in soil cultures.		148
<u>CHAPTER VIII. Taximetical studies.</u>		
General introduction .		158
Methods in Numerical Taxonomy.		162
Canonical variate analysis.		165
Principal component analysis.		166
Characters used in the taximetical investigation.		169
Computations and results from the computer.		172
Computations with additional variable seed weight		185
<u>CHAPTER IX.</u>		
General discussion and conclusion.		205
<u>CHAPTER X</u>		
References.		216
Appendix.		

EXPERIMENTAL TAXONOMY OF STELLARIA SPECIES

CHAPTER I. INTRODUCTION.

Boundaries between taxa.

Formal taxonomy in its ultimate analysis deals with the study of individuals with a view to assigning them to the group of taxa recognised. An individual for the purpose is defined as one possessing physiological independence and lacking ^{any} some form of physiological relationship with others (Heslop-Harrison, 1960, p.13). The boundaries between taxa are made to coincide along the lines of greatest discontinuities (Whitehead, 1954). The selection of criteria along which to shape these lines of discontinuities is of paramount importance especially where taxa of specific and infra-specific categories are concerned. The validity and usefulness of taxa, as a matter of fact, depend upon the sound basis of selection of characters on which they are based.

"Good" versus "bad" characters.

To give permanence and sound basis, therefore, a skilled taxonomist always chooses characters which he terms as "good" and discards those which he considers as "bad". By "good" characters, as against "bad" ones, he means the characters which in their ultimate expression are but less modifiable by fluctuations in the factors of environment. Wernham (1912) considered "fortuitous" characters superior to "biological" ones as phylogenetic criteria because the former he thought as being merely due to inheritance while the latter ones he supposed to be attributes developed in response to stress to some particular biological function or physiological requirement. The terms

"fortuitous" and "biological" of Wernham (loc. supra cit.) were replaced by "constitutive" and "non-constitutive" respectively by Diels (1921).

Constitutive characters.

These characters are better as phylogenetic criteria and have no direct relations to either environment or some biological function. However, it is unfortunate that characters of this group find minimum use in the delimitation of basic categories, especially the taxa at or below the level of species around which most of the investigations of experimental taxonomy revolve. Mode of phyllotaxy, the numerical relations and symmetry relations in the flowers are some of the examples of this type of characters.

Non-constitutive characters.

These are the characters as have direct relation to some vital function or advantage. As phylogenetic criteria they are inferior to constitutive ones. They have been divided into the following sub-categories.

(a) Functional. They are intimately connected with some special function but are influenced by external conditions, e.g. the adaptation of flowers to particular insects, fruits to dispersal, etc.

(b) Epharmonic. They are apparently connected with the mode of life of plants, but nevertheless remaining constant under varying external conditions, e.g. the microphyllly of Ericoideae, the succulent nature of Crassulaceae, formation of bulbs in Oxalis, etc. These may be regarded as adaptations that have become more or less fixed.

(c) Adaptive. These characters show a range of quantitative variation within extremes of tolerance of the species. The absolute size of the plant as a

whole, leaf, flower and its constituent parts, seed and pollen grains, etc. are some of the examples of this group of characters. The use of the term "adaptive" for this group of characters does not quite sound to be appropriate and justifiable since epharmonic and functional characters are, as a matter of fact, equally adaptive. The term "adaptive" of Diels (loc. cit.) has been therefore preferred to and replaced by the term "plastic" (Sprague, 1948). In all general purpose and special classifications characters from this group find maximum applications.

Personal judgement in taxonomic delimitation.

Unfortunately the limit between most of the taxa, as laid down in the hierarchy of taxonomical nomenclature is largely determined by personal judgement. The relative importance of one and the same character has been variously estimated by different workers in the field. A particular single character or a set of a few characters, for example, in a group of plants may be regarded as more important than the others by one taxonomist who bases his taxa accordingly. Just another single character or a set of a few characters may be regarded as more important by another taxonomist in his scheme of taxonomic delimitation. Unless of course the characters under reference show complete correlation the taxa in the two systems of grouping will be quite different. This can be seen in the review of nomenclature of the species under investigation. Varied treatment of the same group of plants has given rise to several competing systems whose value it is difficult to assess. The number and status of taxa created in such groups depend upon the relative weighting of the characters of the individuals in the group. The characters

employed for the delimitation of taxa are mostly subjective, arbitrary and in most cases without any quantitative limit and as such they vary from worker to worker. This results in the same group of plants being treated in several ways. The literature on taxonomic research abounds in instances of "nomen nova", "stat. et comb. nov.", transfer, change of status etc. Instances are also not uncommon where one taxon has been split into several and vice-versa. This has created an impression in some quarters that taxonomists are no more than "lumpers" and "splitters". This attitude has given rise at most times to inflation in taxonomy (Harris, 1964).

The choice and concept of characters vis-a-vis the purpose and procedure in taxonomy.

Characters provide bases for all taxonomic delimitations and interpretations. What are the attributes as may be regarded as characters? How should they be treated? What is their relevance to the purpose in hand? Whether all the characters should be given equal weighting or there should be differential weighting of characters? These are some of the pertinent and controversial questions which taxonomists of the day are confronted with. Phenetic classification is the primary aim of taxonomy according to Davis and Heywood (1963). The phenons and the O.T.U.s in the numerical taxonomy are based upon taxonomic affinity (similarity) in numerical terms. The organisms are classified from a large sample of their characters. The groups (phenons) are polythetic (sensu Sneath, 1962, 1964) and natural in the sense that their members have mutually highest similarities. Phenetic groups are considered to be equivalent to "natural" groups (Sneath, 1964; Heslop-Harrison

1964) of the pre-Darwinian era. The Kansas group of numerical taxonomists headed by Sokal is making attempts at combining the phylogenetic and empirical approaches in taxonomy. The phenetic classifications (Sneath & Sokal, 1962; Sneath, 1964; Davis & Heywood, 1963) in all essential aspects is the extension of Adansonian classification. It differs from the pre-Darwinian natural classifications in that the affinity is determined mathematically by computers. The phenetic system is thus able to employ larger numbers of characters and imparts a greater degree of precision and objectivity to the taxa. It has the advantage of repeatability for future reference and the elements of subjectivity in the classification is minimised to a greater extent. It is swifter and more accurate than the intuitive methods.

Concept of characters.

The concept of characters as recognisable entities is the product of man's necessity to communicate and thus to describe. For this description and communication characters are needed. Characters may be quantitative or qualitative. Qualitative characters have been used in the past in description but they lack objectivity and precision. Therefore the trend in modern taxonomy is towards using quantitative characters. As pointed out by Fein (1961) our taxonomy by the seventies of this century would all be expressible in quantitative terms. The concept of character, as used in the numerical taxonomy varies from worker to worker. Sokal and Sneath (1962) and Davis and Heywood (1963) advocate for a unit character. If a composite character is used it must be broken up into unit characters. They define character as any quantitative attribute which a taxonomist separates from the individual

for the purposes of comparison. Cain (1959), however, considers unit character as any attribute which can be considered independent of others being considered simultaneously. The quantitative characters may again be "size" or "meristic" characters. Only "size" characters have been used in the present investigation as they provide continuous variables which have a tendency towards normal distribution. The characters in the present sense of the term may be drawn from a part of the plant either vegetative or floral.

The range and pattern of variables drawn from floral parts provide better characters for the purposes of phenetic classification.

Canonical variance and relative weighting of characters.

Several methods of expressing affinity or variability in mathematical terms are available. These methods will be described in the chapter on biometrical investigation. In the meantime it may be pointed out that a mathematical procedure is available by which an improved phenetic grouping could be achieved. This method has distinct advantages over the cluster analysis of Sokal and Sneath (1962). Instead of working out the percentage of similarity, total variability is calculated here. It also provides procedure for partitioning this total variability (in-between and within taxa) into several components. These components further sort out the characters which can account for the total variability.

A great caution has to be exercised in the selection of characters. It can be shown that the limits between the taxa may get blurred up if no selection of right characters has been made. This explains the fallacy of

equal importance being given to all characters. In spite of accuracy in computation the limit between taxa may not come out distinctly in the absence of right selection of characters. Machines can facilitate and hasten computation but can not replace the discretion which a taxonomist uses in sorting out and selecting characters.

Canonical variance analysis as used in the present investigation indicates that the load of discontinuity is not distributed equally on all characters. To find out the "fulcrum" or "fulcrums" along which taxa are balanced is the most important task in numerical taxonomy. This can be appreciated better by a taxometrician than a mere statistician or mathematician who deals with abstract mathematical ideas applicable only where rigorous uniformity is to be expected.

The phenetic classification as advocated by Sokal and Sneath (1962) and supported by several others may appear attractive but it definitely suffers from certain biological conceptual drawbacks. Those with insight in processes of evolution would definitely agree that the path of evolution and differentiation is not so uniform, smooth and simple as has been supposed by several biometricians who take an unrealistic view of things.

Furtherance of objectivity of phenetic groups.

Characters drawn from phenotypes may or may not show correlation to other attributes. Morphological concepts of species may provide a workable system where the discontinuities are sharp and steep but in "critical" or "problem" groups where the related taxa form a continuous spectrum, morphological limits between taxa may be obscured. In such groups,

discontinuity, if at all it exists, has to be sought along finer character gradients or along genetic, cytological, physiological or phytochemical aspects. In many cases species have been formed by intuitive methods but later investigations have suggested that they are actually aggregate species and segregates have been identified.

It is especially true where polyploidy is involved. From the days of Winge (1917) onwards the role of polyploidy in creating genetic barriers has been realised more so with the experimental synthesis of many such forms found occurring in nature. Hybridisation and polyploidy, no doubt, are important tools of speciation. They are macroevolutionary processes. In this context it may be said that between the forms with free gene flow and forms completely genetically isolated, there are several intergrading forms. How to dispose these intergrading forms off in the hierarchy of nomenclature is really a difficult problem. That is why the early enthusiasm of defining taxa (especially species) upon the basis of mutual fertility - sterility criteria has calmed down to a greater extent.

In the dynamic world of living organisms it is really difficult to have an ideally stable nomenclatural system. Nomenclatural procedures are only to facilitate communication but so far the changes taking place (both micro- and macroevolutionary) in them are concerned, they have to be understood by newer and more sophisticated experimental techniques. Gregor (1963) has rightly said that results of experimentation should be more utilised in understanding the nature of taxa rather than using to define them.

Computer quickens the testing of validity of taxonomic discretion.

Morphological continuity within taxa as assessed intuitively needs to be checked by sophisticated techniques of computer taxonomy. In many cases it may be detected that character gradients may be finer enough to expose taxonomic delimitation. Such cases of anomaly could be detected easily and quickly by the use of computers. These groups are to be assessed further in terms of their attributes using newer techniques of experimentation.

Sometimes (especially in the critical groups) the phenetic taxa may not coincide with the newer findings in the group. The differences in the genotypes are manifested more in terms of wider ecological and physiological tolerance, increased fertility and early sexual maturity, etc. How then are these findings to be reconciled in terms of phenetic groupings? We can indicate such groups and point out the attributes along which discontinuity could be discerned. The taxa of the phenetic grouping may or may not be phylogenetic (see Davis and Heywood, 1963).

As Sneath (1964) points out there are no objective checks to confirm this, especially in angiosperms where fossil findings are so meagre. Even in fossil forms the comparative morphology mostly provides evidence for assessing (speculating) phylogeny. Objectivity of the taxa however, can be appreciated with reference to other aspects of study.

Turrill (1939) found the "alpha" taxonomy changing under the impact of newer findings so as to take the shape of future "omega" taxonomy as he called it. He pointed out that our present taxonomy has made a little

headway towards that. This stage he calls "beta" taxonomy. As a concept of taxonomic principle it is a valuable contribution but it voices the cause of a simplicity long dead. The problem is not only of assimilating and absorbing newer findings in a system that seeks to define groups on the basis of discontinuity, howsoever small or artificial that may be. What is required is a technique sufficiently discriminating ~~as~~ to enable continuity, for example to be categorised and placed accurately within a reference system.

Many attempts have been made to define and re-define taxonomic species in the light of new experimental data. It has led to the realisation that this is an impossible and purposeless task. Every advance in taxonomy adds to the difficulty rather than mitigating it and this in itself is a just cause for suspecting that our current concepts are probably unable to give birth to practices capable of dealing with accumulating information. The number of characters to be used is limited by the patience of the investigator (Mayr, 1957). It is not possible to make a relevant choice of characters if the ultimate goal is completely natural classification (Lam, 1959).

Phenetic grouping - an extension of Adansonian classification.

Morphological and anatomical attributes have been largely made use of in all classificatory schemes including the phenetic or natural groupings in numerical taxonomy because of their ready accessibility. Other characters are increasingly being used but often the question has been raised whether the results would be acceptable for general purpose classification. It has often been tacitly assumed that natural groups would be morphologically

expressible and that they comprise non-overlapping groups. But these assumptions are open to question. As Lam (loc. cit.) points out all groupings must be compromises because of particular selection of characters and degree of precision with which they can be defined.

Maximum-attribute or phenetic classification has been taken to be most serviceable because it carries the largest number of informations (Gregor and Gilmour, 1941; Bremekamp, 1939; Davis and Heywood, 1963). Such classifications following Michael Adanson (1737 - 1806) give equal weighting to each character and the taxa are based upon the correlation of characters between them. They are polythetic and based upon overall similarity. According to Sokal and Sneath (1962) "no single attribute in theory is sufficient and necessary for membership in the group so long as the members share a high proportion of characters".

This classification is unacceptable to some taxonomists because they think it to be non-evolutionary and therefore non-phylogenetic. The romantic notions about the place of phylogenetic speculation in taxonomy are long overdue for abandonment (Heslop-Harrison, 1964). In angiosperms, classification based on phylogeny is unattainable except for special cases, and then mostly at or near the species level. Because of the complexity and multi-dimensional nature of evolutionary relationships, what pass for such classifications vary from unconsciously phenetic classification to distorted special classifications produced by unjustifiable weighting of characters.

The conversion of true classification with something that might

approach a phyletic one involves a whole series of problems of interpreting and weighting characters (Davis and Heywood, 1963; Heslop-Harrison, 1964). The construction of phylogenetic trees and shrubs is an intriguing activity: nevertheless it is not taxonomy, but merely one use of the data of taxonomy. A balanced appraisal of the potential role of new kinds of data in general taxonomy merits attention from all who would over-value the classificatory importance of one or a few specialised criteria.

Neither caryological nor phytochemical criteria have any special a priori claim to importance for comparative taxonomic purposes. It is surely an entirely valid conclusion, when both constitute merely an expression of the genotype in no way different from readily accessible morphological and anatomical characteristics. This phase of quantitative taxonomy deals with mathematical determination of affinity at all levels. The taxa here are constructed on the basis of mathematically determined similarity, the affinity being treated as an independent taxonomic dimension free from phylogenetic or other considerations. It thus involves a revision of the whole basis of taxonomic theory.

Marriage between concept and technique.

The traditional taxonomy based mainly upon the study of casually acquired herbarium specimens has been subjected to change of outlook by extending its aims and methods, enlarging its concepts, and improving its descriptive matter. The modern phase of taxonomy requires a close collaboration between the herbarium workers on the one hand and the experimentalists on the other. Herbarium workers and the naturalists are in a position

better than other botanists to suggest the groups which require intensive revision. The mutual co-operation, thus, between the herbarium workers and the experimentalists would go a long way ahead in solving many intricate problems of taxonomy dealing with the range, pattern and causes of variability in the "critical" groups. Turrill (1953) has rightly remarked - "This would by introgressive hybridisation of methods and ideas produce hybrid vigour in plant taxonomy (see Heslop-Harrison, 1960, p. VI). The main problem in the "critical" groups is to determine experimentally whether the indistinctness of discontinuity along which taxa could be shaped is due to incomplete differentiation, hybridisation or some other reproductive peculiarities which have created minor grouping of biotypes.

Population v. individual in relation to quantitative measure of variability.

Taxonomists, irrespective of their views on species, have come to realise the importance and usefulness of the study of population rather than single casual or fragmentary specimen accidentally acquired. This helps to study the variational anomaly in the group of plants under investigation. Use of some indefinite adjectives like bigger than, smaller than, etc. has created further confusion in the comparative description of some taxa (Whitehead, 1955). Apart from differences in the size of the flower, for example, in different individuals of the same species, even in the same individual flower produced early are significantly bigger in size than those in the later ones. This indicates clearly the confusion created by such subjective approach in the study of the taxa. To give precision and usefulness to various taxonomic categories particularly at or below the level of

species, it is therefore desirable that the range, nay the pattern of variation must be stated in precise terms.

Another important consideration in the type of the investigation as the present one is to analyse the causes of variation. Phenotypic variability in the plants may be caused due to variation in the environmental factors and also of genotypic pattern. Both of them when subjected especially to wider range tend to be normal in their distribution. Population of plants as examined in nature are the result of interaction between genotype and environment mediated through cytoplasm. In studying the range and pattern of variation, one has to go into the further details of its analysis because both phenotypic and environmental variabilities tend to be normal in their distribution.

This can be resolved by the comparative culture of seedlings raised from the seeds from various parts of the tolerance of the species. This helps in separating heritable from non-heritable variabilities, more so when the plants are grown over a number of generations. To arrive at such a conclusion the growing of plants for a number of generations is emphasised because instances are known where some of the characters artificially introduced in plant due to some variation in the environmental factors tend to be heritable up to a number of generations. In the case of barley, for example, it has been shown that early ripening is introduced by giving temperature shocks and this tends to be heritable up to several generations. This can be done by growing plants under the uniform climatic conditions where differences observed in the phenotype and biology of the samples could

be assignable to varying genotypic patterns. If the differences tend to disappear in toto, it means that plants are genotypically alike and various forms are the ecads of the same genotype. Thus comparative culture of plants is called for separating the causes of variability. This separation of genotypic variabilitics from the phenotypic ones constitutes one of the cardinal techniques of experimental taxonomy.

In the case of genotypic variations left over as remainder, genotype analysis is important. This gives a clue to the understanding of the pattern of genetic variation in the group of plants under investigation.

All variations assignable to ecological factors can further be subjected to analysis by varying individually one of the components of the environment whilst the remainder are kept constant. It is a well-known fact that every genotype has not one but a range of environmental conditions when viewed in terms of its ecological amplitude. This range within which it can grow successfully producing flowers and seeds is termed as the range of tolerance of the genotype under question. As a matter of fact the concept of range is in itself an abstract one. It is almost impossible to define range in terms of physical factors because of large numbers of variables being involved. It cannot thus be visualised what the reaction of a given genotype will be under different combinations of environmental factors. All that can be done by experimentation is to establish certain cardinal points in it which can be done by varying only one of the components whilst others are kept constant.

Range of tolerance and variation are genotypically controlled and

thus it can be appreciated that it is the breeding system which is important above all and controls the behaviour of plants in nature. The persistence of a given biotype in biological cotinuum depends primarily upon its breeding behaviour and the problem of speciation can be looked upon in the light of this. Speciation, of course, is an experimental term which means origin and development of reproductively isolated gere-pools. The level of variation at which a given taxon should be termed a species has to be decided according to the breeding system.

Apomicts have different means of variation as compared to amphimicts. Even in these two broad groups there are several breeding systems. It is a matter of common experience that even in apomicts there is marked phenotypic variability. Several may be the causes of this variability. Even in the vegetatively propagated crops like the rosaceous fruit trees, sugar-cane, potato, etc. sometimes sexual reproduction does take place leading to the production of one or several biotypes which become established as such. The breeders in such a group of plants/ artificially introduce such characters as high yield, better quality etc. and once this character is established they propagate the crop vegetatively. If these plants are allowed to reproduce sexually there is little chance of getting the useful parental characters.

In the amphimicts it is known again that there are several types of breeding systems and speciation is to be studied and looked into accordingly. No amount of observational technique can ensure to record the actual range of variation existing in certain groups of plants, and therefore

comparative culture can better give an insight into the variation within the group.

Material for experimentation.

In the light of above introductory considerations the three species of chickweeds were selected for the present study. These species belong to the subfamily Alsinoideae, tribe Alsineae and the genus Stellaria of the family Caryophyllaceae. They are included in the section ~~of~~ Eustellaria, sub-section Petiolares ~~Stellaria~~. The species under investigation are:-

- (a) Stellaria neglecta Weihe Greater chickweed;
- (b) Stellaria media (L.) Vill. Chickweed; and
- (c) Stellaria pallida (Dumort.) Piré Lesser chickweed.

They appeared to be suitable for the investigation of the type at hand for the following reasons:-

- (a) ^{They are found growing as weeds and ruderals and} ^{are} characterised by quicker establishment and shorter life-cycle.
- (b) All the three species are found growing in Great Britain and so the material for study can be easily acquired.
- (c) So far as known they are cleistogamous and therefore inbreeding forms. The species as far as known are mutually incompatible. This seems to have narrowed down the number of factors causing variation. Continued self-breeding in such form over a number of generations leads to homozygosity and thus to genetic uniformity. For the study of phenotypic variability such species as constitute the Stellaria media (L.) Vill. complex appeared to be quite suitable.

(d) They form a morphological cluster where subjective methods of assigning an individual to a known group does not work satisfactorily. This it was thought would provide a good material to test the occurrence of polyplotypes, if any, and range of variability.

MATERIALS AND METHODS

specimens

Herbarium/and seeds of all the three species were used . for the present investigation..

Their source , locality and dates of collection are being given below :

Herbarium specimens - They were all obtained from the Druce Herbarium , Botany School,University of Oxford and the Herbarium of the Botany School,University of Cambridge.The investigation was confined to the British forms only.An attempt was made to include in biometrical studies samples of specimens from all possible vice-counties within the zone of their distribution.In the case of Stellaria pallida(Dumort.)Piré coastal as well as inland forms were included.In all three species older as well as recent collections were included.Some of the earlier determinations of Dr G.C.Druce inter alia for specimens of the Druce Herbarium had been checked by Prof.A.R.Clapham mainly on the basis of size and tuberculation of the seeds and relative dimensions of sepals and petals.The earlier determinations of the specimens of S.pallida(Dumort.)Piré and S.neglecta Weihe from the herbarium of the Botany School ,Cambridge had been checked by Mr.P.D.Sell.This recent check on determinations of the specimens proved useful and facilitated further investigation.

The seeds - Seeds of Stellaria media(L.)Vill. were collected from plants growing in the vicinity of the Silwood Park during the autumn of 1962 and the following spring and summer of 1963 -'64.They were taken both from the sun and shade forms of the species.

These seeds in comparative culture under standard conditions in the glasshouse behaved morphologically and physiologically as if sampled from a single population. Live plants were also collected from v.-c.27(Norfolk) during the month of April, 1964 and grown in sand culture during the subsequent months. The soil used for the purpose was loam with appropriate amount of John Innes fertiliser. Morphology of the flower, vegetative parts and meiotic chromosome was found to be the same as ^{the} local forms.

For all cultural work seeds of S. pallida and S. neglecta were collected from v.-c.17(Surrey) during the months of April - June 1963 - '64. Seeds of S. pallida were also collected from plants growing on the glacial sands in the shade of Pinus sylvestris L near Sheltham Gate just over the culvert, the O.S. 1" Ref. being Clappers' Ford 965619. Seeds of this species were also obtained from coastal forms of the species from near Bledburg v.-c.27(East Norfolk). Live plants brought from the same site were also grown in sand culture in the glasshouse. These coastal specimens in their general morphology showed complete correspondence with the inland forms of v.-c.17 under reference. The number and morphology of meiotic and mitotic chromosomes afforded additional evidence in support of this conclusion.

Seeds of S. neglecta were collected mainly from two sites of v.-c. 17 O.S. 1" Ref. being Mytechett Gate 41/ 90656 and Emmetts' Mill 41/ 998618. In addition some seeds were collected from plants growing by the stream near the campus of the Weybridge Technical College, Brooklyn, Surrey. Meiotic studies included flower buds from these specimens also.

Culture techniques - Water culture was generally preferred to sand culture in the experimental investigation of growth behaviour. The main aim of these experiments was to record primary data for growth analyses and to compare these species in respect of some standard parameters of growth. The accuracy of value of these parameters available for comparison depends upon the uniformity of conditions under which the plants are cultured. The same degree of accuracy was necessary also where estimates of uptake of N, P and K had to be made in terms of unit weight and weight of the whole plant. The estimates of uptake of these elements were also made for all the three species cultured in glasshouse in soil samples from sites of S. neglecta and S. pallida. This was for a comparative study of uptake of these elements in nature and that under artificially controlled nutritional conditions in culture solutions. In addition these experiments were designed to show the comparative ability of each species to extract nutrients.

The extent and nature of variability of these parameters can best be understood in relation to varying levels of mineral nutrition only when conditions of culture are kept fairly uniform. Water culture provides a better medium where concentrations of various macro- and micronutrients and pH values can be maintained at a desirable level according to the aim and purpose of experimentation.

Plants were cultured in soil only where the experiments were designed to study the comparative effects moisture regimes on growth. The soil used for the purpose was mixture of sand and peat

with suitable combination of John Innes Fertiliser. All the three species were also grown in soil from the sites of S. neglecta and S. pallida.

Selection of culture solution - To select a balanced and suitable solution for culture is very important. The solution must contain all the macro- and micronutrients in a balanced proportion and and at the same time the pH also must be suitable for the growth of plant. In selecting a suitable solution frequent refernces were made to Hewitt's " Sand and Water Culture Methods used in the Study of Plant Nutrition" C.A.B. Technical Communication No. 22 ,1952; Arnon & Johnson (1942); Stafford & Magaldi(1954); Snaydon & Bradshaw (1961 , 1962); Rorison(1956) and Myerscough(1963). The table below shows the range of molarity of various nutrients in complete media for a large number of flowering plants(Hewitt 1952).

Table - 1

NUTRIENT	MOLARITY	
	Min.	Max.
K	0.002	0.010
Ca	0.002	0.005
Mg	0.001	0.010
NO ₃	0.005	0.010
PO ₄	0.00025	0.002
SO ₄	0.001	0.010
Bo	3 p. p . m.	
Mn		
Zn		
Fe	Dilue X 10 for deficiency levels.	

The table given above formed the basis for composition of solutions to be used in the culture experiments. The composition of the solution finally adopted for experimental work is being given below. This solution from here onwards will be known as normal culture solution. The dilution levels both for phosphorus and nitrogen were 1/10, 1/50, 1/100 and N/500.

Table - 2

Nutrients	Quantities in g./litre				
	N	N/10	N/50	N/100	N/500
1. $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	0.25	-----	-----	-----	-----
2. $\text{CaH}_4(\text{PO}_4)_2 \cdot \text{H}_2\text{O}$	0.25	-----	-----	-----	-----
3. $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	0.25	-----	-----	-----	-----
4. NaCl	0.08	-----	-----	-----	-----
5. KNO_3	0.70	0.07	0.014	0.007	0.0014
6. FeCl_3	0.005	-----	-----	-----	-----
7. KCl	-----	0.468	0.5096	0.5148	0.5189

For different deficiency levels of nitrogen the amounts of potassium nitrate had to be reduced and this created a corresponding deficiency of potassium also. This reduction in the amount of potassium was compensated by the addition of potassium chloride giving the same quantity of potassium. These adjustments can be read in Table 2 above. Manipulations in the concentrations of the salts did not bring about any significant change in the pH of the solution. These readings ranged from 5.0 to 5.6 and were supposed to be approximately uniform for the work. These

values were read on portable Pye Cambridge pH meter using combined glass electrode.

For deficiency levels of phosphorus the amounts of calcium phosphate were reduced and the corresponding deficiency made up by addition of calcium sulphate. As shown in table 2 . six salts were used in the composition of the normal culture solution but an additional one (KCl) had to be used for different deficiency levels of nitrogen. However, for different levels of phosphorus deficiency, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ already included in the make-up of the normal culture solution was used for making up the the corresponding deficiency of calcium. The deficiency levels of phosphorus were the same as that used for nitrogen, i.e. 1/10 , 1/50 , 1/100 and 1/500. The amounts of calcium sulphate and calcium phosphate at different levels of phosphorus deficiency are noted below in a tabular form.

Table - 3

Nutrients Quantities in g./litre at different dilution levels

	P/10	P/50	P/100	P/500
$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	0.4036	0.4173	0.4190	0.4204
$\text{CaH}_4(\text{PO}_4)_2 \cdot \text{H}_2\text{O}$	0.025	0.005	0.0025	0.0005

The rest of the salts and their respective amounts were the same as used in the normal culture solution. For all references from here onwards the normal culture solution will be represented by the notation N or P as the case may be and the various deficiency levels of nitrogen and phosphorus by the first letter of the element under investigation subscripted with the number representing the time of dilution of that element, i.e. N/10, N/50, N/100,

N/500 ; P/10 , P/50 , P/100 and P/500. The pH values at different deficiency levels of phosphorus ranged from 5.0 - 5.6 as in the case of nitrogen deficient solutions.

Both nitrogen and phosphorus deficient solutions

- Two types of solutions referred to above represent the deficiency levels with respect to either nitrogen or phosphorus. A third grade of solution was also prepared in which the same levels of deficiency was created with respect to both nitrogen and phosphorus. These solutions have been named as I - A , I - B , I - C and I - D ; the one with normal concentration of nitrogen and phosphorus being known as normal culture solution (N). These solutions were used for growing plants of Stellaria media only. The main purpose was to see the extent to which the species can withstand starvation due to both these macronutrient elements. These solutions differed markedly in their pH concentrations as can be seen from the table below. Therefore they were all adjusted to the same conc. of 5.5. In this and all other experiments where adjustment in pH was necessary, N/5 HCl or N/10 NaOH^{was} used .

Solution	pH (combined electrode)
I - A	5.1
I - B	5.6
I - C	7.8
I - D	7.2

Solutions with reciprocal levels of nitrogen and . P.

- A fourth type of solution with reciprocal levels of N and P was used for the deficiency level experiments with S. media .

These solutions have been named as below. The combinations of different levels and P of N/have been given therein against the solutions.

Table 4

Notations for the sols.	combination	pH readings
II - A	P. N/500	5.2
II - B	P/10. N/100	6.2
II - C	P/100. N/10	7.2
II - D	P/500. N.	7.8

The pH for all of them was adjusted to 5.5.

All the chemicals used were laboratory grade reagents so as to minimise the effects of impurities. Reagents of the same make and grade were used throughout for the sake of uniformity in all experimentations.

Calcium as calcium sulphate

Calcium sulphate was preferred to Cal. carbonate because the former readily makes calcium readily available to the growing plants without affecting the pH as does the latter. Calcium sulphate used was of Analar grade ($\text{CaSO}_4 = 172.18$) supplied by H. & W.

Phosphate as calcium phosphate

This is most readily available form of phosphate. It is never sufficiently dissociated to make calcium ion available (Russell, E.W. 1961).

This was of Laboratory Reagent Grade supplied by B.D.H. ($\text{CaH}_4(\text{PO}_4)_2 \cdot \text{H}_2\text{O}$, =252.09)

Mg as magnesium sulphate

Mg was used as $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ (=246.5) , Analar , H. & W. This makes both Mg^{++} and SO_4^{--} available readily to the growing plant.

Sodium as NaCl (=58.45) , Analar grade , H & W

This compound is a source of sodium because Cl^- ion like SO_4^{--} is not known to have appreciable effect on the growth of the plant (Russell, E.W. 1961).

Potassium and nitrogen as KNO_3 (=101.11), Analar Grade, H & W.

This provides both K and N to the growing plants.

Fe as $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ (=270.32) , H & W , G.P.R.

This is supplied in the Fe(ic) form (hydrated). For all other micronutrients reliance was put on impurities present in chemicals used which provided them to the levels required by the plants.

KCl (=74.5) , Analar , B.D.H. as substitute for potassium nitrate

This substitution was made in experiments with deficiency levels of nitrogen.

Preparation of the solution - In preparing solutions solvent used was water distilled in Manesty Water Still Model OOB Electrical. In all weighings accuracy was maintained up to the fourth decimal place of a gram. The machine used for the purpose was Stanton Electrical Balance Model B-20. The same machine was used for all weighings of plant materials also.

Dissolving the salts - The solutions were prepared in carboys or polythene aspirator bottles. Salts were added one by one and simultaneously the solution was kept stirred constantly by air-pump (diaphragm type AF-410). Sulphates of Ca and Mg were dissolved in the last followed by calcium phosphate.. These solutions were kept stirred overnight for the complete dissolution of salts. A freshly prepared solution was not used for more than six weeks.

The choice of containers for water culture

The boxes used were originally designed as food containers. They were adapted for large scale water culture of plants. They are square boxes of polystyrene. The dimensions are 12 X 12 X 5 cms. and capacity 600 mls. Polystyrene has the advantage of being chemically inert material and therefore suitable as a container for the culture solution. Just beneath the rim in the middle of one of the sides of the square was fitted an outflow tube. This was meant for overflow of any extra quantity of soln. above 600 mls. Overflow tubes in all the boxes were fitted in identical position of the boxes. This uniformity was maintained because the level of the solution inside the box was maintained by this tube.

Painting the boxes - The boxes were open at the top. The outside of the bottom surface and all the vertical faces except one were painted black to make the chamber light-proof from four sides. The remaining fifth side was covered with black cartridge paper held in position by rubber bands. This was necessary to minimise the algal growth in the solution.

Inspection window facilitated the periodical examination of the progress of root development and to distangle the roots of the individual plants when getting mixed up with one another. Utmost care was taken in applying the paint in a thin but uniform layer. Boxes were thoroughly examined before use and if the paint at places had become faint permitting light through the sides of the box, it was repainted and the sides were made uniformly dark. While applying paint to the boxes care was taken to ^{avoid} any paint getting upon or inside the rim. The chemicals in the paint, if they get into the solution, may grossly upset the growth of the plants.

Fitting polystyrene foam bases - Another step in the preparation of the boxes was the cutting and the fitting of the foam bases. These bases were cut from the polystyrene foam sheets. Five bases were glued in their position inside each box. Two of these were glued just on the inner wall by the sides of the inner end of the overflow tube at the same level as the tubes. Three bases of the similar type (c. 1 X 1 X 0.7-1.0 cm.) were fitted on the inner sides of the other three vertical faces. The bases were glued to the sides of the boxes with Rawlplug Durofix.

Preparation of the lids - The lids were each a piece of polyvinylchloride backed by fiber glass matting (Type GM, Part No. GM2, Holt Product Ltd, New Addington, Surrey). The fiber glass matting was glued to the p.v.c. lid with durofix putting small blocks of it at places. The Durofix was allowed to dry for about an hour. The lid was then ready for use. In putting the Durofix at the back of the lid care was taken not to seal off the bigger

holes except at the corners. The lids when cut to size from p.v.c. sheets were perforated with holes of two sizes, smaller holes were .0.3 mm. and bigger ones 0.7 - 0.8 mm. in diameter.

GROWTH ANALYSIS

Growth analysis is customary way of studying the performance of plants in terms of various vital processes in relation to the factors of the environment. The ultimate form of the plant is the result of sum total of its performance in terms of vital processes in relation to environmental complex. Considerable analysis of each into its major components is inevitable. However, as stated by Evans & Hughes (1961), multiplication of observations and too fine an analysis would merely confuse. Important attributes of the plants must be distinguished to be related to the aspects of the environment which have important effects upon them. The progress curve of the dry weight and leaf area show in simplest terms the performance of plants, but in addition there can be derived from the primary data a number of relations falling into two types as follows:

Those relating to the morphogenetic condition of the plants are -

(a) percentage of dry weight in total fresh weight of leaf, stem and root;

(b) the fraction of total dry weight to be found in the leaf, stem and root (leaf, stem and root weight ratios) ;

(c) the ratio of total leaf area to total plant dry weight (leaf area ratio) and

(d) the ratio of leaf area to leaf weight (specific leaf area).

Those relating to growth processes are -

- (a) mean relative growth rate(MRGR)in dry weight of the plant as a whole;
- (b) MRGR of individual parts and
- (c) rate of increase of dry weight wt. per unit leaf area (mean unit leaf rate or net assimilation rate).

The RGR in dry weight has long been realised to be a function of great biological significance ,integrating as it does the resultants of a great variety of vital processes .This ratio ,however, is composite in its make-up and therefore creates difficulties in analysis. The effects of environment are better understood by breaking it down into components , analysing each separately and then recombining the results. The RGR of individual parts is also important but not easy to analyse separately .The plant grows as an entity as a whole and RGR of one part must be related to that of the rest.This brings back to the complexities just mentioned.

In the present investigation a few of the parameters , as have been thought to be meaningful in comparing the performance of the species, have been used.The main purpose was to see whether these species deserve the rank assigned to them if judged in terms of values for these parameters. It may happen that when related species (as judged from phenetic similarity)are cultured under identical conditions of the glasshouse they may not have significantly different RGR values.

However, it is possible that their morphogenetic conditions may be different. This may be due to difference in the period of sexual maturity and thus productivity. Period of sexual maturity and fertility balance are two important markers for the morphogenetic condition of the plant. Sexual maturity is a function of hormonal balance which again is related to age, environmental condition and genetic make-up .

When plants were cultured under the standard conditions of the glasshouse it was found that in spite of morphological similarity the species differed markedly in behaviour of flower production. As an accompaniment to this followed the differences in the values of α . This is an integrated expression for the morphogenetic condition of the plant and is also used for predicting the future performance of plants in terms of yield etc. (sensu Whitehead & Myerscough 1962).

Parameters used in the present investigation

- (1) Shoot/Root ratio which is the ratio of dry weight of shoot in mgs. / dry wt. of root in mgs.
- (2) Leaf area ratio , i.e. the ratio of total dry wt. in mgs. to leaf area in cms.²
- (3) The ratio of MRGR(mgs./mg./ week) to MRGR of leaf area increase (cms²/ cm² / week). The ratio has been termed α by Whitehead & Myerscough (loc. cit.).
- (4) Mean unit leaf rate (or net assimilation rate) expressed as mgs./ cm² / week .

The notations used and the derivation of expression for them are as follows:

(1) The leaf area ratio

$$\frac{\text{Mean total leaf area per plant in cm}^2}{\text{Mean total dry weight per plant in } 10^{-3} \text{ gms}} = \frac{\bar{L}_A}{\bar{W}}$$

(2) Shoot/root ratio

$$\frac{\text{Mean dry weight of shoot per plant in } 10^{-3} \text{ gms.}}{\text{Mean dry weight of root per plant in } 10^{-3} \text{ gms.}} = \frac{\bar{S}_W}{\bar{R}_W}$$

(3) $\frac{\text{Mean relative growth rate}}{\text{Mean relative rate of leaf area increase}} = \alpha$

(a) Mean relative growth rate $\bar{R}$ over a time interval $t'' - t'$ is derived from R the relative growth at any instant as follows:

$$R = \frac{dW}{dt} \cdot \frac{1}{W} \quad \text{where } W = \text{total dry weight of plant at time } t.$$

$$\bar{R} = \int_{t'}^{t''} R dt = \int_{W'}^{W''} \frac{dW}{W} = \log_e W'' - \log_e W'$$

As shown by Fisher this requires no assumption regarding the change of W with time.

(b) The mean relative rate of leaf area increase likewise over an interval of time $t'' - t'$ can be derived from R_{LA} the relative rate of leaf area increase at a given constant as follows:

$$R_{LA} = \frac{d L_A}{dt} \cdot \frac{1}{L_A}$$

where L_A = leaf area of plant at time t .

$$R_{LA} = \log_e L_A'' - \log_e L_A'$$

$$a \text{ is now } = \frac{\log W'' - \log W'}{\log L_A'' - \log L_A'} = \frac{\log_e W'' - \log_e W'}{\log_e L_A'' - \log_e L_A'} = \frac{\bar{R} \text{ (mgs./mg./week)}}{\bar{R}_{LA} \text{ (cms.}^2\text{/cm}^2\text{/week)}}$$

(4) Mean rate of increase of dry wt. per unit leaf area (mean unit leaf rate or net assimilation rate)

$$= \frac{1}{L_A} \cdot \frac{dw}{dt} \dots \dots \dots (1)$$

Some authors assume E to be constant (unpublished lectures of Briggs, see also Evans & Hughes 1961) in that case

$$E \int_{t'}^{t''} L_A dt = \int_{W'}^{W''} dw \dots \dots \dots (2)$$

In case of some rapidly growing plants mean value of E for a single day may be obtained but weekly periods are more usual. The mean value of E , E_m is then required such that

$$E_m (t'' - t') = \frac{t''}{t'} \frac{Edt}{t'} = \frac{W''}{W'} \frac{dw}{L_A} \quad (3)$$

Williams assumed linear relationship between L_A and W and then

$$E_m (t'' - t') = (\log_e L_A'' - \log_e L_A') \frac{(W'' - W')}{(L_A'' - L_A')} \quad (4)$$

where W' , L_A' and W'' and L_A'' represent respective values at the first and the second harvest.

Briggs has shown that if it is assumed that $W = a + bL_A^2$, then

$$\text{then } E_m (t''-t') = 2. \frac{W'' - W'}{L_A - L_A'} \quad (5)$$

The mean unit leaf rate can be calculated in several ways but the formulae (4) and (5) given above been used in the present investigation.

Estimation of N, P and K in the plant material

All the three species were grown in culture solution using different concentrations of N and P and amounts of N, P and K estimated in them. The uptake of these elements was also estimated in ^{plants grown in} soils from the sites of S. pallida and S. neglecta.

Milling the plant material - Plant materials were kept in an oven at a temp. of 80° C. for twenty-four hours and then powdered in grinding mill and passed through 60 B.S. sieve. The powder was used for the estimation of the elements under investigation.

Procedure for the estimation of nitrogen : The method employed involves the conversion of plant material into ammonium sulphate by addition of conc. sulphuric acid in a Kjeldahl digestion flask. An aliquot of the solution was then transferred to the outer chamber of Conway Micro-diffusion Unit and its ammonia released by addition of alkali, to be absorbed in the central chamber of the unit. This was then titrated against N/50 HCl.

0.2 gm. of plant material was weighed out on a small rectangle of Whatman No. 42 filter paper and was carefully slid into Kjeldahl flask (30 mls.) , 1.0 gm. of micro-Analar potassium sulphate and 0.01 gm. of selenium dioxide were then added. The content was then moistened with a few drops of water delivered from a . . . pipette. It was allowed to stand for a few minutes for water to penetrate the plant material. After adding 5 mls. of conc. micro-Analar sulphuric acid the content was heated slowly at first and more strongly then on the digestion rack. The flask was rotated from time to time. The heating was continued until the content was clear , and then for a further period of one hour. It was then diluted with little water and the contents filtered in a 50 ml. volumetric flask. The filtrate was diluted to 50 mls.

The titration : Into the inner chamber of micro-diffusion unit 1. ml. of boric acid was run (this need not necessarily be accurate because its purpose is merely to absorb ammonia). In the outer chamber was run 2 mls. of digest solution . The glass lid was then smeared with vaseline and placed over the unit. The unit was slightly tilted by resting it on a separate spare lid and the lid was sufficiently displaced to allow introduction of pipette tip. 1 ml. of 50 % KOH soln. was then rapidly delivered into the outer chamber. The chamber was then re-covered quickly. The KOH soln. was merely used to release ammonia from the digest solution and therefore accurate measurement was not necessary. An ordinary graduated 1 ml. pipette was therefore used for the purpose. The unit was rotated 10 - 20 times to ensure mixing of alkali and digest . The amount used in the outer chamber was 2 mls. and therefore a period of three hours was allowed for absorption of ammonia.

The solution in the inner chamber was titrated against N/50 HCl. The original colour of the mixed indicator as made up was pale red. When ammonia was absorbed the colour was pale green. When one titration was completed, the final colour reached was used as a sample for the rest of the analyses in the batch. The colour changed from pale-green to an almost colourless before the tint of red could be detected.

Determination of phosphorus in the plant material

The colorimetric method used for the estimation of phosphorus uses the unreduced vanadomolybdophosphoric yellow colour. The advantage of this method over various blue reduced molybdate complex methods and are - (a) greater simplicity / rapidity of determination because of only one mixed reagent being used instead of usual three or four, (b) greater stability of yellow colour as opposed to blue colour. (this colour remains unchanged for about a week or even more) and greater (c) freedom from interference. Its major disadvantage is that it is relatively insensitive (approx. 1/10 the sensitivity of the blue methods (for full comparison see M.L. Jackson's "Soil Chemical Analysis", Constable 1958)).

Ashing the plant material: 0.5 gm. of plant material was weighed out. It was placed in a muffle furnace initially at a temperature of 300° C and then slowly raised to 450° C. The crucibles were removed after twenty-four hours and cooled. To the ash in the ^{crucible} 2 mls. of water and 0.5 ml. of 15N nitric acid were added with great care. The solution was then filtered in a 50 mls. flask using Whatman No. 42 filter paper and made up to the mark with water. The same ash solution was also used, with suitable dilution for determination of K by flame photometry.

10 mls of ash solution were pipetted into a 50 ml. flask. To this was added 10 mls. of combined reagent and this was made up to the mark until the colour began to develop. It was read after one hour. Standards were prepared in the same way but using 2, 4, 6, 8 and 10 mls of standard 50 p.p.m. P solution. A blank was also prepared using reagent and water only and this was used to set the zero of the EEL colorimeter. A calibration graph for EEL reading v. ppm. was drawn. The unknowns were read and their content determined from calibration curve. Ilford OB10 blue filter was used for the reading.

Preparation of HNO_3 -vanadate-molybdate reagent : Solution A was prepared by dissolving 25 gms. of ammonium molybdate in 400 mls. of water. Solution B was prepared by dissolving 1.25 gms. of ammonium metavanadate in 300 mls. of boiling water. Solution B was then slowly cooled and 250 mls. of conc. HNO_3 was added to it. It was then cooled to room temperature and finally solution A was poured into B and mixture diluted to 1 litre. It was stored in dark bottle.

Preparation of K standard soln. for the EEL photometer

The same ash solution as prepared for the estimation of P by EEL colorimeter, was used for the estimation of K flamephotometrically. Since the flame photometer measures the concn. of K in terms of the quantity of element itself in solution, standard soln. prepared from KCl were made up to contain $1\text{mg}/100\text{ mls.}$

Calculation : 0.477 gm. of dry Analar KCl was accurately weighed and dissolved in pure distilled water, washed in a 500 mls. flask and made up to mark with pure distilled water. To obtain the necessary standard solution for use with flame photometer this stock solution was diluted 1: 50.

Atomic wt. of K = 39.1

Mol. wt. of KCl = 74.56

Therefore, 0.477 gm. of KCl contains $\frac{0.477 \times 39.1}{74.56} = 0.25$ gm. of K.

Thus 500 mls. of solution will have 250 mgs. of K or 50 mgs./100 mls.

Dilution of 1 : 50 gives a standard solution of 1mg./100 mls.

CHAPTER III. MORPHOLOGY AND NOMENCLATURE OF THE SPECIES.

Stellaria media (L.) Vill.

There has been much confusion over the nomenclature of this species as it is understood in the present context. Stellaria media was described under the basionym Alsine media L. by Linnaeus in his Fl. Lap. 147 (1737) as follows:

" 186. ALSINE foliis ovato-cordatis *

α Alsine media Bauh. pin. 250.

Alsine minor Lind. wiks. 2.

Alsine chamaedryoides spec. Till. ab. 3.

Alsine. Frank. spec. 2. Till. ic. 75.

β Alsine altissima nemorum Bauh. pin. 250.

Alsine maxima solanifolia Montz. pug. fig. 2.

Alsine minor sylvestris Rudb. Vall. 2.

hort. 5. Lind wiks. 3.

γ Crescit (α) ubique, praefertim ad latera Alpium.

δ Unicam eandemque (α β) esse plantam."

This basionym has again been used in Linnaeus's Sp. Pl. 272 (1753) as follows:

" (1) media. 1. ALSINE petalis bipartitis, foliis ovato-cordatis.

Fl. Lapp. 186. Fl. Suec. 369. Hort. Cliff. 173. Gron. virg. 161. Roy lugdb. 449.

Alsine media Bauh. pin. 250.

Alsine minor Dod. pempt. 29.

Habitat in Europae cultis. . "

The only other author to have used this name is Velloso who has described the species in his Flora Fluminensis, 127 (1825). Using Linnaeus's type specimens, collections and concepts, Cyrillo transferred the specific epithet A. media L. to Stellaria media (L.) Cyr. He appears to be the first author to have used this binomial. An account of this was published in his Charact. Comment. 36 (1784). His concept of the species, however, includes only the forms with ten perfect stamens. He himself comments in his description that in Linnaeus's previous collection of Stellarias forms with ten perfect stamens were very common which he later transferred to the genus Alsine.

Cyrillo, however, is inclined to restore the forms with ten perfect stamens, deeply bifid petals, three styles etc. to Stellaria media (L.)Cyr. From this description it would appear that his concept of the species is rather narrow and limited as compared to those of Linnaeus (loc. cit.), Villars (1789), Sibthorp (1794), Velloso (loc. cit.), Smith (see Lejeune and Courtois's Fl. Bel. II, 90 (1828); also Bluff and Fingerhuth's Fl. Germ., I, 560 - 561 (1825)), Chater and Heywood (1964) and even Mayer (1952) who treats S. neglecta Weihe as a variety of S. media (L.) Vill.

Cyrillo's nomenclature of the species, however, can not be appropriately adopted for the British forms of the species which all have less than ten perfect stamens, the commonest number being 3 - 5. It appears to approximate the characters of S. neglecta Weihe. The name S. media (L.) Cyr., Charact. Comment. 36 (1784), being earlier could have found priority but presumably for reasons given above recent manuals on British flora

(Clapham, Tutin and Warburg, 1962; Dandy, 1958) as well as continental and European flora (Weimarck, 1963; Mayer, 1952; Chater and Heywood, 1964 in Fl. Eur.) adopt the combination S. media (L.) Vill. Hist. Pl. Dauph. 3, 615 (1789). Cyrillo's concept excludes the British forms of the species and probably typical forms of S. media from other countries also.

The basionym Alsine media is presumably correct because S. media as at present understood is the only species occurring in Lapland (the locality of the basionym). The typification therefore appears to be correct. The two species S. media and S. neglecta have often been confused one for the other mainly on the basis of number of stamens and relative lengths of sepals and petals. In the present investigation (see chapter on cytology) it has been shown that although the two species morphologically merge into each other, they have different and distinct genotypes and should therefore be regarded as distinct species. Cytological findings find support from taximetical and physiological investigations. So far as British specimens are concerned, forms with ten perfect stamens, petals more or less equalling sepals and found inhabiting the margins of streams, lakes etc. are clearly separable from S. media. In general facies both these species resemble each other more closely than each one of them separately to S. pallida.

A chronological list of synonyms and partial synonyms is given below. Some of these synonyms are obligate but most of them appear to be facultative synonyms.

- (1) Alsine media L. Fl. Lapp., p. 147 (1737).
- (2) A. media L. Sp. Pl., I, 272 (1753).

- (3) Stellaria media (L.) Cyr. Charact. Comment., p. 36 (1784).
- (4) S. media (L.) Vill. Hist. Pl. Dauph. 3, 615-616 (1789). Dandy, L.B. Vas. Pl. Ed. I (1958). Clapham, Tutin & Warburg, F.B.I., 306-307 (1952) and 242-243 (1962). Mayer, Pl. Sl. Terr. 52 (1952). Chater & Heywood, F. Europeae, 134 (1964). Weimarck, Skane's Flora, 268 (1963).
- (5) S. media (L.) Sibth. Fl. Oxon., 140-141 (1794).
- (6) Alsine media (L.) Vell. Fl. Flum., 127 (1825).
- (7) Stellaria media Wight ex Edgew in Hook. f. Brit. Ind. 1, 229 (1884).
- (8) S. media (L.) Smith, Smith britt: 473. Lejeune & Courtois, Fl. Bel. II, 90 (1828). Bluff & Fingerhuth, Fl. Germ. I, 560-561 (1825).

A note on the treatment of this species in Flora Europeae (1964).

The three species Stellaria media, S. neglecta and S. pallida have been treated in Stellaria media group (3 - 5) in Fl. Eur. Almost all the characters show overlap and it has been pointed out that morphological distinction is possible only when all relevant characters are considered together. The three species have been separated on the basis of hairiness, number of stamens, size of seed and relative lengths of sepals and petals and comparative size of the plants on the whole for all the three species.

The treatment of the species S. media (L.) Vill. does not appear to be satisfactory. The upper part of stem in S. media sp. media is supposed to have 1 - 2 lines of hairs. The British form of the species come under

this description. All the herbarium specimens of this species used in biometrical investigation (see chapter on taxometrics) are characterised by possession of petals. The ratio of sepal/petal lengths in herbarium specimens work out to be higher because petals are more delicate and as such get shrunken and shrivelled more than sepals. The length of petals in live plants varies from shorter than to more or less equal to the length of sepals. No British form of the species has been found to be without petals. However, the creation of variety S. media subsp. media var. apetala Gaudin, ^{may be} appears to be based ^{on a} probably upon some earlier erroneous description. So far as the number of stamens is concerned it has been said to be "(0) 3 - 5 (10)". The usual number is 3 - 5 and the forms with 0 and 10 stamens if at all can be found, would probably be ~~rather~~ ⁱⁿ in description rather than actual existence. In all herbarium specimens examined and in personal collections, the author has not come across either pistillate forms or forms with ten stamens. It is therefore suggested that these numbers may be deleted from the description. Haskoll (1949) reported the mean number of stamens 3 - 4 based on scorings made from different population samples from various parts of England as against the numbers 3, 5 or 10 noted (and/or copied) in different Floras. His observations have since been confirmed by Davis and Heywood (1963) with reference to northern populations of Stellaria media (sensu stricto). Part of the confusion in many Floras has been due to inclusion of S. neglecta as a variety of S. media.

Stellaria media with $2n = 44$ (Sinha and Whitehead, under publication in New Phytol.) can not be cytologically confused with S. pallida (Dumort.) Piré which has $2n = 22$. Certainly this inclusion of apetalous forms in

S. media appears to have been due to some confusion. Any such form which has been on some obvious morphological basis regarded as S. media var. apetala Gaudin rather than S. pallida or S. apetala should cytologically and morphometrically be investigated. It is suggested that until then S. media ssp. media var. apetala Gaudin may be treated with S. pallida (Dumort.) Piré.

S. media subsp. postii Holmboe Berg. Mus. Skr. I (2): 70 (1914) was established by Holmboe in honour of G.E. Post. He considered this subspecies to be synonym of S. media (L.) Cyr. and S. media var. pubescens Willd., as noted in the protologue of the original diagnosis of the subspecies. The characters spread out in the original diagnosis of Holmboe (loc. cit.) do not quite agree with those given in Flora Europaeae. The number of stamens for example, has been noted to be 5 - 10 as against constant number ten in the diagnosis of the author. This needs to be clarified. The length of stem similarly has been given as up to 60 cm. as against up to 50 cm. in the original diagnosis.

The subspecies S. media ssp. cupaniana (Jordon and Fourr.) Nyman. Consp. 111 (1878), appears to have been based upon Jordan and Fourreau's description of Alsine cupaniana in Brav. Plant. Nov. II, 19-20 (1868) and Nyman's Consp. Fl. Eur. (1868) (loc. supra cit.). The qualifying measures of plant-parts as given in Fl. Eur. do not appear to have been mentioned in either of the above references on which this description appears to have been based. They on the other hand, surprisingly fit with the diagnosis of S. neglecta Weihe. Alsine cupaniana as noted by Jordon and Fourreau (loc. cit.) is a ruderal in parts of Sicily near Panorum. This has been considered to be a synonym of Alsine major Cupani, A. media var. grandiflora Guss. and

A. grandiflora Ten.

This form has been separated from A. media by seeds twice as big, anthers bright purple as against dull red of A. media, subcordate leaf base, larger corolla and broader petal lobes. Nyman's nomenclature is based upon the same concepts and specimens. He has only transferred A. cupaniana to S. cupaniana. Rather S. cupaniana of Nyman is presumably an obligate synonym of A. cupaniana.

Although reported from different geographical areas the taxonomic status of these two subspecies appears to be non-conclusive. Unless cytological, morphometrical and physiological studies of these forms are made, it would probably be advisable to treat them with S. neglecta Weihe. As pointed out earlier, cytological investigations and comparative culture would make their position clear. That S. media ssp. postii is a form of S. neglecta is probable because Holmboe in comments following his diagnosis states that this subspecies agrees with S. neglecta in all essential respects except in hairiness of stem. He, however, treats S. neglecta as a ssp. of S. media. This creates an impression that splitting of taxa only on hairiness or some such highly subjective character should always be checked by experimental methods. Hairiness or such other characters in themselves are highly plastic. The same genotype in relation of its adaptation to varying conditions within the range of tolerance may produce several phenotypes and delimitation of taxa on such characters would definitely lead to never-ending task in taxonomy. The creation of species, for example, in Hieracium, Rubus, Crataegus etc. has exposed the conceptual and methodological imperfection of

the classical taxonomy based exclusively upon morphology.

Characters should be looked into their retrospect of adaptative significance and range of expressibility. Sometimes forms of apparently similar morphology have been found to have possessed steep genotypic discontinuities and to have differed in their physiological, edaphic and genetic behaviour. These points of discontinuities could be discernible only when such forms are subjected to comparative culture and also investigated cytogenetically. It may be noted that suggestions on the taxonomic treatment of forms from outside Britain are based upon the experience on the British form of the species. The present investigation is based exclusively upon the available forms from Britain.

Stellaria pallida (Dumort.) Piré.

This species was supposed to have been described under the basionym Stellaria apetala Ucria, Römer Archiv für die Botanik, I. I, 68 (1796) by German worker Ucria as follows:

" 11 Stellaria apetala Ucria. Prostrate, foliis immis subpetiolatis, summis sessilibus, floribus apetalis." i.e. Prostrate, lower leaves subpetiolate, upper ones sessile, flowers apetalous.

The specific epithet S. apetala of Ucria has ever since been used in different senses by different taxonomists. Some have used it as a specific epithet (either in the same sense or in different senses) whilst others have used it either as subspecific or varietal epithet.

The name Alsine pallida was given by Du Mortier for Belgian forms of the species and the diagnosis was published in his Comp. Fl. Belg. II,

90-91 (1828) which runs as follows:

" 784.

A. pallida Dumort. l.c. - caulibus filiformibus, foliis ovatis-acutis, floribus apetalis, pedunculis fructiferis rectis. - In cultis solo arenoso. fl. Martio - Maio "

Explanation to symbols -

Signum indicans speciem rursus inquirendum.

Planta monocarpica, annua.

The same diagnosis was published with some comments again in Bull. Soc. Bot. Belg. 12, 176 (1873). This species of Du Mortier was transferred to the genus Stellaria by Piré, an account of which was published in Bull. Soc. Bot. Belg. 2, 49 (1863). The binomial adopted was S. pallida (Dumort.) Piré. This name has been used for the British form of the species by J.E. Dandy in L.B.V. Pl. (1958). The name adopted by Clapham, Tutin and Warburg, F.B.I. 306-307 (1952) is S. apetala Ucria incl. S. pallida (Dum.) Piré and S. Boraeanae Jord. The same authors have used the combination S. pallida (Dum.) Piré, ibid. II, 242-243 (1962) with S. apetala auct.; incl. S. Boraeanae Jord. as synonym.

Some taxonomists in Britain (Chater, Heywood, Dandy, Meikle and others) observe a distinction between S. apetala and S. pallida. Ucria's and other authors' S. apetala have therefore been excluded from the synonym of S. pallida (see Fl. Eur. I, 134). According to them the type for S. apetala Ucria is S. media L. They consider that Ucria's mis-identification and thus mis-naming has ever since been wrongly followed in some

subsequent references and manuals. These wrong identifications are thought to be S. media var. apetala Gaudin (1828). Ucria's nomenclature, therefore, in spite of being earlier has been abandoned as it is supposed to have been based upon wrongly identified specimens.

No specimens of this description (as followed in Fl. Eur.) have been found either in the lots of herbarium materials examined or in the populations of plants observed so far by the author. It is felt that S. apetala Ucria or S. apetala auct. may be regarded as a synonym of S. pallida (Dumort.) Piré. As a matter of fact both the epithets S. pallida and S. apetala, which are adjectival forms but ~~are used here in the genitive case,~~ ^{why not in the} are misnomers. This species of Stellaria as seen in comparative culture and in natural habitat is neither pallid nor completely apetalous. The notion of pallid colour is either based upon the colour of the herbarium specimens or from the colour of the species under depauperated growth conditions. Both names therefore appear to be equally valid and Ucria's name being earlier should get priority. However our forms of S. pallida are either apetalous or with rudimentary petals.

So far as the specimens from Britain are concerned, the name adopted in Br. Pl. List (1928) was S. media (L.) Vill. var. apetala (Ucria). The synonyms given for the species was S. boreana (Jord.) and S. pallida (Dum.). H.K. Ainsy-Shaw (1938) in his identification of some specimens collected from Bainton, Northamptonshire (v.-c. 32) by Mrs. C.L. Wilde (1934-1935) and communicated to him by E.B. Bishop adopted the above name. However, he expressed his inclination to follow London Catalogue 11th Ed.

(1925) and to raise the variety to the level of species. The locality, date of collection and characters of the specimens together with their taxonomic position according to Airy-Shaw are given below:

<u>No.</u>	<u>Locality</u>	<u>Date of Collection</u>	<u>Characters</u>
1	Wall of farmyard.	May 21, 1934.	Sepals glabrous, as also most of the peduncles.
2	" " "	" " "	Ditto but with longer internodes.
3	" " "	April 19, 1935	Same as (2) but with stouter stems.
4	Ant-hills in field at Ashton. All four of seemingly same form.	" " "	Sepals and peduncles pubescent, rather densely so, colour of the leaves dark-green as against yellow-green of 1, 2 & 3. Typical of the variety (or sp.) which character suggested to Du Mortier his name of <u>pallida</u> .
5	By railway near Ballast pits.	April, 1935	Sepals and peduncles densely pubescent, internodes long, colour as in (4).

These forms in the light of Béguinot's (1910) classification (Nuovo. G. bot. ital. N.S., 17, 348-390) were allocated to the following combinations:-

- (a) 1, 2 and 3 (i.e. Ran 808, 809 and 813 respectively) - S. media (L.)
 Cyr. ssp. apetala (Ucria) Bég. var. glabella (Jord. & Fourr.) Rouy and Fouc.
 (b) 4 (i.e. Ran 814).
S. media (L.) Cyr. ssp. pallida (Dum.) Bég. var. boraeana (Jord.) Bég. (but

the earliest varietal epithet is provided by the synonym S. apetala var. minor Rouy and Fouc.).

(c) 5 (i.e. Ran 815).

S. media (L.) Cyr. ssp. pallida (Dum.) Bég. var. intermedia (Rouy and Fouc.) Glirke.

The British forms of glabrous S. pallida (Airy-Shaw, 1938) agree with the original description of Alsine glabella Jord. and Fourr. better than do the specimens distributed by Béguinot as S. apetala var. glabella (Fl. Ital. Exsicc. No. 532 b). There seems to be little justification for maintaining S. apetala and S. pallida as independent species, as least as far as North European material goes, merely on the basis of glabrous or hairy sepals respectively. Béguinot's memoir is an important and valuable piece of work but not the last word on the taxonomy and status of the forms included in the S. media group.

Some characteristic forms of plants were collected by C.E. Moss (1910-11) from Higham and Kennet Heaths, Suffolk under the name S. apetala Opiz. The plants are described thus - "A characteristic, ephemeral, prostrate, apetalous plant on loose soil on sandy heaths of West Norfolk and Suffolk, spreading along the sandy soils into the east Cambridgeshire. The same plant has been collected by E.S. Marshall from near Mildenhall in Surrey and elsewhere. According to him this plant differs much from the coast plants and he thinks them to be a major, Rouy and Fouc. = S. apetala Ucria. There small compact plants appear to be Rouy and Foucaud's S. minor among the synonyms given for which are S. boraeana Jord. and Alsine pallida

Dumort. It is described as follows: "Fewilles caulinaires plu on moins rapprochées, petites ($\frac{1}{2}$ -1 centimètré), plante basse (5-15 centimètrés), à tiges grêles, vertes, glaucescentes; calice poilu, à sepales ovales-oblongs-obtus on obtusiuscules; capsula ovoide, dépassent peu le calice".

Stellaria neglecta Weihe.

This as a species has been the most confused part in the Stellaria media group. Its existence as a species separate and distinct from S. media was recognised by Weihe and the original diagnosis can be seen in Bluff and Fingerhuth's Fl. Germ. I, 560 (1825). It runs as follows:

"1166 St. neglecta: decandra caulibus procumbentibus dichotomis linea pilosa notatis, foliis ovato-lanceolatis inferioribus petiolatis, calycibus pubescentibus pedunculo sub-anthesi longioribus, capsula calycem parum superante, seminibus discoideis margine muricatis.

Circa Mennighiiffen. Princip. Mindensis. ad margines rivulorum.

Mai - Jul. (similis (St. mediae) a qua differt foliis angustioribus et longioribus, pedicellis florum sub anthesi saltem brevioribus calycis foliolis oblongo-lanceolatis, neque ut in illa ovato oblongis, petalis calycem plerumque superantibus semper saltem aequantibus, staminibus 10, seminibus majoribus brunneis compresso-disciformibus, disco-tuberculatis circa margines muricibus longioribus cinctis, quibus notis accedit magis St. latifolia, sed haec etiam recedit, caule ascendente, foliis omnibus basi angustiori sessilibus, adeoque magis ellipticis, neque in superiori caule late sessilibus, tum petalis calyce brevioribus. Hyeme neque floret neque usquam perstat, ut solet St. media Weihe in litt."

The same diagnosis and concept has been adopted by Lejeune and Courtois in Fl. Bel. (loc. cit.). Jordan and Fourreau in their Bre. Pl. nov. (1868) have used the name S. Elisabethae referable to F. Schultz. Herb. norm. no. 443. According to them it is a synonym of S. neglecta. They however confine the concept of species to only forms with glabrous sepals. Some authors use the combination S. media var. neglecta Koch (1841). Koch (1841) and others have treated S. media var. neglecta as a synonym of S. media var. major. In all our specimens examined and plants grown, the number of stamens has been found to be ten and the petals are almost equal to the sepals. The determination of ratio of sepals and petal lengths presents some difficulty due to reasons stated earlier in the description of S. media. The ratio of their lengths can better be determined in fresh materials. The plants of this species are very specific in their requirement for the induction of flowering. Plants grown in culture solution or soil culture in the glasshouse grew vigorously but they never attained the hormonal balance for flower induction. Live plants in the initial stage of flowering, brought from their original habitat and grown in soil culture in the glasshouse could flower profusely. Plants in the original habitat flower from May to July and then the flowering parts decay but the stems remain alive. New tillers come out from then which overwinter and flower again next year. The seedlings even in their original habitat take longer time to attain sexual maturity. In the case of S. media a period of 4 - 5 weeks is enough to attain sexual maturity. In the case of other two species flower production takes place only after the peak period of vegetative

development.

The range of distribution of these species can be seen in Figs. 1 - 3 which represent the distribution map of these species in the British Isles.

Comparative diagnostic features.

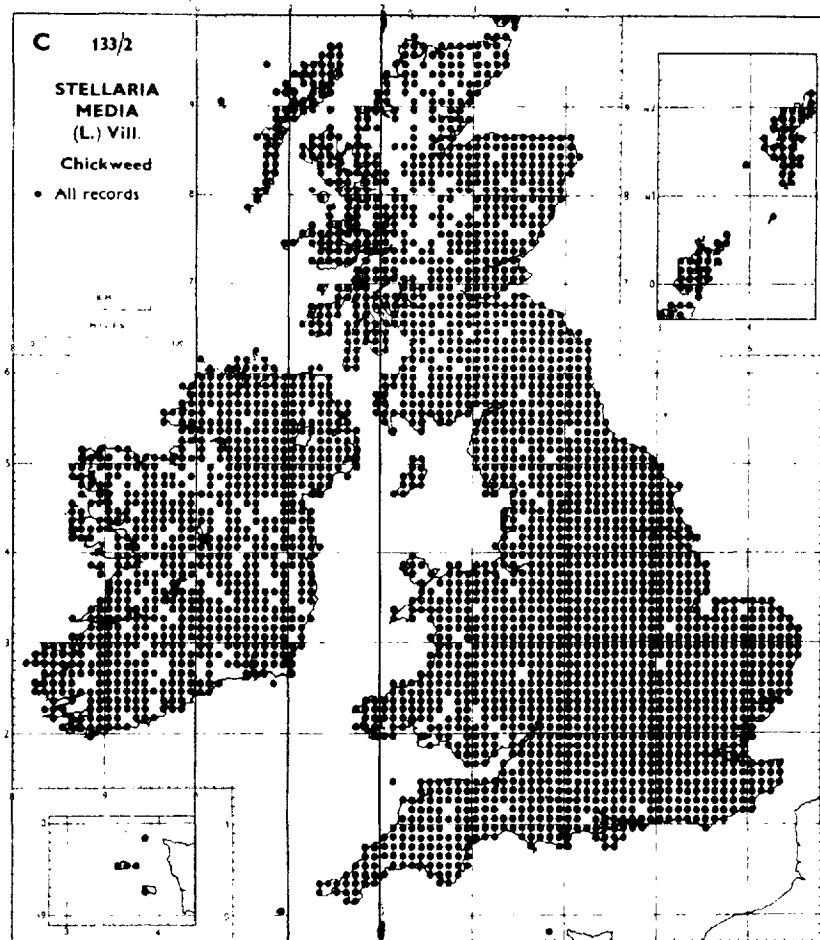
(1)	(2)	(3)
<u>S. media</u> (L.) Vill. - Chickweed	<u>S. pallida</u> (Dum.) Piré - Lesser chickweed	<u>S. neglecta</u> Weihe - Greater chickweed
1. Stems 5-40 cm., usually with a single line of hairs down each internode.	Stems up to 40 cm. tall, hairiness same as in (1).	Weak branching stems, 25-90 cm., procumbent below and then ascending, hairiness same as in (1) and (2).
2. Lower leaves 3-20 mm., ovate-acute long stalked, upper ovate or broadly elliptical usually larger (up to 25 mm.), acute or shortly acuminate, <u>±</u> sessile. All <u>±</u> glabrous or ciliate at the base.	Pale green ovate leaves, usually less than 7 mm., most of them short-stalked, smaller than (1).	Lower leaves ovate, subcordate, acute or shortly acuminate, long-stalked with blades 1-2.5 cm. and stalks twice as long. Upper leaves up to 5 cm., petiole ciliate.
3. Fls. in terminal dichasia, pedicels with a single line of hairs. sepals	Fls. smaller than (1), cleistogamous, pedicels same as (1).	Fls. biggest, c. 10 mm. diam., lax dichasia, pedicels glabrous or pubescent.
*4. 3.5-5.25 mm. with mean of c. 4.2 mm.	2.1-3.6 mm. with a mean of c. 2.95.	3.5-6 mm. with a mean of 5.06.
5. Petals white, deeply bifid with contiguous lobes subequal to $\frac{3}{4}$ of the length of sepal.	Petals 0 - minute.	Petals equalling the sepals, other features same as in (1).
6. Stamens usually 3-5 with violet anthers.	Stamens 1-3 with grey violet anthers.	Stamens usually 10.

* Measurements based upon specimens used in taximetrics

7. Fruit stalk downwardly curved, often wavy.	Fr. stalks usually short, not reflexed.	Fr. stalk 25-30 mm., at first spreading and reflexed, finally erect.
8. Seeds reddish brown, muricate to reniform, round flat, tubercles rounded to flat topped. 0.9-1.2 mm. in diameter. Average wt. per 100 seeds = $36.26 \pm 1.15^{**}$ mg.	Seeds pale yellowish brown. 0.5-0.9 mm. in diameter - small blunt tubercles. Wt./100 seeds = 13.13 ± 0.61 mg.	1.0-1.5 mm. - slender acute tubercles. Wt./100 seeds = 77.21 ± 1.93 mg.
9. A polymorphic species having the widest range of tolerance and plasticity. It is characterised by early sexual maturity and is a ubiquitous form. $2n = 44$. Weed of cultivated crops and also a ruderal.	A characteristic species on light glacial sands in the shade of <u>Pinus sylvestris</u> L. A common plant of dunes and inland weed of cultivated plants. Takes longer period for sexual maturity, vegetative growth is vigorous under higher nutritional artificial conditions but reduced fertility. Flowers in April - May. $2n = 22$.	A common plant of hedge-rows, wood margins, stream sides and shady places. Very specific to its natural habitat for flowering etc. Some forms overwinter. Can be grown vegetatively under artificial conditions but difficult to attain hormonal balance to induce flowering. $2n = 22$.

figural limit
~~**~~ Standard error at 5% excluded probability.

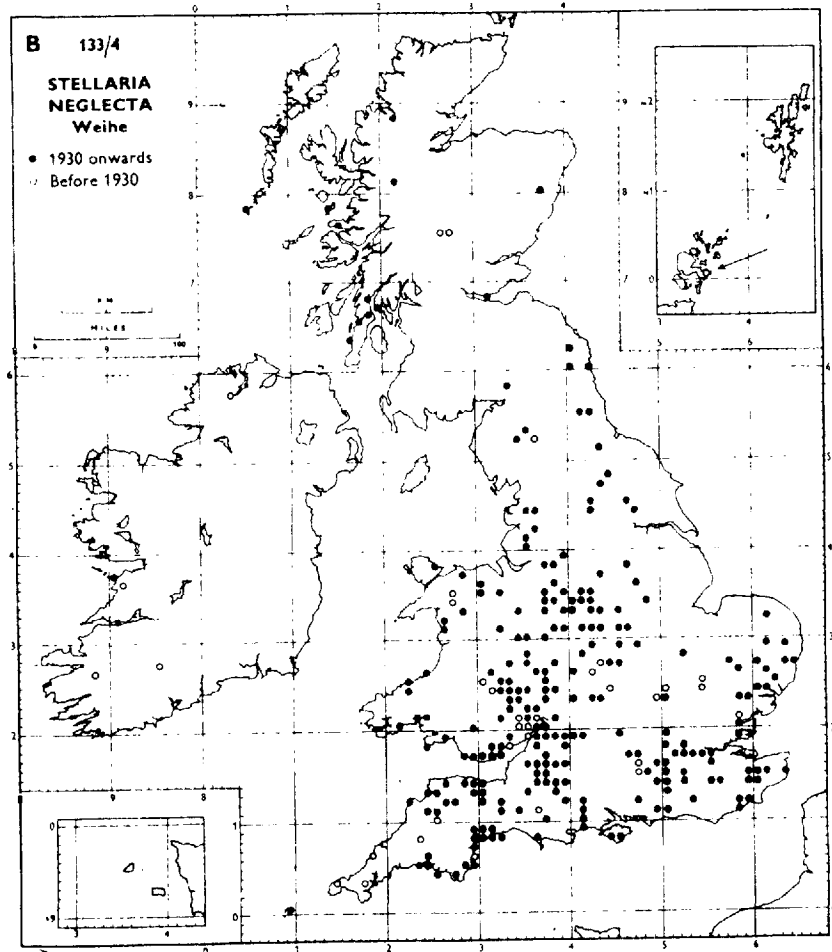
CARYOPHYLLACEAE



(From Atlas of the British Flora, Nelson & Sons.
publ. B.S.B.I., 1962.)

Fig. 1. The distribution of Stellaria media (L.) Vill. in the
British Isles

N.B. Each dot represents at least one record in 10 kca. square of the
of the National Grid.



(From the Atlas of the British Flora)

Fig.2. The distribution of *Stellaria neglecta* Weihe in the British Isles.

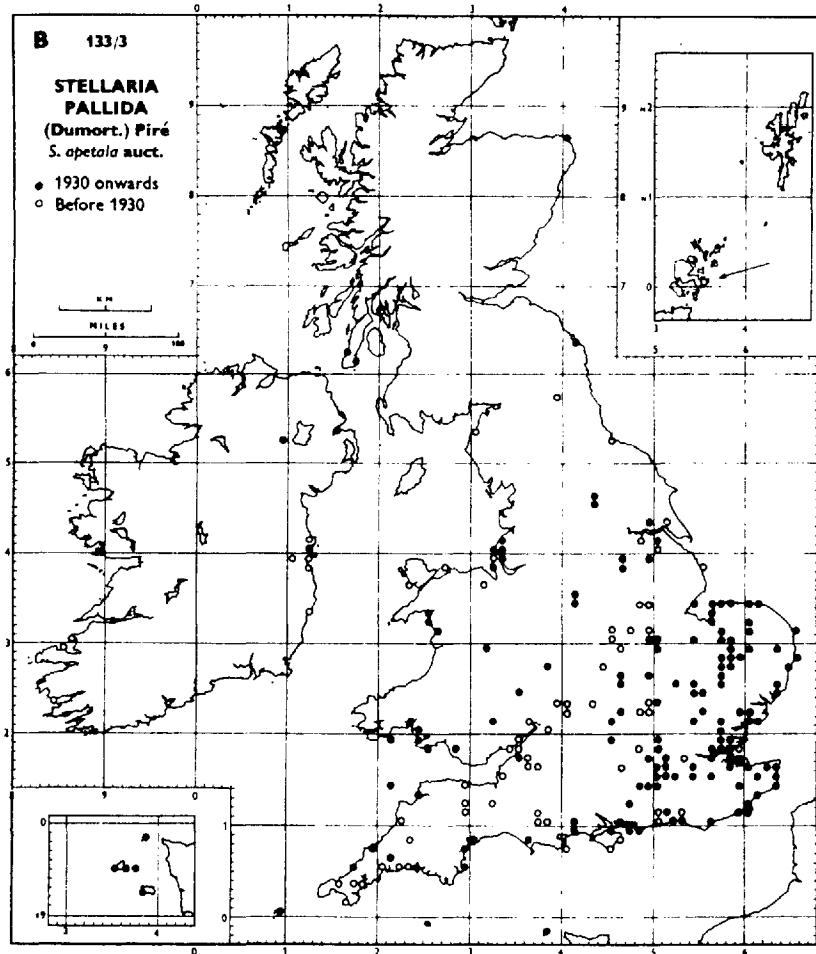


Fig.3. The distribution map of Stellaria pallida(Dum.)Piré
in the British Isles.

(from the Atlas of the British Flora)

CHAPTER IV .
CYTOLOGICAL STUDIES

In establishing the biological status of taxa at the specific and infra-specific level in terms of what they look like — concept of characters and thus their selection, their weighting and the choice of computational technique for working out the correlation co-efficient of characters, — provide basis for their assessment in relation to morphology , breeding and other behaviour pattern vis-a-vis ambient factors. In the investigations of this nature studies of chromosome morphology, number and behaviour provide important tools for understanding the biological nature of plants in relation to their general morphology.

Chromosome number and morphology : Role of chromosome number and morphology in taxonomy has been discussed by Löve (1954, 1957, 1961) and by Darlington (1956) in his Chromosome Botany. Chromosomes are the seat of hereditary material (although the role of extra-chromosomal determinants has been gaining recognition for the last several years) and therefore special role has been claimed for cytological data. Cytological findings have to be accepted as comparative data on par with other evidences. Karyotype analysis (the study of chromosomes at mitotic metaphase) and behaviour of chromosomes in respect of pairing , chiasma frequency and their terminalisation co-efficient have been used for interpretative purposes.

The importance of chromosome number as a comparatively most constant single character has been universally recognised. With a few exceptions all individuals of a species generally have a constant number. In case of a few hybrids and polyploids inconstancy is due to somatic instability (Vaarama, 1948; Sachs, 1952). In this connection it is important to note that chromosome number of plants grown under artificial conditions may differ from those growing in natural conditions because of variations permitted by selection. Mis-identification of materials specially in the critical groups may be another source of error. Sometimes within the populations of apparently homogeneous species polyploids or cytodesms have been identified. An elegant demonstration has been given by Löve & Löve in Triglochin maritimum complex where numbers ranging from $2n = 12$ to $2n = 144$ have been found to exist, some of the polyploids of this complex have been given the rank of separate species. In most of the aggregate species, segregates have been identified on the basis of chromosome number and morphology. Confusion on the count of number of some of the species has been mainly due to their difficult taxonomy and cytology. In the case of plants belonging to critical groups it has been noted that despite their distinct genotypes morphologically they look alike. In light of improved techniques of microscopy and photomicrography most of the earlier counts need to be remade.

In this connection it is worth quoting Löve and Löve (1961)

"...the fact remains that most chromosome numbers are still determined either by cytologists lacking taxonomical training or by taxonomists

lacking cytological skill and experience ." Any report on the chromosome number of critical groups has to be accepted with great caution unless the reporter is one of the specialists . Counts in each case have ^{based} to be/ on scorings from different populations .Counts from a single population sometimes leads to misleading conclusions. As Larsen says "----- one may compare this situation with a herbarium in which each species is represented by a single sheet only.Even this does not explain the situation adequately because herbarium sheets are available to future workers for matching but cytological preparation is seldom available for inspection .

In groups of plants with chromosome series , simple multiple relationships are found to be of great taxonomic value. Chromosome numbers serve as good markers of the differences where other discontinuities are to be found.They often indicate the presence of reproductive barriers although this should not automatically be taken for granted.

Polyploidy : In the evolution and spread of Angiosperms polyploidy has played the most important role.Some cytotaxonomists maintain that diploids and polyploids should be treated as separate species no matter what the apparent degree of morphological differences are involved. It is based upon assumption that chromosome characters are more important than others and thus it is given a priori weighting.It is presumed that diploids can be separated from the polyploids by genetic barriers through the formation of sterile hybrids.

Löve gives^a/priori weighting to chromosome morphology.

He makes his case by stating that it is the chromosomes which determine the character, characters do not determine the nature of chromosomes. The absolute size of chromosomes of karyotypes is fairly constant feature of species and is genotypically controlled. In some of the genera of flowering plants the volume ratios have been found to vary up to 1 : 1000. The reason for these differences are not evident. It has been shown by Darlington that size of the chromosomes is not the indication of their genic content. In case of wild Dicots where the chromosomes are dot-shaped to small rods, karyograms do not prove to be much useful. No informations more than mere nubmer can be gained^{from}/such studies.

In addition to chromosome number, the genomic constitution in relation to variation in form, size and volume of chromosomes, including the number and size of the satellites and distribution of heterochromatin give useful taxonomic informations. In general studies comparative study of idiograms reveal the extent of changes that have taken place at the submicroscopic level — although chromosome changes and rearrangements can take place which are not reflected in the karyograms. Swanson(1958) points^{out that}/in any comparative cytological studies data from morphological, cytogenetic and cytochemical studies must be integrated.

The present investigation : In view of foregoing considerations meiotic and mitotic studies of all the three species were done with a view to comparing and correlating the cytological data with biometric and physiological ones. Conflicting reports on the chromosome number for the species included in the Stellaria media group have made it difficult to infer whether the basic number for the group is ten and/or eleven. The main reason for this is that most published accounts are based either upon somatic counts only or are referable to dates when techniques of chromosome studies were not so developed. So far the present three species of Stellaria are concerned reports have been published by Negodi(1935,1936) for Italian specimens ; Peterson(1935) , Lökvist(1963) for Swedish material ; Löve & Löve (1956) for Icelandic material and Mulligan(1961) for material from Canada. The only casual reference to the British form of the species can be seen in Blackburn & Morton(1957) . This information is summarised in the Table 5 on the page 77.

Cytology vs. cryptic species : So long as one works with Linnaean species with widely discontinuous morphological markers , the type method appears to work and provide a referable system. The inherent imperfection of the system becomes manifest only where a "spectrum" of variation with contiguous or overlapping bands are met with or when the system shows incompatibility to assimilate new facts of discovery pertaining to the group. The system that works when the knowledge about the group is limited is not the best scientifically. Inconclusiveness of this method has been shown by repeated attempts to define and redefine species in face of new experimental data. Morphological concept of the species faces crisis when question of assimilation of ^{new} data comes into

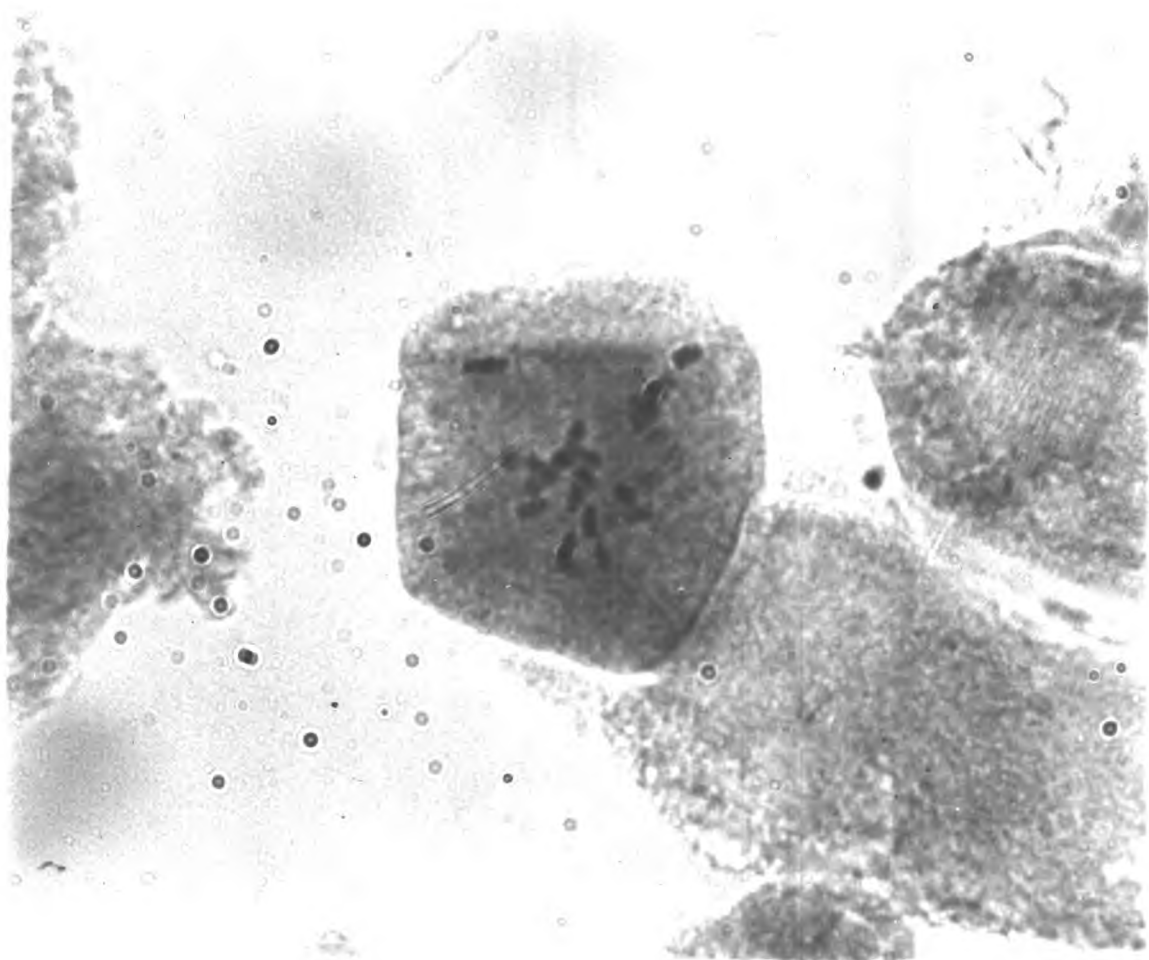
play or where related biotypes can not be separated on the basis of morphological discontinuity.

The sps. of Stellaria under investigation form a morphological cluster where distinct biotypes with different ecological niches are so indistinguishable morphologically that probability of mis-identification is fairly high. Review of the nomenclatural hierarchy would reveal that these biotypes have sometimes been confused as paramorphs of the single ubiquitous species Stellaria media.

This cytological investigation forms part of an attempt to show how cytological, taximetric and ecological study of related organisms serves to separate groups inseparable in terms of the concept of the gross morphology of late forties.

Mitotic studies : These studies were done from active stage of division in root tips. The root tips for the purpose were obtained from plants grown in pots and from germinating seeds. The divisions were found to be active between 9 - 12 a.m. Healthy root tips for the purpose were cut with a sharp pair ^{of} scissors and immediately plunged into pre-treating agent. A saturated solution of p-Dichlorobenzene in distilled water was used as a pre-treating agent. The material was fixed in 1:3 acetic alcohol for one and a half hours. Before fixation root tips were washed carefully to remove all traces of pre-treating solution. Root tips in pre-fixative and in fixative were shaken on Microid flask shaker at a speed of about 80/minute.

The root tips were then dipped in absolute alcohol for an hour and then transferred to 70% alcohol for preservation. They were hydrolysed in N HCl for 15 - 20 minutes at a temperature of 60⁰ C. The usual hydrolysis period is 5 - 10 mts. but this material needed an unusually long period for the process. The acid was then drained and Schiff's reagent prepared after the schedule of Darlington & Lacour was added to it. The root tips were squashed and suitable plates photographed and some were also drawn under camera - lucida. These are given in pages 74 - 76 , Figures 4 to 6. It can be seen that the somatic number for Stellaria pallida and S. neglecta both is 22 as against 44 in S. media . Chromosomes are small enough to permit the preparation of karyograms.



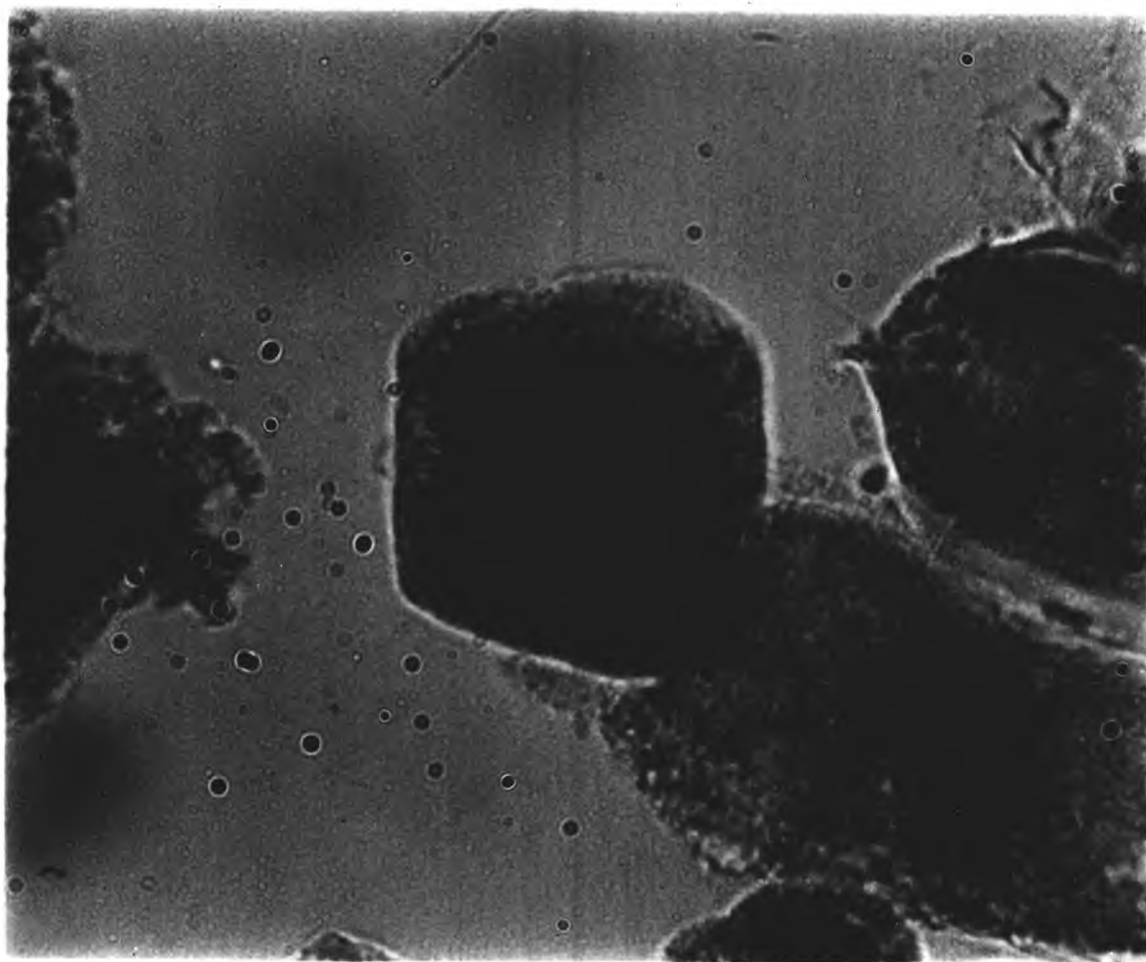


Fig.4. Somatic metaphase in Stellaria pallida(Dumort.)Piré showing twenty-two chromosomes.

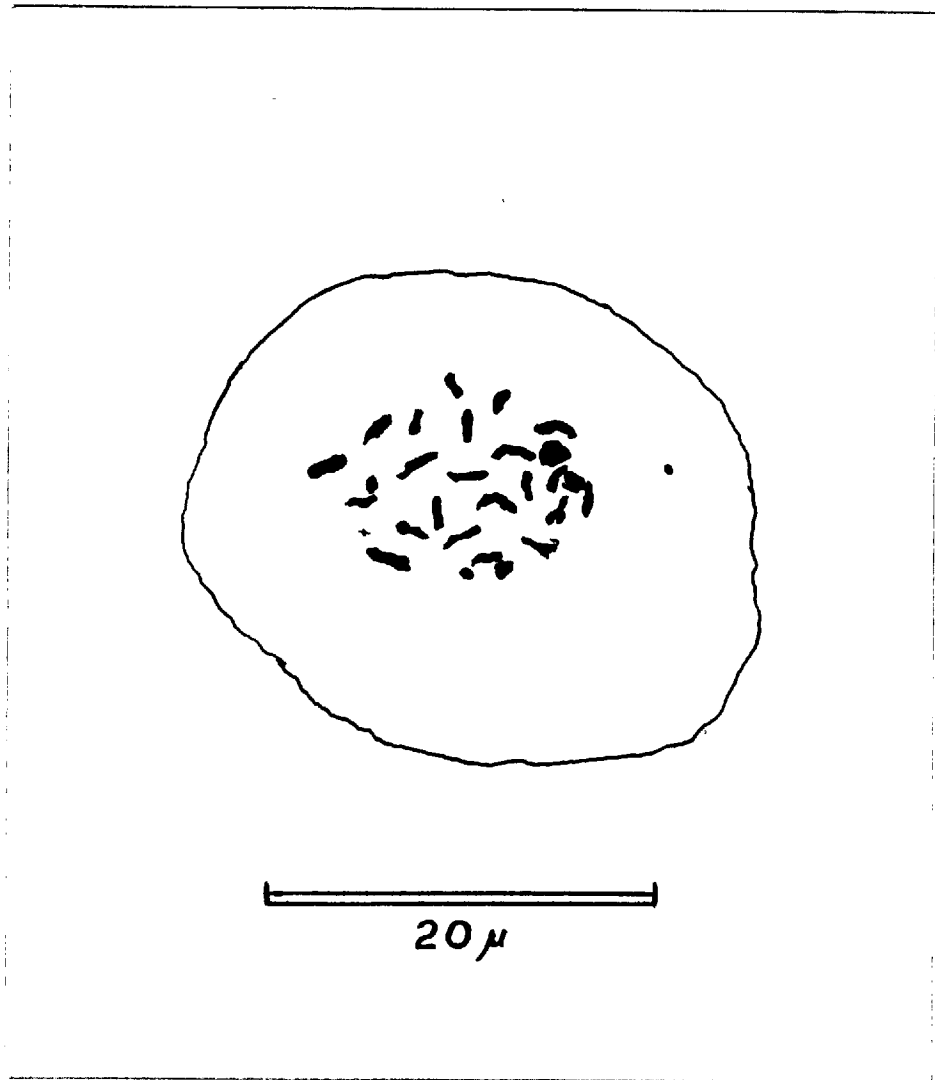


Fig.5. Camera-lucida drawing of somatic metaphase in Stellaria neglecta Weihe showing twenty-two chromosomes.

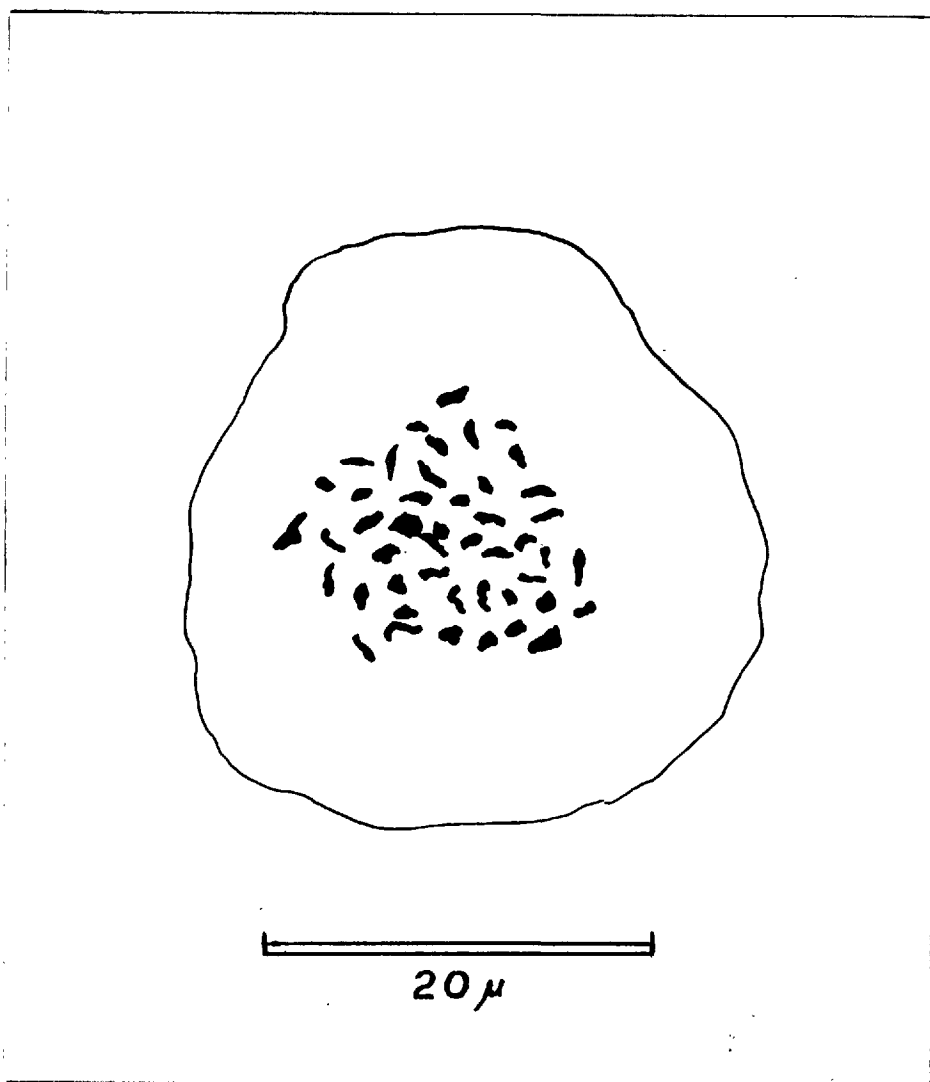


Fig.6. Camera-lucida drawing of somatic metaphase in
Stellaria media(L.)Vill. showing forty-four chromosomes.

Table 5

<u>Stellaria media</u> (L.)Vill.	2n=40	Rocén 1927;Negodi 1935,1936; Györffy 1940;Blackburn(in Peterson) 1936;Lökvist 1963; Mulligan 1961.
	2n=42	Peterson 1936;Löve & Löve 1956.
	2n=44	Peterson 1933,1936; Blackburn & Morton 1957.
	x=11 n=22	Ø Ø Ø Sinha & Whitehead 1965.
<u>S.neglecta</u> Weihe	2n=22	Peterson 1933,1935,1936; Blackburn & Morton 1957;Lökvist 1963.
	x=11 n=11	Ø Ø Ø Sinha & Whitehead 1965.
<u>S.pallida</u> (Dumort.)Piré	2n=22	Peterson 1935,1936; Blackburn & Morton 1957;Lökvist 1963.
	2n=20	Negodi 1935,1936.
	x=11 n=11	Ø Ø Ø Sinha & Whitehead 1965

Meiotic studies : These studies were done following the usual procedure. They were all done on pollen mother cells in active division during prophase I . Fixative used was the same as in mitotic investigations but the proportion of acetic alcohol was changed to 1 : 2 instead 1:3 usually employed. This gave better results on this material .The stain used was acetic carmine as against Schiff's reagent in mitosis. In the case of Stellaria media distinction was always made between fertile and sterile anthers. In the stage of bud used for the purpose it is difficult to make this distinction but practice makes the task easier.

As mentioned in Chapter II all these cytological investigations were based upon materials from the v.-cs Berkshire, Surrey and Norfolk.

Division in general was found to be non-synchronous but this phenomenon was more marked in S. media where stages from mid-prophase to early anaphase were found in the squash of the same anther. The suitable plates were photographed under apochromatic oil-immersion objective of Laborlux Leitz Research microscope . Camera-lucida drawings were also made of suitable plates. These results on meiotic studies are under publication (Sinha & Whitehead ,1965 ,New Phytol.). For the purpose of illustration some photomicrographs have been given in Figures 7 to 11 .

From the photographs and camera -lucida drawings it was concluded that basic number of the group is probably eleven . S. pallida and S. neglecta appear to be diploids with differing genic balance and chromosome morphology.

S.media with $2n=44$ appears to be an allotetraploid and its possible ancestors might be S.pallida and S.neglecta. The dimorphism of the bivalents at diplotene and diakinesis would support this opinion. The possibility S.media being an autotetraploid of S.neglecta as suggested by Peterson(loc. cit.) appears to be ruled out by the pairing behaviour of bivalents at least for the British population. Peterson claims to have raised sterile triploids between S.neglecta and S.media for the Swedish materials. An attempt was made to test his hypothesis by making reciprocal cross between S.media and S.neglecta during the summer of 1963. Three hundred crosses were ^{made} but no success was achieved in raising any hybrid. This failure to produce hybrids together with chromosome number and morphology led to the conclusion/ ^{that} the separation is complete and they do not share a common gene pool.

In chromosome morphology, as in morphology of other plant parts, S.media appears to have combined the features of both S.neglecta and S.pallida, its putative ancestors. The characters of S.neglecta overweigh to those of S.pallida which would suggest the dominance of ^{complements of} S.neglecta alleles. The stenoplastic nature of S.media as compared to euryplastic nature of the other two species may be due to heterosis following hybridisation and polyploidy.

S.media is characterised by wider range of tolerance and earlier sexual maturity compared to the other two species and this has no doubt contributed to its success as a weed. Ability to produce wider range of phenotypes is due to genetic flexibility.

This genetic potentiality to produce wider range of phenotypes without any impairment in its general biology appears to be the key to the success of the species. This explanation for plasticity in face of environmental variation is more plausible than the ability to throw up new or closely adapted genotypes. This is more so because S. media has the advantage ⁱⁿ of being self-compatible without being seriously restricted/ its range of environmental tolerance. Such an appropriate type of genotype may be produced (along with some measure of heterosis) as a result of one or more acts of hybridisation as enunciated by Baker(1964).

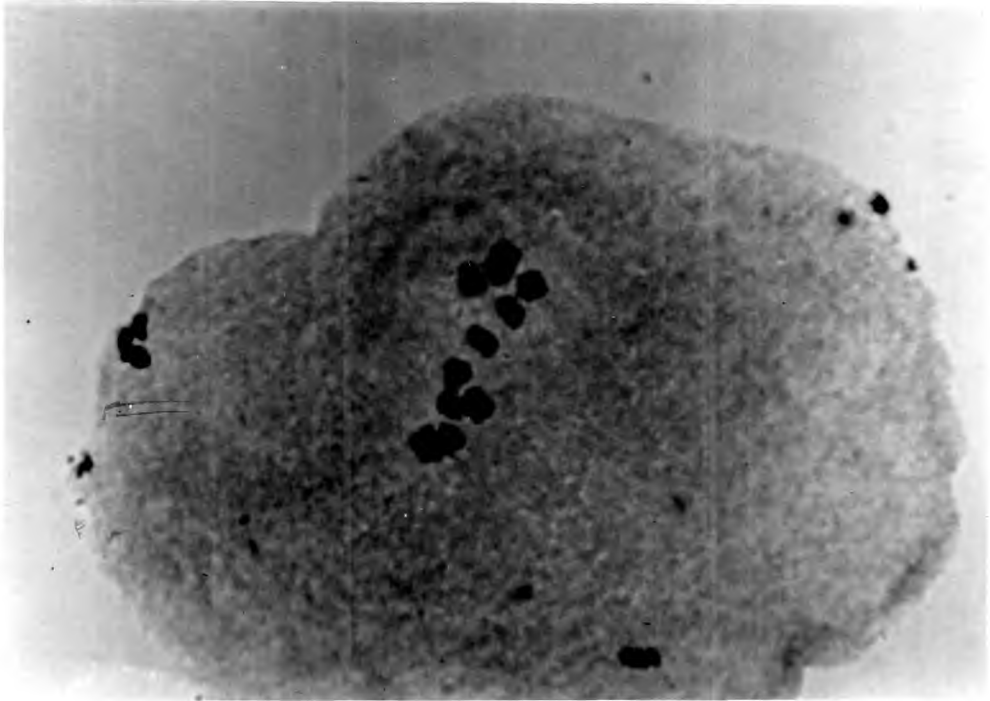


Fig.7. Early metaphase¹ in Stellaria pallida (Dumort.)Pirè showing eleven bivalents in which chiasmata have terminalised and centromeres are clearly visible.

(x 2500)



X. 2500

Fig.8 . Diakinesis in prophase I in Stellaria media(L.)Vill
showing twenty-two dimorphic bivalents.

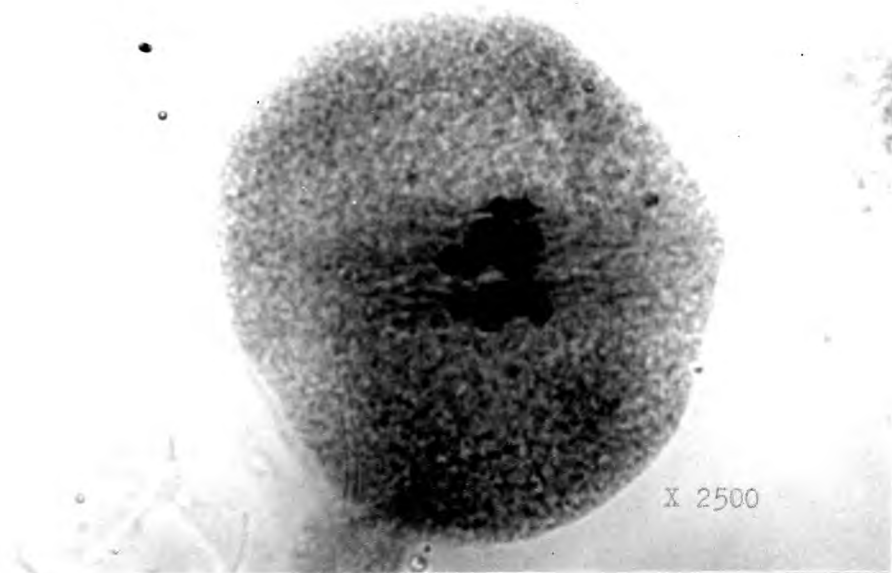


Fig.9. Early metaphase I in Stellaria neglecta Weihe showing eleven bivalents.

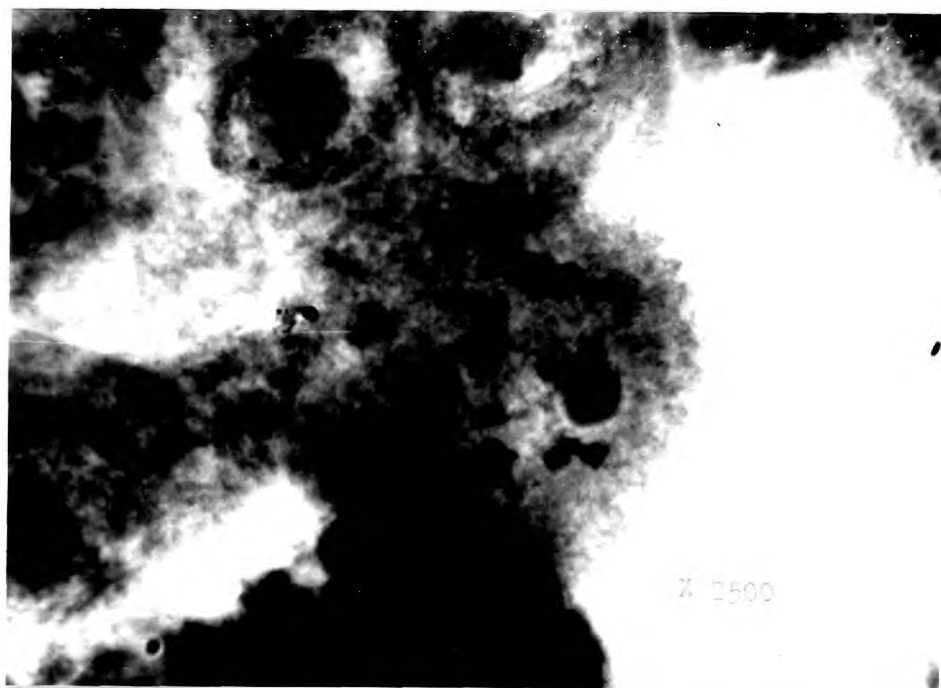
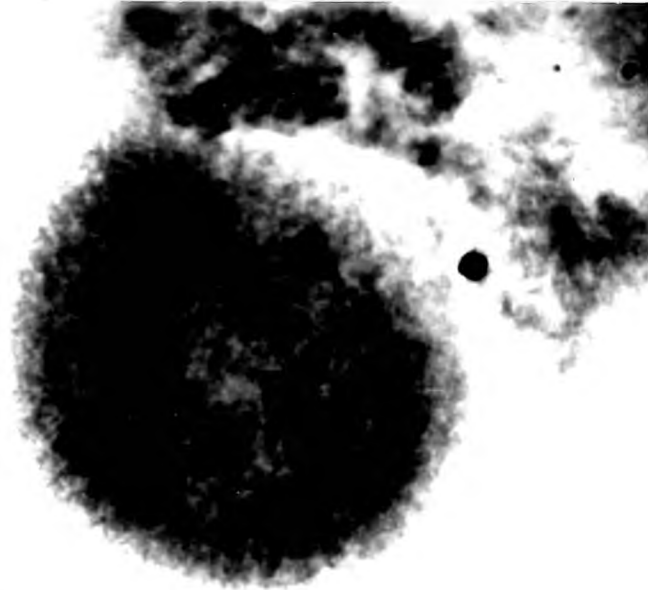


Fig.10. Diplotene in prophase I in Stellaria neglecta Weihe
showing eleven bivalents of which two are seen to be
associated with the nucleolus.



x 2400

Fig.11. Diplotene in Stellaria neglecta Weihe at prophase I showing eleven bivalents of which three are seen to be associated to the nucleolus, euchromatic and heterochromatic zones are also distinguishable.

CHAPTER V.EFFECTS OF ARTIFICIAL SHADING ON THE GROWTH AND MORPHOLOGY OF THE SPECIES

Species in their habitats: The species under investigation - as seen from their overall performance in natural habitats - behave differently in respect of their general response to edaphic factors, seasonal variations and available visible radiation. They grow in distinct ecological niches and have therefore different distributional pattern in Britain (see Figs. 1-3 for their distribution). Stellaria neglecta grows beside running streams or in other ecological niches where soil is moist, often with poor drainage. S. pallida grows in well-drained sandy soils typically in glacial sand in the shades of Scots Pine (Pinus sylvestris L.). Both these species in Britain flower during definite and different parts of the year, S. pallida flowers at the end of March-April and S. neglecta at the end of May-June. In contrast to both the former species S. media has the widest range of tolerance and is rather ubiquitous flowering throughout the year.

Scope and purpose of the experiment: In an attempt to study these species in terms of some parameters of growth and morphogenesis, investigations were made of their performance under varying degrees of artificial shading. Various attempts have been made to study the growth and morphology of individual species in response to total amounts of radiation and both its components intensity and photoperiod per se in the framework of some quantitative relations. However one difficulty in the study of such processes is that they normally all show ontogenetic drift under

natural and semi-natural conditions of light.

It is possible to establish exact quantitative relationships in respect of light intensity only when the plants are grown under rigorously controlled conditions. Light has a marked regulatory effect on growth apart from its photosynthetic effect. Macdougall as early as 1903 described differences between plants growing on their food reserves in the dark and those growing in the light and observed effects upon stem elongation , stem extension , leaf expansion and leaf shape in many species.

Among other growth responses known to be influenced by the light are leaf initiation, geotropism of shoots and roots , hair formation , plumular hook formation, root elongation and germination. Morphogenetic processes and period of sexual maturity are also known to be influenced by intensity of light and/or photoperiod. Light relations of plant communities and photomorphogenesis in stems have been reviewed by Anderson(1964) and Vince(1964) respectively .The control of plant growth and development has been treated by Mohr(1964).The effect of intensity and photoperiod has been studied by Butler(1963), Newton(1963) and Milthorpe & Newton(1963).The effect of artificial shading has been investigated by Evans & Hughes(1961) in Impatiens parviflora DC. These are just to mention a few examples.

Plants actually differ in their photomorphogenetic behaviour and development under different conditions of light. Some plants grow successfully in exposed conditions while others grow in

shade under trees in forest communities and elsewhere. They have accordingly been grouped into sciophytes, heliophytes, facultative sciophytes or heliophytes etc. by Daubenmire (1959). The present study is more concerned with a comparison of performance in relation to light rather than a detailed investigation of general response of plants to light.

As has been pointed out by Evans & Hughes (1961) several aspects of the light regime prove to have important influences on growth. Unit leaf rate ($\bar{E}$) is practically proportional to the mean total daily radiation up to about $100 \text{ cal. cm. day}^{-1}$, and almost independent above $300 \text{ cal. cm. day}^{-1}$, in which region it is unaffected by daylength. Specific leaf area ($\frac{LA}{LW}$) has a marked ontogenetic drift, the form which is much affected by mean total daily radiation. Leaf weight ratio ($\frac{LW}{W}$) is practically independent of mean daily total radiation, but is slightly affected by daylength.

Experimental procedure : Artificial shading was created under polythene nets in the greenhouse. These nets were mounted upon wooden frames of size 3' X 2' 6" X 2' and they were placed on the wooden bench in the greenhouse. Three such tents were made during the month of August 1963. They were mounted with one, two and three layers respectively of the net. The surfaces of the benches which worked as base were covered with black polythene sheets to cut off the light from below the surface of the benches.

Seeds were sown in loamy soil in wooden boxes 1' 6" X 9" X 5". When seedlings had attained first leaf stage, they were transplanted to growth boxes. The seedlings were carefully selected for the uniformity of size and development. Eight seedlings were transplanted in each box and five such boxes were used for each species. Thus in all fifteen boxes were

randomised inside each tent.

The intensity of light in each tent was measured every day with Edgeware Photometer at 10 a.m. , 2 p.m. and 6 p.m. The values of these readings for eight uniformly sunny and eight cloudy days were accepted for working out the average intensity of light inside each tent. The intensity of light inside each tent was calculated in terms of percentage of light in open conditions in the greenhouse was found to be 80 , 60 and 45 % respectively. These percentages will be used ⁱⁿ referring to light intensity in respect of this experiment.

Plants were grown in normal culture solution and harvesting was started two weeks after transplanting the seedlings. The number of plants harvested at each harvest was five. Roots, stems and leaves were pressed separately in folded blotting papers. By leaf is meant here only the lamina of the leaves. Petioles were included with the stem. These blades were printed on photographic bromide paper and their area was determined later by planimeter. The plant parts were kept at a temperature of 80°C . in an oven for forty-eight hours. The dried materials were stored in desiccators and weighed on Stanton Balance. The primary data were recorded in the form of dry weights of roots, stems and leaves together with leaf area. The values for all the parameters used in the present context were calculated from these primary recordings. The primary data together with necessary derivations from them are noted in the following pages.

EXPERIMENTAL RESULTS AND DERIVATIONS FROM THEM

Table 6

45% Light

Stellaria media (L.) Vill.

Harv. No.	$\bar{L}_A$ (cm ²)	$\bar{W}$ (10 ⁻³ g.)	$\text{Log}_e \bar{L}_A$	$\text{Log}_e \bar{W}$	$\bar{R}$ (mgs/mg/week)	$\bar{R}_{LA}$ (cms ² /cm ² /week)	α
1.	6.8 ±0.8	16.6 ±1.8	1.91692	2.80940	-----	-----	---
2.	17.5 ±2.5	39.2 ±3.8	2.86220	3.66868	0.85928	0.94528	0.909
3.	36.8 ±4.6	92.4 ±12.5	3.60550	4.52613	1.71673	1.68858	1.016
4.	60.64 ±5.6	161.8 ±18.3	4.10493	5.08649	2.27709	2.18801	1.040
5.	71.1 ±7.6	207.6 ±14.6	4.26409	5.33565	2.52625	2.34717	1.076
6.	74.5 ±5.8	267.2 ±11.8	4.31080	5.58801	2.77861	2.39388	1.160

60% Light

1.	7.0 ±1.2	18.6 ±1.5	1.94591	2.92316	0.91198	-----	-----
2.	18.5 ±1.8	46.3 ±5.3	2.91777	3.83514	0.91498	0.97186	0.938
3.	37.2 ±3.2	104.2 ±9.3	3.61362	4.64637	1.72321	1.66771	1.033
4.	59.2 ±6.2	182.4 ±11.4	4.08092	5.20621	2.28305	2.13501	1.069
5.	70.1 ±5.9	247.2 ±29.5	4.24992	5.51021	2.58705	2.30401	1.122
6.	70.5 ±6.3	301.2 ±18.5	4.25561	5.70777	2.78461	2.30971	1.205

continued from page 90

80% Light

Harv. No.	$\bar{L}_A$	$\bar{W}$	$\text{Loge} \bar{L}_A$	$\text{Loge} \bar{W}$	$\bar{R}$	$\bar{R}_{L_A}$	α
1.	6.3 ± 0.6	19.3 ± 2.5	1.84055	2.96011		-----	---
2.	18.2 ± 2.3	53.0 ± 4.3	2.90142	3.97029	1.01018	1.06087	0.952
3.	36.4 ± 4.6	122.2 ± 10.2	3.59447	4.80536	1.84525	1.75402	1.052
4.	57.1 ± 8.3	228.2 ± 14.4	4.04480	5.43024	2.47013	2.20425	1.112
5.	62.5 ± 7.8	306.44 ± 20.5	4.13517	5.72490	2.76479	2.29462	1.204
6.	66.7 ± 11.3	383.2 ± 21.7	4.20020	5.94855	2.98844	2.35065	1.266

Table 7

Stellaria neglecta Weihe

45% Light							
1.	8.2 ± 1.3	19.2 ± 3.2	2.10413	2.95491		-----	---
2.	26.4 ± 3.2	41.6 ± 4.5	3.27336	3.73735	0.78244	1.16923	0.669
3.	57.4 ± 6.2	85.5 6.5	4.05004	4.44852	1.49361	1.94591	0.767
4.	82.4 ± 7.1	147.7 ± 7.2	4.41159	4.99520	2.04029	2.30746	0.885
5.	98.7 ± 6.2	187.5 ± 11.6	4.59209	5.23237	2.27746	2.48796	0.915
6.	118.3 ± 5.8	234.5 ± 18.3	4.73888	5.45746	2.50255	2.63475	0.949

carried over on the next page

Stellaria neglecta Weihe continued 60% Light							
Harv. No.	$\bar{L}_A$	$\bar{W}$	$\text{Log}_e \bar{L}$	$\text{Log}_e \bar{W}$	$\bar{R}$	$\bar{R}_{L_A}$	α
1.	-7.8 ± 1.1	20.8 ± 3.5	2.05412	3.03495	---	---	---
2.	26.4 ± 2.8	49.6 ± 6.2	3.27336	3.90600	0.87105	1.21924	0.714
3.	54.8 ± 6.2	102.7 ± 8.2	4.00369*	4.63184	1.59689	1.94957	0.809
4.	86.1 ± 5.8	189.6 ± 9.5	4.45510	5.24495	2.21000	2.40139	0.920
5.	103.5 ± 11.2	246.2 ± 11.5	4.63963	5.50618	2.47123	2.58551	0.957
6.	121.6 ± 10.8	310.2 ± 12.4	4.80072	5.73722	2.70227	2.74660	0.983
80 % Light							
1.	7.3 ± 1.5	22.2 1.9	1.95019	3.10009	---	---	---
2.	23.1 ± 2.0	55.4 5.2	3.13983	4.01458	0.91449	1.18964	0.768
3.	52.0 ± 6.2	114.6 ± 11.2	3.95124	4.84155	1.74146	2.00105	0.870
4.	87.1 ± 8.3	244.2 ± 14.2	4.46706	5.49799	2.39790	2.51687	0.952
5.	105.5 ± 12.2	332.5 ± 22.4	4.65864	5.80664	2.70655	2.70845	0.999
6.	125.6 ± 10.6	423.1 ± 25.2	4.83305	6.04762	2.94753	2.88286	1.022

Stellaria pallida (Dumort.) Pire

Table 8

Harv L No.	$\bar{W}$	$\text{Log}_e \bar{L}_A$	$\bar{\text{Log}}_e \bar{W}$	$\bar{R}$	$\bar{R}_{LA}$	α
1.	2.5 ± 0.4	6.2 ± 1.1	0.91629	1.82455	—	—
2.	9.1 ± 1.2	14.8 ± 2.5	2.20827	2.69463	0.87008	1.29198
3.	24.8 ± 2.5	34.8 ± 3.3	3.21084	3.54962	1.72507	2.29455
4.	44.7 ± 3.2	67.0 ± 8.8	3.79997	4.20469	2.38014	2.88368
5.	60.4 ± 3.7	105.8 ± 6.5	4.10099	4.66144	2.83689	3.18470
6.	70.0 ± 6.2	171.3 ± 12.2	4.24850	5.06451	3.23996	3.33221
60 % Light						
1.	2.3 ± 0.3	6.8 ± 0.8	0.83291	1.91692	—	—
2.	8.7 ± 1.9	17.3 ± 2.3	2.116332	2.85071	0.93379	1.33041
3.	23.1 ± 2.2	43.6 ± 5.2	3.13983	3.77506	1.85814	2.30692
4.	44.1 ± 5.5	83.4 ± 8.5	3.78646	4.42365	2.50673	2.95355
5.	66.2 ± 4.8	131.7 ± 10.2	4.13036	4.88051	2.96369	3.29745
6.	69.1	202.2	4.23555	5.30925	3.39233	3.40264

continuation from the previous page

80 % Light

1.	2.7 ± 0.5	7.2 ± 0.9	0.99325	1.97408	—	—	—
2.	10.2 ± 2.5	19.5 ± 2.9	1.33223	2.97041	0.99533	1.32914	0.748
3.	28.3 ± 4.2	51.7 ± 8.5	3.34286	3.94546	1.97138	2.34610	0.839
4.	47.7 ± 8.3	102.2 ± 9.2	3.86793	4.62694	2.65286	2.87168	0.923
5.	66.1 ± 9.8	163.6 ± 10.2	4.11911	5.09747	3.12339	3.19792	0.976
6.	75.6 ± 8.3	238.8 ± 14.3	4.32546	5.47148	3.49740	3.33221	1.049

Mean unit leaf rate

Table 10

45 % Light

Between harvests	<u>Stellaria media</u> (L.)Vill.		<u>Stellaria neglecta</u> Weihe		<u>S. pallida</u> (Dum.) Presl	
	$\bar{E}$ (Formula 1.)	$\bar{E}$ (2)	$\bar{E}$ (1)	$\bar{E}$ (2)	$\bar{E}$ (1)	$\bar{E}$ (2)
1 - 2	1.996	1.860	1.438	1.294	1.683	1.482
1 - 3	4.255	3.477	2.621	2.021	2.941	2.095
1 - 4	5.097	4.306	3.996	2.836	4.152	2.576
1 - 5	6.971	4.906	4.627	3.148	5.477	6.384
1 - 6	8.857	6.164	5.150	3.403	8.147	9.108

60 % Light

1 - 2	2.342	2.172	1.887	1.684	1.770	1.181
1 - 3	4.752	3.873	3.396	2.616	4.080	2.897
1 - 4	6.639	5.099	5.174	3.595	5.410	3.301
1 - 5	8.340	5.929	6.088	4.050	6.443	3.646
1 - 6	10.278	7.292	6.984	4.472	9.292	5.473

80 % Light

1 - 2	3.004	2.751	2.499	2.184	2.179	1.906
1 - 3	5.995	4.819	4.136	3.116	4.077	2.870
1 - 4	9.059	6.589	6.999	4.703	6.062	4.008
1 - 5	11.702	8.347	8.555	5.501	7.886	4.546
1 - 6	13.930	9.969	9.767	6.033	10.583	5.915

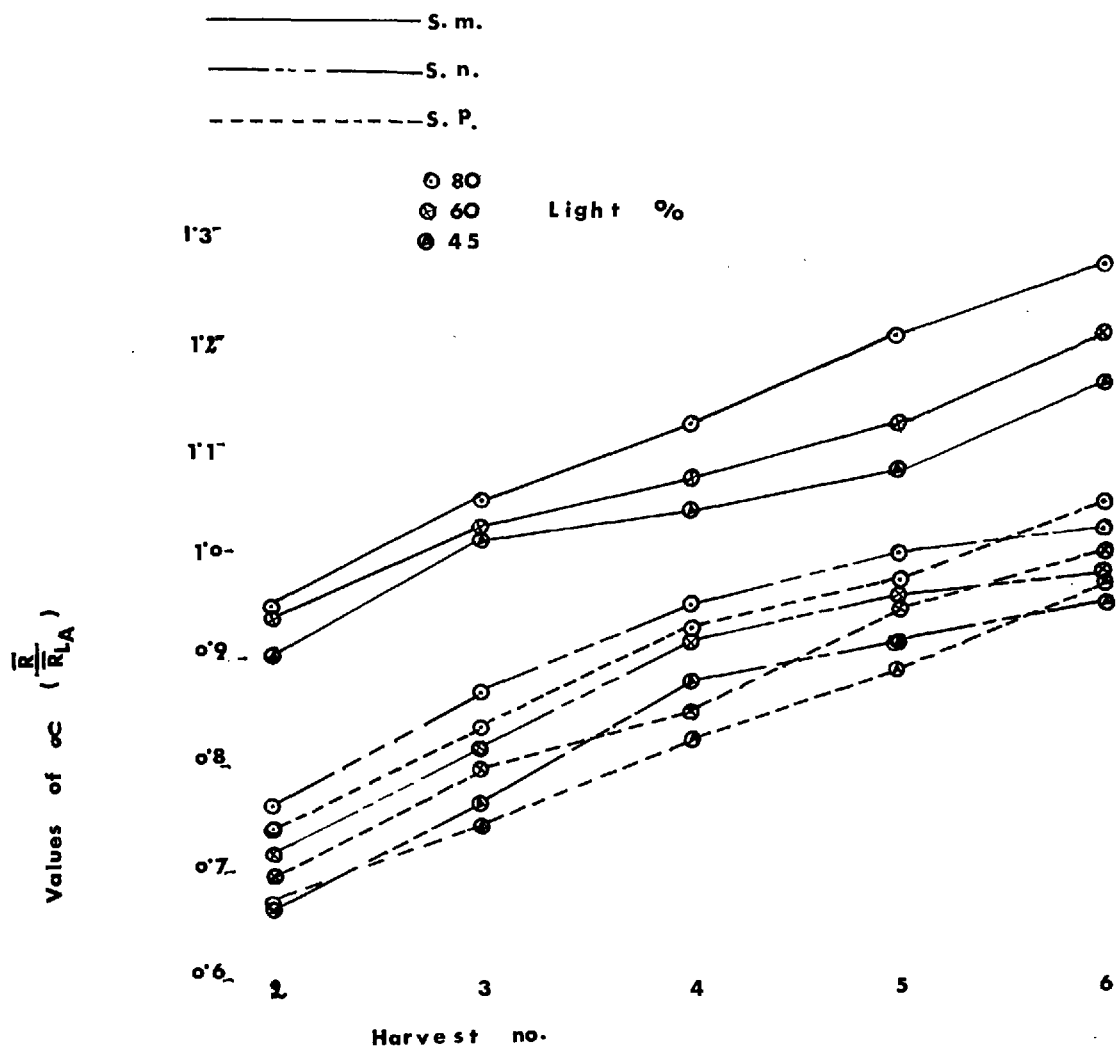


Fig. 12.

Effect of shading on Progress

Curve of dry wt.

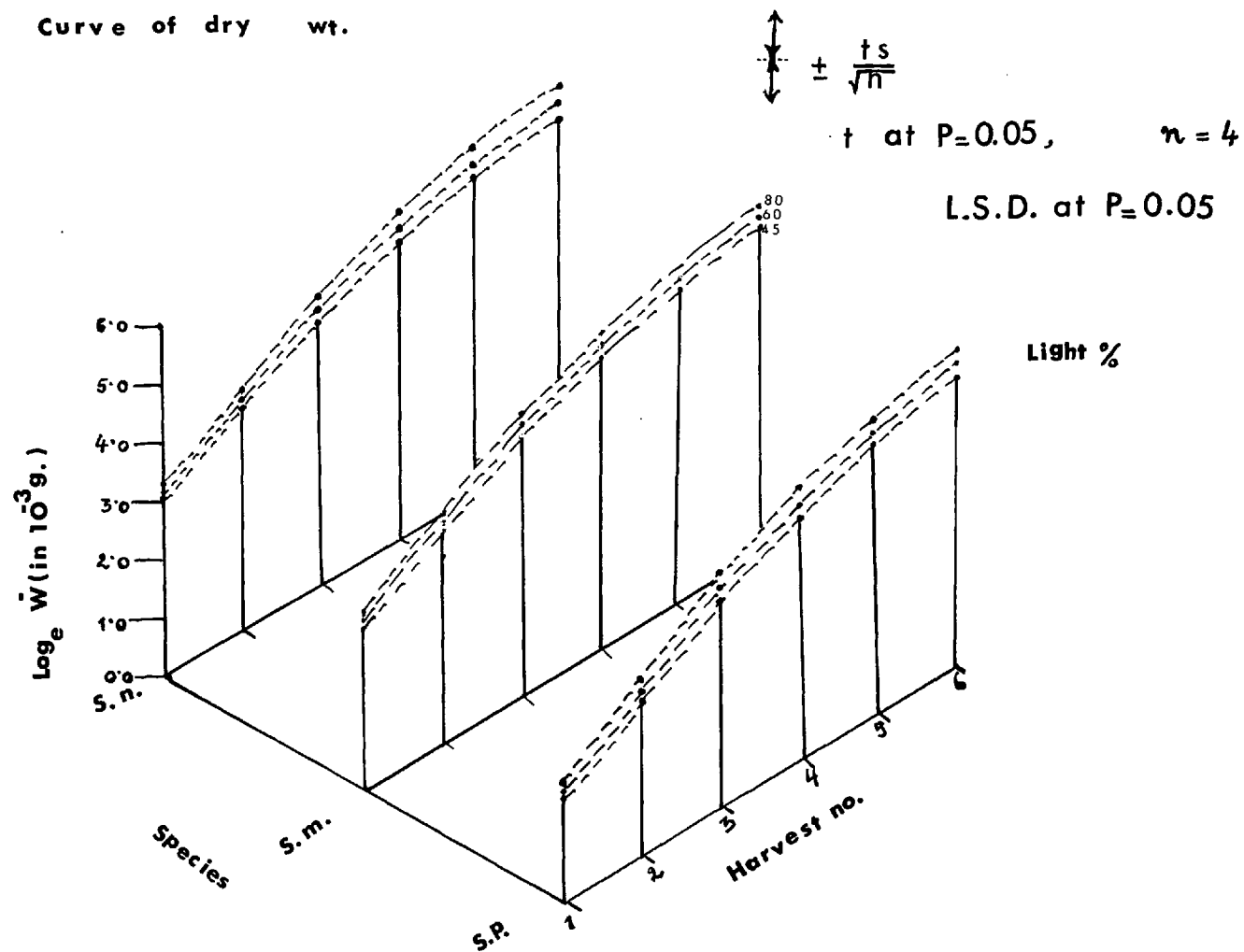


Fig. 13.

Effect of shading upon leaf area ratio

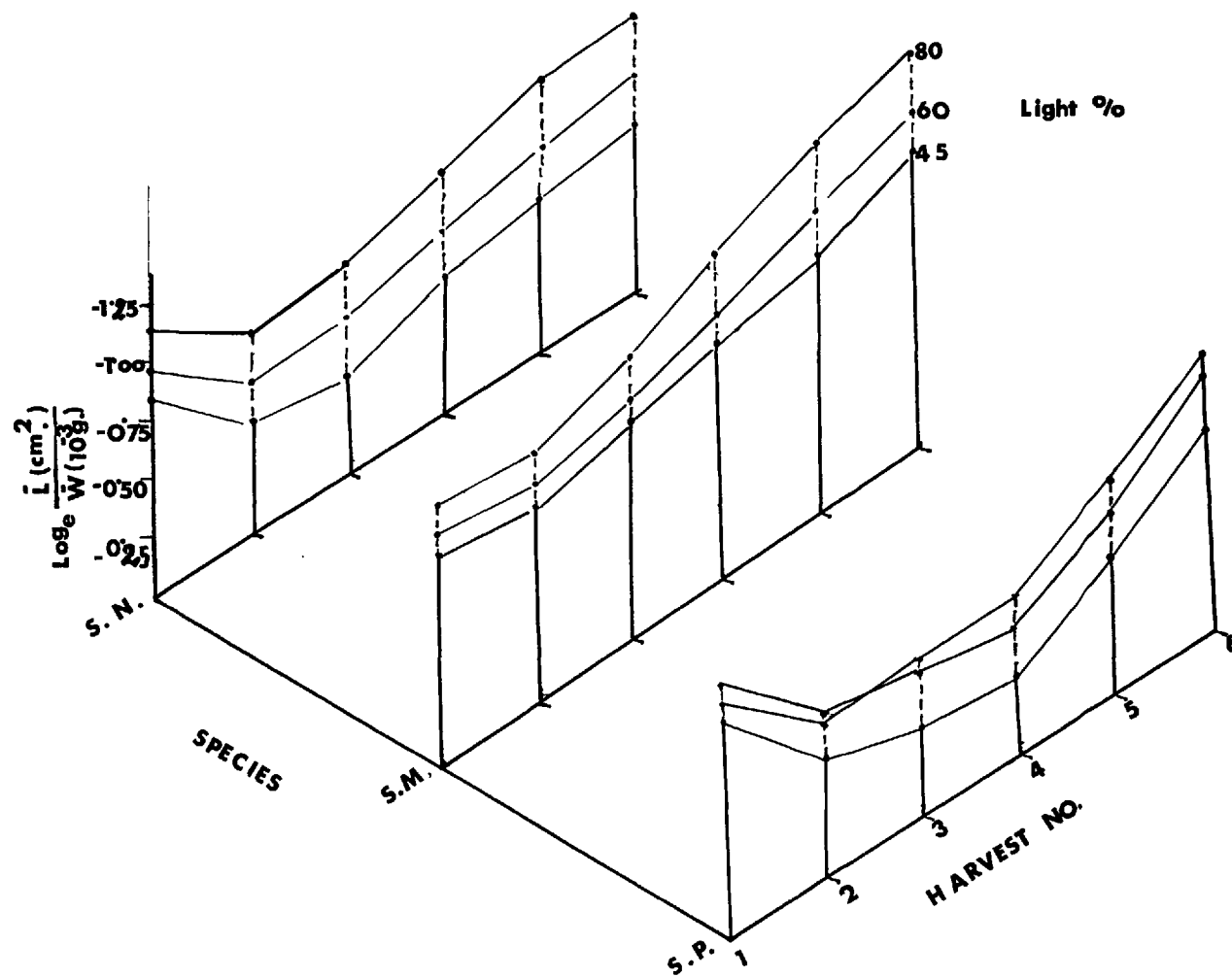


Fig. 14.

Primary data were recorded in the form of dry weight of roots , shoots and leaves together with leaf area. From these data the following parameters were calculated and compared :

(a) The mean total dry weight of plants at each harvest expressed to their natural logarithms ($\log_e$).

(b) Mean relative rate of dry-weight increase between the first and the successive harvests (mgs/mg./weeks) .

(c) The mean relative rate of leaf area increase ($\text{cm}^2/\text{cm}^2/\text{weeks}$). From these two ratios (b) and (c) ; α , i.e. $\frac{\bar{R}}{\bar{RLA}}$ was calculated.

(d) The mean unit leaf rate ($\bar{E}$) also otherwise known as Net assimilation rate .

Observations and discussion - The total dry weight and leaf area per plant for each harvest for each species at three light regimes were calculated from the primary data. Five plants were taken at each harvest .The mean values of primary recordings together with those derived for the parameters used have been given in the accompanying tables. Progress curves of dry weights , values of α and L.A.R. have been graphically represented in Figures 12 to 14 .The difference between S. media and S. neglecta in terms of dry weight gain is to an extent as calls for for a test of significance to test the validity of these differences. The significance of the differences in means of total dry weight at the sixth harvest was done by calculating the value of d using the standard formula.

The formula used was
$$d = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

The values of d are given below:

Values of d between <u>S. m.</u> and <u>S. n.</u>	Light regimes		
	80 % 2.69	60 % 0.90	45 % 3.36
<u>S. m.</u> and <u>S. p.</u>	12.90	9.90	12.65
<u>S. n.</u> and <u>S. p.</u>	14.17	13.67	6.42

Differences between S. media and S. neglecta can be appreciated only statistically in terms of dry weight. The difference at the 60 % light regime is not significant at the sixth harvest but significant at the fourth and fifth harvest. There is a marked difference between the dry weights of S. pallida on the one hand S. neglecta and S. media on the other. S. pallida is therefore clearly distinguishable from other two species in terms of dry weight gain. The other two species do not differ so much at each harvest but show clear differences in their morphogenetic conditions. It is to be noted that during the period of growth only S. media could produce flowers and fruits. The other two species despite their vigorous growth did not flower at all.

From overall performance of these species in terms of several parameters of growth it can be seen that species having similar pattern of mean relative growth may show gross differences in their morphogenetic conditions. The index α as used by Whitehead & Myerscough

(1962) appears to be the suitable parameter for the comparative assessment of related annual species of plants like the ones under investigation . It can be seen from the table and graph of α that its values for S. media at each harvest was always higher than those for the other two species. This reflected differences in the morphogenetic conditions of the species.

In S. pallida and S. neglecta increase in dry weight was accompanied by greater leafiness. In S. media , however, increase in dry weight was accompanied by diminishing increase in leafiness. Leaf area ratio has been shown in Table 9 and Figure 14 (p.99). The ratios of leaf area to total dry weight have been calculated in terms of cms.^2 and mgs. and for graphical presentation these ratios have been transformed to $\log_e$. The L.A.R. for S. media was always smaller than the other two species indicating that it has higher photosynthetic efficiency even at decreased light intensity. The performance of S. media in respect of other parameters also is better than the other two associate species. In terms of general vigour and morphogenetic features this the most efficient of all the three species. This accounts for its ubiquity and extended distribution and wider tolerance..

The mean unit leaf rate

Addition of dry matter in the body of plant is mainly the function of photosynthetic activity of leaves. The usual parameter used in growth analyses to measure this activity is $\bar{E}$ (Mean unit leaf rate , also known as Net assimilation rate). which is increase in dry weight in mgs. per cm.^2 of leaf surface per week.

This is also an index of photosynthetic efficiency and its values vary with change in ambient factors under which the plants of a particular species or different species are made to grow. It was thought that comparison of these species in respect of this parameter may have some reflection upon their taxonomic status .

In the development of concept of growth analysis several formulae have been proposed from time to time for calculation of $\bar{E}$ but none of them can claim universal or general applicability. However, the present investigation deals with the comparative assessment of three apparently different taxa of plant rather than study of a single individual species under different or one set of conditions. Two formulae have been used here for the calculation of $\bar{E}$ for the purpose of comparison. They are the following:

$$(1) \quad \bar{E} = (\log_e L_A - \log_e L_{A1}) \frac{W_2 - W_1}{L_{A2} - L_{A1}}$$

This is based upon linear relationship of L_A to W .

$$(2) \quad \bar{E} = \frac{2(W_2 - W_1)}{L_{A2} - L_{A1}}$$

This is based upon the square relationship of L_A to W .

Using ^{the} data of Briggs, Williams(1946) has determined

the values of $\bar{E}$ by graphical method and has shown that these values are intermediate between those of linear and square assumptions of the relationships between total weight and leaf area. Coombe(1960) has shown that differences in the estimates of $\bar{E}$ between these two assumptions are negligible when $\frac{LA_2}{LA_1}$ is large. A generalised expression to determine the values of $\bar{E}$ was $\frac{R}{R_{LA}}$ obtained by Whitehead & Myerscough(1962) and in this the value of α (ratio of mean relative growth to mean relative rate of leaf area increase $\frac{R}{R_{LA}}$) becomes of prime importance. Between the two harvests at t_1 and t_2 for which the value of $\bar{E}$ is desired, the relationship of W to LA , irrespective of their individual relationship with t , is represented by : $W = kL^\alpha + c$ where k and c are constants.

This is the generalised form of which linear and square assumptions are special cases. This integral equation for estimating $\bar{E}$ is then

$$\bar{E} = \frac{W_2 - W_1}{L_{A2}^\alpha - L_{A1}^\alpha} \left(\frac{L_{A2}^{\alpha-1} - L_{A1}^{\alpha-1}}{\alpha - 1} \right) \frac{\alpha}{\alpha - 1}$$

In the equation $W = kL^\alpha + c$, c is negligible. It is important only during early stages of germination when the dry weight of the seed is a large proportion of the total dry weight and the cotyledons or the first leaves are already expanded. The values of $\bar{E}$ have been derived from the values of α at all levels of shading between harvests 1 - 6. These values are given on page 105 in the table 11. It can be seen that S.media has the highest values of $\bar{E}$ at all levels of light indicating that it is the

most efficient of all the three species in respect of photosynthetic performance. For the purpose of comparison all the three formulae used give the same conclusion. It can be seen therefore that α is not only an index of morphogenetic condition but also of physiological attributes of the plants.

Table 10 A Values of $\bar{E}$ according to Whitehead's formula at varying levels of light

Between harvests	Species.	Light percentages		
		45%	60%	80%
1 - 6	<u>S.media</u>	8.60	11.63	12.74
1 - 6	<u>S.neglecta</u>	5.47	7.07	9.59
1 - 6	<u>S.pallida</u>	8.12	9.46	11.41

From the values of $\bar{E}$ in this ^{as} well as in Table 10 on page 96 it can be seen that S.media has the highest values of Mean unit leaf rate, S.neglecta has the lowest and S.pallida comes nearer to S.media rather almost equalling it. S.neglecta despite lowest values of Mean unit leaf rate has dry weights almost equal to S.media specially at the later harvests. This is due to enhanced rate of expansion of leaf surface coupled with higher ^{initial} "bonus" of seed weight. S.pallida in spite of higher Mean unit leaf rate than S.neglecta and almost equal to S.media has lowest dry weights because of lower "bonus" of initial dry seed weights. This explains for the differential behaviour of the species in terms of their morphogenetic patterns.

Formation of fructifying parts depends not on total dry weight but upon morphogenetic patterns. In the case of

S.neglecta and S.pallida increase^d weight is . distributed in maintaining the photosynthetic moiety of the plants whereas enhanced photosynthetic efficiency in S.media leads to formation of flowers and fruits. This phenomenon can be seen from the values of Leaf area ratio in Table 9 on page 95 and Fig. 14 on page 99 also . S.media has the lowest values of L.A.R. indicative of its highest photosynthetic efficiency. Thus it can be inferred that increased physiological activity and thus balanced morphogenetic pattern in S.media as compared to the other two species leads to earlier sexual maturity . This confers adaptative and survival advantages to the species and accounts for its ubiquity and extended distribution.

CHAPTER VIEffect of Nitrogen and Phosphorus on the growth and morphology of the species.

Nitrogen is one of the most important macronutrients of plants. It is a constituent of all proteins and hence of protoplasm. It is therefore essential for plant growth. It is usually taken up by plants either as ammonium or nitrate ions . The absorbed nitrate is rapidly reduced to ammonium ,probably through a molybdenum containing enzyme.The green leaves convert ammonium ions and some of the manufactured carbohydrates into amino acids. For some plants it has been shown that over a considerable range of nitrogen supply ,increase in leaf area is proportional to the amount supplied.

Increase in the supply of nitrogen relative to other elements leads to higher synthesis of protein in the leaf tissues. This protein in turn enables the leaves to grow bigger and hence to have a larger surface available for photosynthesis.In addition to enhanced rate of formation of leaf area , an increased supply of nitrogen quickens the rate of utilisation of carbohydrates for conversion into protein and protoplasm . Small amount of carbohydrates unutilised in nitrogen metabolism is made available for the formation and thickening of cell walls. These substances belong to the group of nitrogen free carbohydrates . They are mainly cellulosan ,cellulose ,calcium pectate and low nitrogen lignin.

Higher supply of nitrogen increases the proportion of protoplasm to cell wall making the leaves more succulent and less tough. It also increases the fresh weight of the plant due to increase in the amount of protoplasm. It is also known to decrease the proportion of calcium in the dry weight and to reduce the amount of cell wall material. Plants growing with a rich nitrogen supply are generally more liable to attack by insects and fungi because of their thin cell walls. On the other hand a low nitrogen supply leads to small cells with thick walls. Consequently the leaves become fibrous and tough. Plants in low nitrogen supply relative to other nutrients have pale-yellowish to reddish-green leaves. This is due to a higher concentration of sugars in the cells which often favour the synthesis of anthocyanin.

Dark-green colour of leaves is due to excessive supply of nitrogen. In general (specially with cereals) higher supply of nitrogen increases the length of growing period and delays the onset of maturity. Kenneth C. Beeson (1946) reviewed the literature on the effect of nitrogen on the mineral composition, quality and morphogenetic behaviour of plants. Russell (1961) has dealt with some of the problems and effects concerned with nitrogen supply to crop plants. Arney (1952) has studied the effects of nitrogen doses on the growth and morphology of marrow-stem kale. As has been pointed out by Beeson (op. cit.) the mineral composition of plants is a function of many factors, such as differences in soils, use of soil amendments or fertilisers, rainfall and other climatic factors. These factors overlap in their effects or work simultaneously.

Differences in these factors will mutually operate to modify the mineral composition of plants in several ways. For example ,it is possible (a) for the mineral composition of two plants of the same variety growing in different soils to be significantly different without there being any important difference in their size or distribution of their parts, such as leaf , stem or seed head ; (b) for the growth and yield of plants of the same variety to vary in different soils without any important differences in proportion of the parts of the plant; (c) for two plants of the same variety growing in different soils to have quite different distribution of leaf,stem or flower; and (d) for the environmental factors to so modify the quantities of plant constituents such as protein , carbohydrates ,lignin and cellulose as to influence the distribution of other constituents as by deposition of starch with a consequent reduction in the percentage of the mineral elements.

The properties of two soils may be such as to modify the natural flora and thus to produce plants . quite different in mineral composition .The evaluation of the influence of these factors on the plant composition is still proceeding ,and much valuable information of fundamental importance is being obtained.

As a result of these considerations the investigation of the Stellaria species in terms of their growth ,general morphology and morphogenetic behaviour was carried out .As explained , sometimes the plants of the same species growing under affluent to depauperate nutritional conditions differ so markedly in their general facies and in their morphology that morphologists are tempted to treat them

as belonging to different biological units and hence to distinct and different taxa. However, comparative culture under standard conditions in the greenhouse helps to clear up the confusion.

As a part of the present investigations plants of S. media , S. neglecta ^{and} S. pallida were grown in five different concentrations of nitrogen to study their behaviour / ⁱⁿ terms of their growth and morphogenetic pattern. The plants were therefore grown in culture solutions at varying concentrations of nitrogen.

As explained in Chapter II the corresponding deficiency with respect to potassium was made up with addition of potassium chloride. From the primary data recorded, the parameters of growth and morphogenetic condition (same as in the previous experiment) were worked out. They are presented in Tables 11 to 14 in the following pages.

Primary data and the values of parameters derived from them

Table 11

Stellaria media (L.) Vill.

Normal Nitrogen							
Harv. No.	$\bar{L}$ (oms. ²)	$\bar{W}$ (10 ⁻³ g.)	$\log_e \bar{L}A$	$\log_e \bar{W}$	$\bar{R}$	$\bar{R}_{LA}$	α
1.	10.1 ±0.6	22.2 ± 1.6	2.31254	3.10009	--	---	---
2.	25.3 ±2.0	61.2 ±3.8	3.23080	4.11415	1.01406	0.91826	1.104
3.	50.4 ±5.2	134.3 ±12.4	3.91999	4.90011	1.80002	1.60745	1.119
4.	79.4 ±9.6	248.0 ±13.6	4.37450	5.51343	2.41334	2.06196	1.170
5.	94.6 ±8.3	329.2 ±18.5	4.54966	5.79668	2.69659	2.23712	1.205
6.	98.2	428.0	4.59714	6.05913	2.95904	2.28460	1.295
N/10							
1.	6.9 ±0.4	17.6 ±1.2	1.93152	2.86790	----	---	----
2.	16.7 ±1.8	43.6 ±3.2	2.78501	3.78214	0.91424	0.85349	1.071
3.	24.8 ±2.2	102.4 ±10.3	3.21084	4.62890	1.28156	1.27932	1.001
4.	52.2 ±6.2	174.5 ±15.0	3.95508	5.15906	2.29116	2.02356	1.132
5.	70.3 ±5.8	253.0 ±18.2	4.25277	5.53339	2.66549	2.31125	1.153
6.	79.8 ±4.9	319.0 ±21.4	4.37952	5.76520	2.89730	2.44800	1.183

Stellaria media contd.

	<u>N / 50</u>						
1.	4.7 ±0.4	11.3 +1.0 —	1.54756	2.42480			
2.	10.2 ± 1.9	26.2 ±1.8	2.32239	3.26576	0.84096	0.77413	1.085
3.	20.9 ±2.1	63.4 ± 4.3	3.03975	4.14946	1.72466	1.49219	1.155
4.	24.4 ±3.6	98.1 ±5.9	3.38099	4.58599	2.16119	1.83343	1.178
5.	32.2 ±3.8	110.0 ±8.2	3.47199	4.70049	2.27569	1.92441	1.182
6.	36.3 ±3.8	129.0 ±7.9	3.59182	4.85982	2.43502	2.04426	1.191

S.media contd.

Harv. No.	$\bar{L}_A$ (cms. ²)	$\bar{W}$ (10 ⁻³ g)	Log _e $\bar{L}_A$	Log _e $\bar{W}$	$\bar{R}$	$\bar{R}_{L_A}$	α
	N/100						
1.	4.1 ±0.3	8.2 ±0.8	1.41099	2.10413	—	—	—
2.	7.8 ±0.9	17.2 ±1.5	2.05412	2.84491	0.74078	0.64313	1.151
3.	15.4 ±2.1	39.2 ±2.6	2.73437	3.66868	1.56455	1.32338	1.183
4.	19.4 ±2.5	55.3 ±3.7	2.96527	4.01277	1.90864	1.55428	1.227
5.	23.2 ±3.1	68.2 ±8.6	3.14415	4.22244	2.11831	1.73316	1.222
6.	26.5 ±2.9	72.3 ±9.3	3.27714	4.28082	2.17669	1.55428	1.400

N / 500

1.	2.7 ±0.2	6.4 ±0.4	0.99325	1.85630	---	---	---
2.	4.7 ±0.5	11.2 ±0.8	1.54756	2.41591	0.55961	0.55431	1.00
3.	8.1 ±1.6	18.2 ±1.6	2.09186	2.90142	1.04512	1.09861	0.948
4.	8.7 ±0.8	24.6 ±1.9	2.16332	3.19908	1.34278	1.17007	1.147
5.	11.9 ±2.0	39.4 ±3.2	2.47654	3.67377	1.81747	1.48329	1.225
6.	13.2 ±2.2	42.3 ±4.3	2.58022	3.74479	1.88849	1.58697	1.189

Stellaria neglecta weihe

Table 12

Normal Nitrogen

Harv. No.	L_A (cms. ²)	$\bar{W}$ (10 ⁻³ g)	$\text{Log}_e L_A$	$\text{Log}_e \bar{W}$	$\bar{R}$	$\bar{R}_{L_A}$	α
1.	11.2 ±1.3	24.1 ±1.8	2.41591	3.18221	---	----	---
2.	39.5 ±2.2	68.6 ± 3.2	3.67630	4.22829	1.04608	1.26039	0.829
3.	71.7 ±3.1	148.2 ±8.4	4.27249	4.99858	1.81637	1.85658	0.978
4.	118.5 ±8.9	250.0 ±11.4	4.77496	5.52147	2.33926	2.35905	0.991
5.	172.2 ±14.8	354.0 ±19.3	5.14886	5.86930	2.68709	2.73267	0.981
6.	197.5 ±15.3	446.0 ±18.3	5.28575	6.09632	2.91712	2.86984	1.003

N / 10

1.	6.9 ±0.4	15.8 ±1.2	1.93152	2.76001	----	----	---
2.	17.5 ±1.5	39.6 ±3.5	2.86220	3.67883	0.91951	0.93068	0.987
3.	48.2 ±2.2	96.4 ±2.2	3.87536	4.56851	1.80850	1.94384	0.930
4.	71.2 ±4.3	153.6 ±12.4	4.26549	5.03437	2.27436	2.33397	0.974
5.	113.3 ±7.9	239.0 ±20.4	4.73007	5.47647	2.71646	2.79855	0.970
6.	142.6 ±8.6	308.0 ±29.2	4.96991	5.73010	2.97009	3.03839	0.977

Stellaria neglecta

contd.

N/ 50

Harv. No.	$\bar{L}$	$\bar{W}$	$\text{Log}_e \bar{L}_A$	$\text{Log}_e \bar{W}$	$\bar{R}$	$\bar{R}_{LA}$	α
1.	4.3 ± 0.3	10.1 ± 0.5	1.45862	2.31254	----	----	---
2.	10.8 ± 0.9	23.3 ± 1.6	2.37955	3.14845	0.83591	0.92093	0.907
3.	25.5 ± 1.2	57.6 ± 2.3	3.23868	4.05352	1.74098	1.78006	0.978
4.	41.5 ± 3.2	89.3 ± 7.2	3.72569	4.49200	2.17946	2.26707	0.961
5.	48.3 ± 3.0	102.0 ± 5.8	3.87743	4.62498	2.31244	2.41881	0.956
6.	51.4 ± 2.8	112.2 ± 6.8	3.93964	4.72029	2.40775	2.48102	0.970

N/100

1.	4.0 ± 0.3	7.9 ± 1.0	1.38629	1.95869	----	---	---
2.	8.8 ± 0.9	14.1 ± 1.6	2.17475	2.64617	0.68745	0.78846	0.871
3.	20.1 ± 1.2	31.4 ± 2.5	2.99573	3.44681	1.48812	1.60944	0.924
4.	36.3 ± 2.6	50.2 ± 4.3	3.59182	3.91601	1.95732	2.20553	0.887
5.	43.3 ± 3.5	59.2 ± 4.8	3.76815	4.08092	2.12403	2.38186	0.891
6.	48.2 ± 4.1	64.1 ± 6.4	3.87536	4.01604	2.05735	2.48907	0.826

<u>N / 500</u>							
Harv. No.	$\bar{L}_A$	$\bar{W}$	$\text{Log}_e \bar{L}_A$	Log_e	$\bar{R}$	$\bar{R} \bar{L}_A$	α
2.							
1.	2.8 ± 0.3	5.9 ± 0.5	1.06471	1.62428	---	----	---
2.	5.9 ± 0.5	8.7 ± 0.4	1.77495	2.16332	0.53604	0.71024	0.754
3.	11.2 ± 0.8	15.3 ± 1.2	2.41591	2.72785	1.10057	1.35120	0.814
4.	16.6 ± 1.1	22.1 ± 1.5	2.80940	3.09558	1.46830	1.74469	0.841
5.	24.8 ± 1.2	32.1 ± 2.1	3.21084	3.46886	1.84158	2.14613	0.858
6.	30.7 ± 2.1	39.4 ± 2.9	3.42426	3.66612	2.07384	2.35955	0.864

Table 13

Normal NitrogenStellaria pallida(Dum.)Piré

Harv. No.	$\bar{L}_A$	$\bar{W}$	$\text{Log}_e \bar{L}_A$	$\text{Log}_e \bar{W}$	$\bar{R}$	R_{L_A}	α
1.	2.05 ± 0.2	6.9 ± 0.5	0.71784	1.93152	---	----	----
2.	12.9 ± 1.6	21.2 ± 2.4	2.55723	3.05400	1.112248	1.83939	0.604
3.	31.8 ± 3.2	50.3 ± 5.2	3.45747	3.91801	1.98649	2.74163	0.724
4.	68.5 ± 4.8	108.4 ± 9.4	4.22683	4.68588	2.75436	3.50899	0.784
5.	102.0 ± 11.9	171.5 ± 16.7	4.62487	5.14458	3.21306	3.90684	0.882
6.	146.5 ± 21.5	231.6 ± 19.8	4.91701	5.44498	3.51346	4.19917	0.836
N/10							
1.	2.03 ± 0.3	6.1 ± 0.7	0.70804	1.80829	---	---	---
2.	10.8 ± 1.7	18.2 ± 2.1	2.37955	2.90142	1.09313	1.67151	0.653
3.	26.4 ± 3.6	42.4 ± 4.7	3.27336	3.74715	1.93836	2.56532	0.755
4.	62.6 ± 6.2	98.3 ± 7.7	4.13677	4.58802	2.77973	3.42873	0.810
5.	95.8 ± 8.9	149.3 ± 12.6	4.56226	5.00599	3.19770	3.85422	0.829
6.	122.6 ± 13.2	205.3 ± 17.4	4.80895	5.32448	3.51619	4.10091	0.857

Stellaria pallida

contd.

N / 50

Harm. No.	$\bar{L}_A$	$\bar{W}$	$\text{Log}_e \bar{L}_A$	$\text{Log}_e \bar{W}$	$\bar{R}$	$\bar{R}_{LA}$	α
1.	2.1 ± 0.3	5.7 ± 1.0	0.74194	1.74047	---	---	---
2.	8.5 ± 1.3	14.3 ± 2.1	2.14007	2.66026	0.91979	1.39813	0.657
3.	22.5 ± 2.6	30.3 ± 3.2	3.11352	3.41115	1.67068	2.37158	0.936
4.	41.5 ± 3.7	66.2 ± 5.2	3.72569	4.19268	2.45221	2.98375	0.821
5.	50.5 ± 4.3	82.2 ± 7.6	3.92197	4.40916	2.66869	3.18003	0.829
6.	72.8 ± 9.9	117.2 ± 13.2	4.28772	4.76389	3.02342	3.54578	0.852

N/100

1.	2.0 ± 0.2	4.1 ± 0.4	0.69315	1.41099	--	----	-----
2.	3.9 ± 0.3	8.3 ± 1.6	1.36098	2.11626	0.70527	0.66783	1.056
3.	11.3 ± 2.0	16.4 ± 3.1	2.42480	2.79728	1.38629	1.73165	0.800
4.	22.5 ± 3.2	34.2 ± 1.9	3.11352	3.53223	2.12124	2.42037	0.876
5.	30.5 ± 3.2	51.0 ± 2.9	3.41773	3.93183	2.52084	2.72458	0.925
6.	47.8 ± 5.6	75.2 ± 12.2	3.86703	4.32015	2.90916	3.17388	0.916

Stellaria pallida(Dumort.)Pire' contd.N / 500

Harv. No.	$\bar{L}_A$	$\bar{W}$	$\text{Log}_e \bar{L}_A$	$\text{Log}_e \bar{W}$	$\bar{R}$	$\bar{R}_{L_A}$	α
1.	1.5 ± 0.3	3.0 ± 0.4	0.40457	1.09361	---	---	---
2.	2.9 ± 0.6	5.0 ± 1.4	1.06471	1.60944	0.51083	0.66014	0.77382
3.	5.2 ± 1.7	8.2 ± 2.1	1.64866	2.10413	1.00552	1.24409	0.80823
4.	8.3 ± 1.9	15.1 ± 2.7	2.11626	2.71469	1.61608	1.71179	0.944
5.	12.5 ± 1.4	26.1 ± 2.9	2.52573	3.26194	2.16330	2.12116	1.019
6.	26.8 ± 3.1	42.1 ± 4.3	3.28840	3.74005	2.64144	2.88383	0.915

Table 14 LEAF AREA RATIO

Dosage	Sp.	$\frac{\bar{L}_A}{\bar{W}}$	$\text{Log}_e \frac{\bar{L}_A}{\bar{W}}$	Sp.	$\frac{\bar{L}_A}{\bar{W}}$	$\text{Log}_e \frac{\bar{L}_A}{\bar{W}}$	Sp.	$\frac{\bar{L}_A}{\bar{W}}$	$\text{Log}_e \frac{\bar{L}_A}{\bar{W}}$
N.	<i>Stellaria media</i> (L.) Vill.	0.454	-0.789	<i>Stellaria neglecta</i> Weinb.	0.464	-0.767	<i>Stellaria pallida</i> (Dum.) Piré	0.362	-1.016
		0.413	-0.884		0.575	-0.553		0.608	-0.497
		0.375	-0.980		0.483	-0.727		0.632	-0.458
		0.320	-1.139		0.474	-0.746		0.631	-0.631
		0.287	-1.124		0.486	-0.721		0.594	-0.520
		0.229	-1.147		0.442	-0.816		0.606	-0.500
N/10	<i>Stellaria media</i> (L.) Vill.	0.392	-0.936	<i>Stellaria neglecta</i> Weinb.	0.436	-0.830	<i>Stellaria pallida</i> (Dum.) Piré	0.377	-0.975
		0.383	-0.959		0.441	-0.818		0.593	-0.522
		0.242	-1.418		0.500	-0.693		0.622	-0.474
		0.300	-1.203		0.463	-0.770		0.636	-0.452
		0.277	-1.283		0.486	-0.721		0.641	-0.444
		0.250	-1.386		0.462	-0.772		0.597	-0.515
N/50	<i>Stellaria media</i> (L.) Vill.	0.415	-0.879	<i>Stellaria neglecta</i> Weinb.	0.425	-0.855	<i>Stellaria pallida</i> (Dum.) Piré	0.368	-0.996
		0.389	-0.944		0.463	-0.770		0.594	-0.520
		0.329	-1.111		0.442	-0.816		0.704	-0.350
		0.299	-1.207		0.464	-0.767		0.629	-0.468
		0.292	-1.231		0.473	-0.748		0.614	-0.487
		0.281	-1.269		0.458	-0.780		0.621	-0.476
N/100	<i>Stellaria media</i> (L.) Vill.	0.500	-0.693	<i>Stellaria neglecta</i> Weinb.	0.506	-0.681	<i>Stellaria pallida</i> (Dum.) Piré	0.487	-0.719
		0.453	-0.791		0.624	-0.471		0.469	-0.757
		0.392	-0.936		0.640	-0.446		0.689	-0.372
		0.350	-1.409		0.723	-0.324		0.657	-0.420
		0.340	-1.078		0.731	-0.313		0.598	-0.514
		0.268	-1.316		0.751	-0.286		0.635	-0.454
N/500	<i>Stellaria media</i> (L.) Vill.	0.421	-0.865	<i>Stellaria neglecta</i> Weinb.	0.491	-0.711	<i>Stellaria pallida</i> (Dum.) Piré	0.500	-0.693
		0.419	-0.869		0.678	-0.388		0.580	-0.544
		0.445	-0.809		0.332	-0.311		0.634	-0.455
		0.353	-1.041		0.751	-0.286		0.549	-0.599
		0.302	-1.197		0.772	-0.258		0.478	-0.738
		0.312	-1.164		0.779	-0.249		0.636	-0.452

The values of $\bar{E}$ were also calculated using the formula

$$\bar{E} = \frac{W_2 - W_1}{L_{A2} - L_{A1}} \cdot \frac{(L_{A2}^{\alpha-1} - L_{A1}^{\alpha-1})}{\alpha - 1} \cdot \frac{\alpha}{L_{A2} - L_{A1}} .$$

These values between harvests 1 - 6 at various dosages of nitrogen for all the three species are given below.

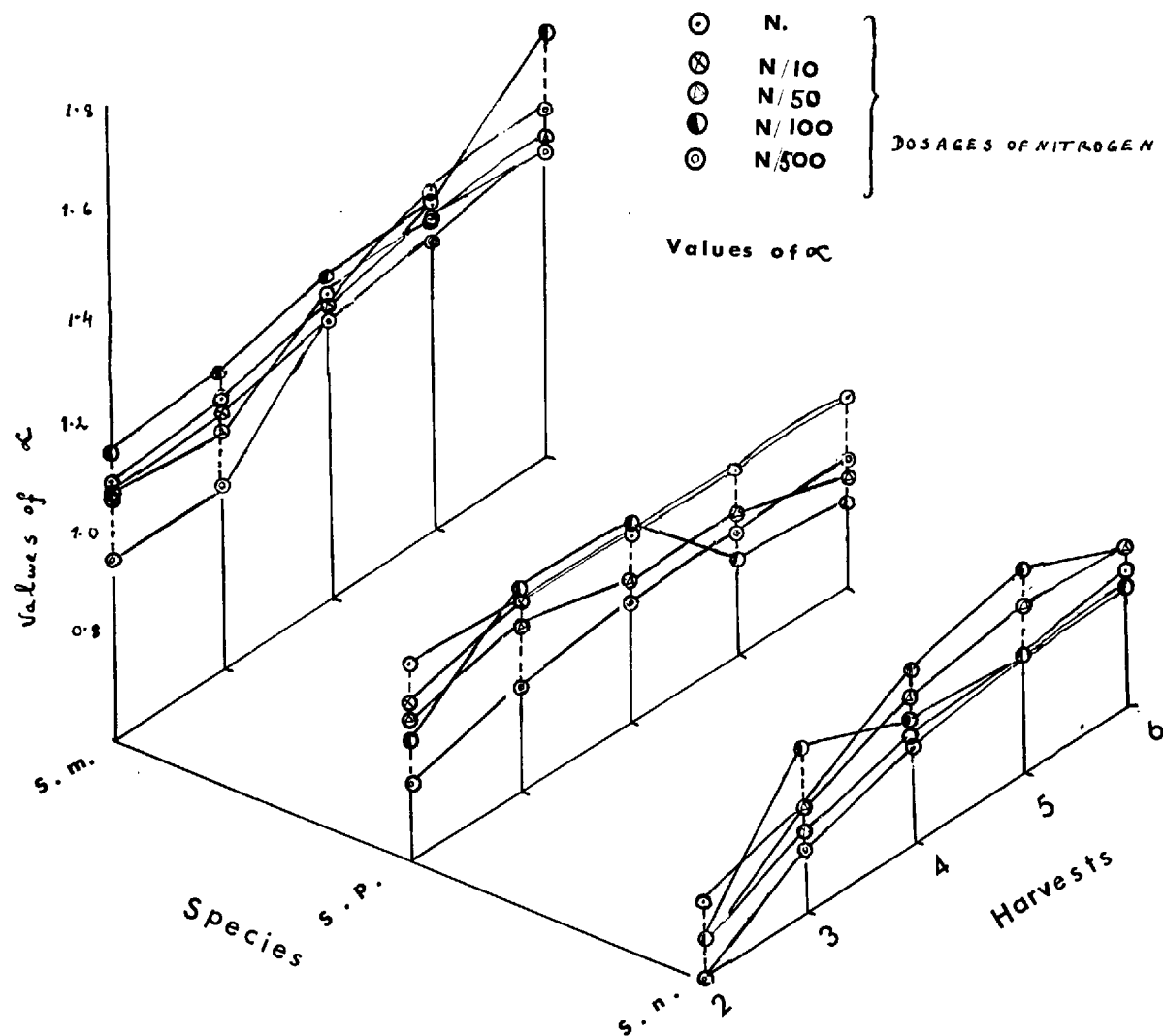
Table 14A

Dosages of N.	Values of $\bar{E}$ between harvests 1 - 6 for all the three species.		
N	<u>S.media</u>	<u>S.neglecta</u>	<u>S.pallida</u>
	9.376	6.703	8.120
N/10	9.266	6.635	8.203
N/50	7.165	5.457	6.381
N/100	6.291	3.680	5.243
N/500	5.225	3.055	4.651

From these values of $\bar{E}$ as well as the values of leaf area ratios given in Table 14 on page 120, it can be seen that S.media has the highest photosynthetic efficiency at all levels of nitrogen dosages. As is usual with most of the plants the dry weights at each harvest go on decreasing with decreasing dosages of nitrogen but the morphogenetic patterns remain unchanged. At all levels of nitrogen S.media produced flowers and fruits but the other two species were characterised by increased leafiness. This similarity in morphogenetic pattern could be seen from the values of

a in the Tables 11 - 13 from pages 111 to 119 and Fig. 15 on the page 123. In the case of amphimicts production of seeds even under depauperate nutritional conditions is the key to the success of species and this marks their stenoplastic nature and wider tolerance. The other two species are characterised by their specificity in terms of their ambient conditions for successful completion of life-cycle. In the case of S. media dry weight from normal nitrogen to N/500 is reduced from 428.0 mgs. to 42.3 as against 446.0 to 39.4 in S. neglecta which shows the enhanced capacity of S. media to withstand starvation due to nitrogen. In the case of S. pallida, however, the dry weight is reduced from 231.6 to 42.0. Thus it can be seen that S. neglecta is the most sensitive species with respect to reduced dosages of nitrogen, next comes S. media and S. pallida has the least sensitivity in terms of dry weight reduction. This does not apply, however, to morphogenetic patterns or to other parameters of growth used in the present context.

These weights together with parameters derived from them can be seen in Tables 11 - 13 and Figs. 15 - 17. It can be seen that despite fall in physiological activity and thus overall reduction in dry wt. the morphogenetic patterns remain all the same. Balanced morphogenesis in S. media even under poorest availability of macronutrients like N makes the species quite distinct and different from the other ones under investigation. In spite of morphological convergence the three groups have different physiological status, growth and developmental patterns. In cases of such convergence, therefore comparison of gross morphology has to be combined with physiological and biological attributes otherwise there is likelihood of fallacious conclusions to be drawn.



123
Fig. 15.

Progress curves of dry wts.

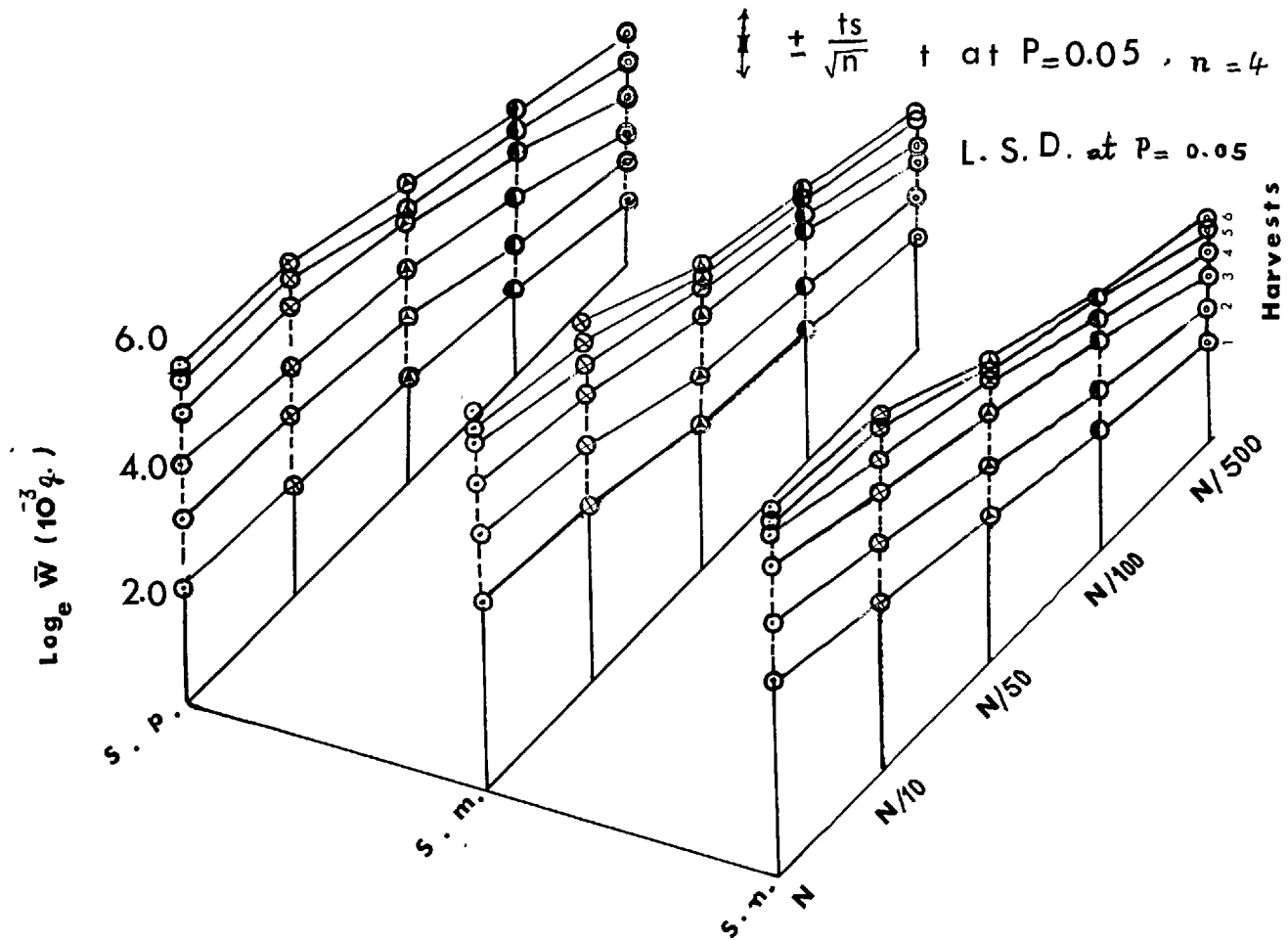


Fig. 16.

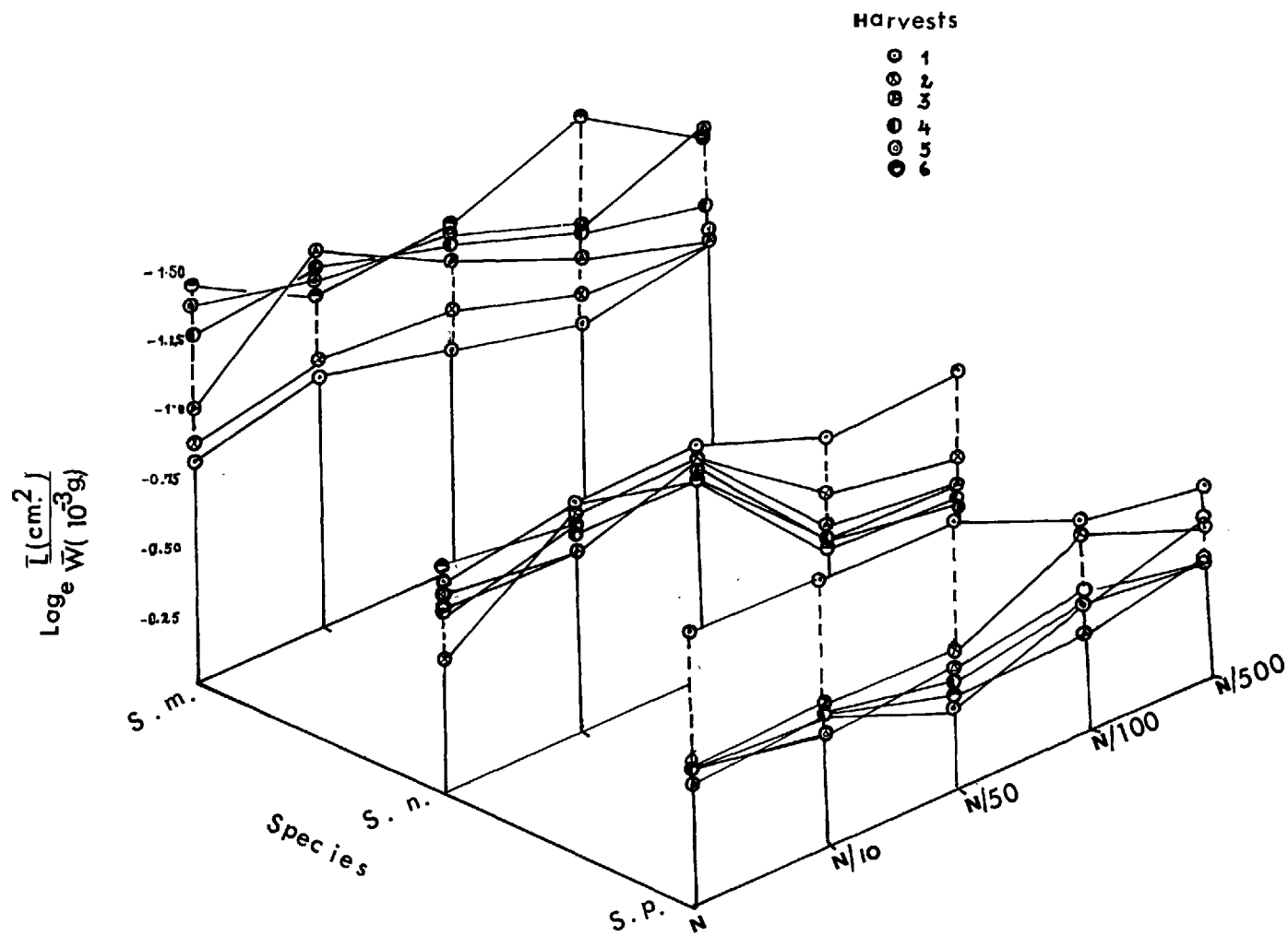
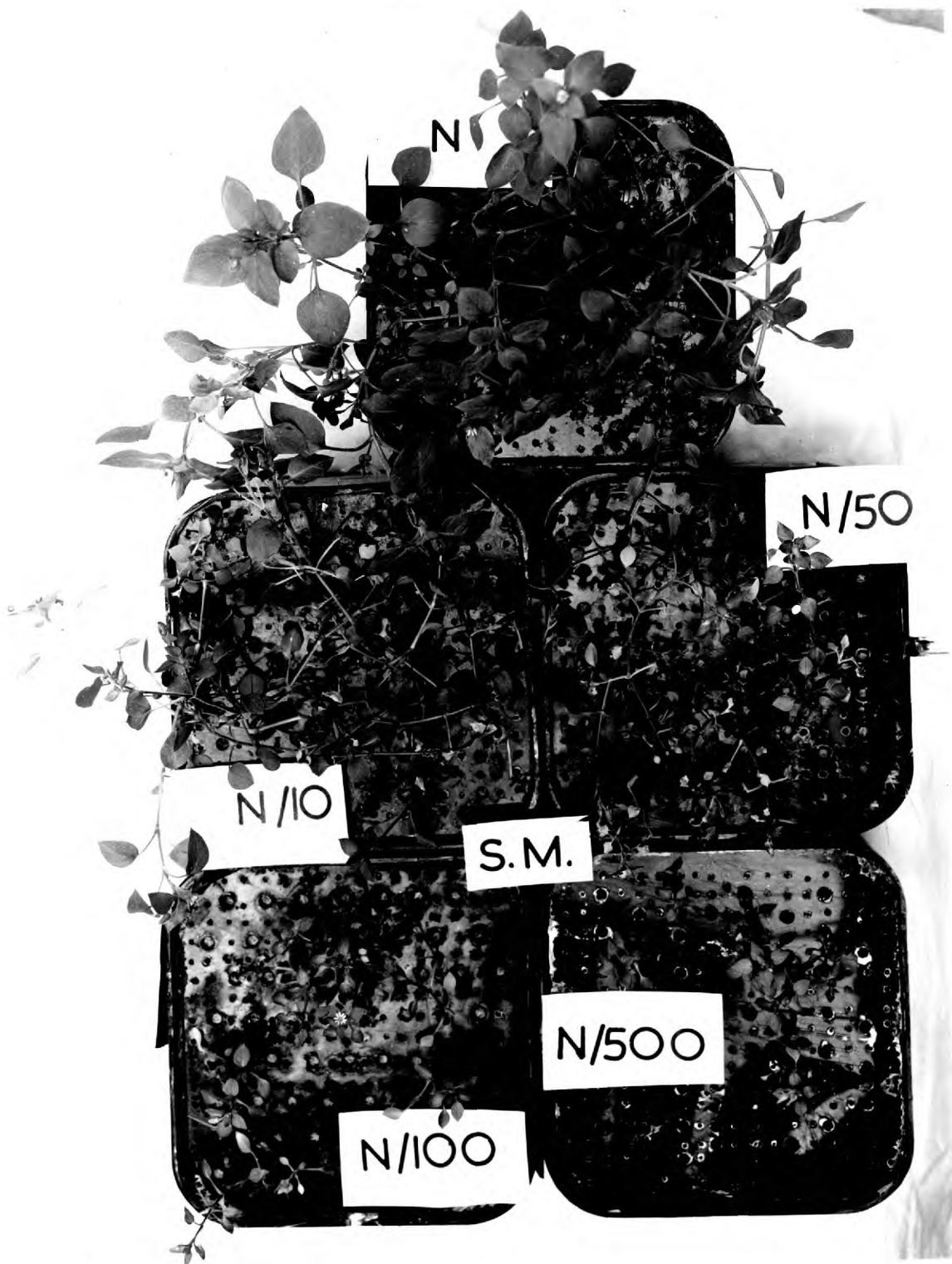


Fig. 17.



18
Fig. Plants of *Stellaria media* grown at varying levels of nitrogen.

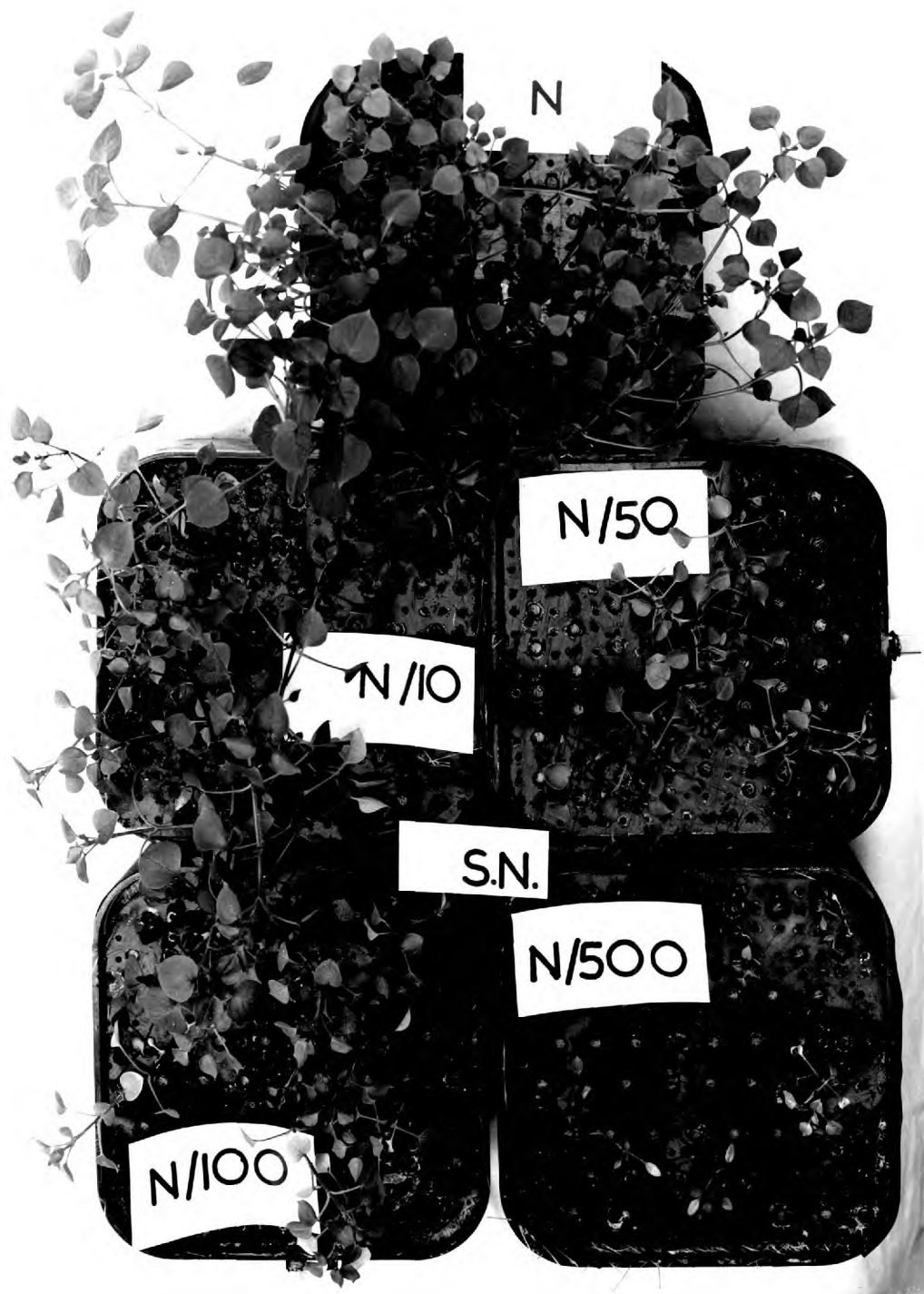


Fig. 19. Plants of *Stellaria neglecta* Weihe grown at varying levels of nitrogen.



Fig. 20. Plants of *Stellaria pallida* (Dumort.) ¹grown at varying levels of nitrogen.

Phosphorus

Phosphorus being an important constituent of nucleic acid is essential for cell division and development of meristematic tissues. This is because phosphorus as orthophosphate, plays a fundamental role in all enzymatic reactions that depend upon phosphorylation. Its concentration in the tissues where its presence is essential can be demonstrated by using some radioactive phosphorus P^{32} mixed with main nitrogen supply. In experiments at Rothamsted Experimental Station its presence has been demonstrated from several hundred to several thousand times more than in the cells that have ceased to divide. In respect of some crop plants it has been shown in Britain that crop plants are on the whole more responsive to phosphate fertiliser in the higher rainfall areas of west than in drier regions in the east.

It is still to be investigated whether this is purely a reflection of the tendency of the soils in the moister regions to be more acid and therefore strong fixers of phosphate in an unavailable form or whether it is due to the crops having higher phosphate demand in wet years. Phosphate deficiency like the one due to nitrogen is difficult to diagnose in the case annual species of plants. It has been shown in some cases that plants may be starving severely for phosphorus without any evident diagnostic symptoms. This has been noted by Russell (loc. cit.) in some cereal crops. In the case of Barley it has been shown that phosphorus deficiency leads to stunted root system and development of red pigment in the dying leaves and at the base of leaves. It has been shown by Meyer et al. (1963) that role of phosphorus and nitrogen in the plant

metabolism is inter-related. Inorganic nitrogen compounds are absorbed and they accumulate in plant tissues when the supply of nitrogen is low.

When available phosphates are abundant in the rooting system the absorption of inorganic nitrogen is depressed. Application of phosphate fertilisers may alter the nitrogen balance of the plant. It is illustrated by earlier maturity of plants when available phosphate is high and delay in maturity when plants are deficient in nitrogen. Correlated with this decrease in protein synthesis there is often an accumulation of sugars in vegetative parts. The purple coloration of leaves associated with P deficiency in corn, tomato and other plants is due to high concentration of sugar which often favours the synthesis of anthocyanin.

There are evidences to indicate that phosphates are more readily accumulated in the plant when nitrogen is supplied in the organic form (urea) than when it is supplied in the form of nitrate. In the case of plants starving for phosphorus large proportion of it may move from older parts to the developing parts which need phosphorus the most. In the case of tomato plants phosphorus may be taken by the developing fruits even from the developing young leaves. It has been shown that mobility of phosphorus from the leaves to the growing organs is very high when external supply of P is very low.

The present experiment was designed to study the growth and morphology of the species. Primary data were recorded from five successive harvests. As usual five plants were harvested at each harvest. These together with derivations from them for the parameters used are presented in Tables to and

Table 15 P/10 *Stellaria media*(L.)Vill.

Harv. No.	$\bar{L}_A$	$\bar{r}$	$\log_e \bar{L}_A$	$\log_e \bar{r}$	$\bar{R}$	$\bar{R}_{L_A}$	α
1	7.7 ± 0.6	19.2 ± 2.8	2.04122	2.95491	--	---	---
2.	18.5 ± 1.9	50.4 ± 5.6	2.91777	3.91999	0.96508	0.87655	1.101
3.	31.2 ± 3.6	118.3 ± 9.6	3.44042	4.77325	1.81834	1.39920	1.299
4.	57.5 ± 4.8	198.2 ± 12.6	4.05178	5.28929	2.33438	2.01056	1.161
5.	76.2 ± 7.2	279.2 ± 10.9	4.33336	5.63195	2.67704	2.29214	1.167
6.	83.4 ± 8.3	360.5 ± 14.7	4.42365	5.88748	2.93257	2.38243	1.230

P/50

1.	5.2 ± 0.3	14.2 ± 1.4	1.62924	2.65324	----	----	----
2.	16.3 ± 3.2	41.2 ± 5.4	2.79117	3.71844	1.06520	1.16193	0.916
3.	32.5 ± 2.5	95.9 ± 7.8	3.48124	4.56331	1.91007	1.85200	1.031
4.	36.2 ± 3.7	135.6 ± 9.5	3.58906	4.90966	2.25642	1.95982	1.151
5.	44.8 ± 3.8	156.2 ± 12.6	3.80221	5.05113	2.39789	2.17297	1.103
6.	56.2 ± 5.2	195.6 ± 14.1	4.02892	5.27605	2.62281	2.39968	1.088

Stellaria media contd. P/100

Harv. No.	$\bar{L}_A$	$\bar{W}$	$\text{Log}_e \bar{L}_A$	$\text{Log}_e \bar{W}$	R	$\bar{R}_{L_A}$	α
1.	4.8 +0.4	10.2 ± 1.6	1.56862	2.32239	---	---	---
2.	9.5 ± 1.2	21.4 ± 3.2	2.25129	3.06339	0.74100	0.68267	1.085
3.	21.3 ± 4.1	56.2 ± 5.2	3.05871	4.02892	1.70653	1.49009	1.145
4.	24.3 ± 3.2	79.4 ± 7.9	3.19048	4.37450	2.05211	1.62186	1.265
5.	28.2 ± 4.2	88.6 ± 7.2	3.33932	4.48413	2.16174	1.77070	1.220
6.	30.5 ± 2.3	100.2 ± 10.4	3.41773	4.62498	2.30259	1.84911	1.245
P/500							
1.	3.2 ± 0.2	8.4 ± 1.3	1.16315	2.12823	---	---	---
2.	5.8 ± 0.6	16.6 ± 2.3	1.75786	2.80940	0.68117	0.59471	1.145
3.	9.3 ± 1.6	26.2 ± 4.3	2.23001	3.26576	1.13753	1.06686	1.072
4.	13.2 ± 2.5	30.5 ± 3.9	2.58022	3.41773	1.28950	1.41707	0.909
5.	16.7 ± 1.7	42.4 ± 6.2	2.81541	3.74715	1.61892	1.65226	0.979
6.	18.6 ± 2.0	51.4 ± 4.8	2.92316	3.93964	1.81141	1.76001	1.029

Table 16 Stellaria neglecta P/10

Harv. No.	$\bar{L}_A$	$\bar{W}$	$\text{Log}_e L_A$	$\text{Log}_e \bar{W}$	$\bar{R}$	$\bar{R}_{L_A}$	α
1	8.0	19.7	2.07944	2.98062	---	---	---
2.	22.8	56.4	3.11352	4.03247	1.05185	1.03481	1.016
3.	60.9	124.2	4.10923	4.82187	1.84125	2.02979	0.907
4.	103.6	209.5	4.64061	5.34478	2.36416	2.56117	0.923
5.	141.2	274.2	4.95017	5.61386	2.63325	2.87073	0.917
6.	183.6	387.2	5.21279	5.95895	2.97833	3.13335	0.950

P/50

1.	5.6	13.2	1.72277	2.58022	---	---	---
2.	13.2	32.9	2.58022	3.49347	0.91325	0.85745	1.065
3.	31.3	69.6	3.44362	4.24276	1.66254	1.72085	0.966
4.	45.6	95.4	3.81991	4.55808	1.97786	2.09714	0.943
5.	53.3	117.6	3.97594	4.76730	2.18708	2.25317	0.970
6.	59.4	129.2	4.08429	4.86140	2.28118	2.36152	0.965

<u>Stellaria neglecta</u>							
cotd.				P/100			
Harv. No.	$\bar{L}_A$	$\bar{W}$	$\text{Log}_e \bar{L}_A$	$\text{Log}_e \bar{W}$	$\bar{R}$	$\bar{R}_{L_A}$	α
1.	4.3	8.7	1.46049	2.16332	---	---	---
2.	9.5	17.4	2.25129	2.85647	0.69315	0.79080	0.876
3.	25.2	39.4	3.22684	3.57311	1.51045	1.76635	0.855
4.	42.4	56.7	3.74715	4.03777	1.87445	2.28666	0.819
5.	49.4	65.4	3.89995	4.18052	2.01720	2.43946	0.826
6.	52.2	69.2	3.95508	4.23700	2.07368	2.49459	0.831
P/500							
1.	3.2	7.2	1.16315	1.97408	---	---	---
2.	6.4	10.5	1.85630	2.35138	0.37730	0.69315	0.544
3.	13.7	17.5	2.61740	2.86220	0.88812	1.45425	0.610
4.	19.5	25.5	2.97041	3.23868	1.26460	1.80706	0.699
5.	27.5	36.8	3.31419	3.60550	1.63142	2.15104	0.758
6.	35.2	44.4	3.56105	3.79324	1.81916	2.39790	0.758

Table 17

Stellaria pallida (Dumort.) Pire
P/10

Harv. No.	$\bar{L}_A$	$\bar{W}$	$\text{Log}_e \bar{L}_A$	$\text{Log}_e \bar{W}$	$\bar{R}$	R_{L_A}	α
1.	2.6 ± 0.3	7.1 ± 0.6	0.95551	1.96009	---	---	---
2.	13.5 ± 1.8	25.6 ± 3.2	2.60269	3.16548	1.20539	1.64718	0.731
3.	29.5 ± 3.9	47.2 ± 4.8	3.38439	3.85439	1.89430	2.42888	0.709
4.	71.4 ± 5.1	110.2 ± 12.3	4.26830	4.70220	2.74211	3.31279	0.827
5.	108.2 ± 9.2	159.6 ± 13.9	4.68401	5.07273	3.11264	3.72850	0.834
6.	129.5 ± 11.7	221.7 ± 15.8	4.86376	5.40129	3.14420	3.90827	0.880
P/50							
1.	2.4 ± 0.2	6.3 ± 0.5	0.87547	1.84055	-----	-----	-----
2.	10.5 ± 1.2	18.3 ± 2.3	2.35138	2.90690	1.06635	1.47591	0.722
3.	28.5 ± 3.2	38.2 ± 3.9	3.34990	3.64284	1.80229	2.47443	0.728
4.	47.4 ± 4.5	75.6 ± 6.7	3.85862	4.32546	2.48491	2.98315	0.832
5.	57.8 ± 7.8	89.3 ± 9.2	4.05699	4.49200	2.65145	3.18152	0.833
6.	82.0 ± 9.2	130.1 ± 10.6	4.40672	4.86827	3.02772	3.53125	0.855

Stellaria pallida

contd.

P/100

1.	2.0 ± 0.13	4.3 ± 0.3	0.69315	2.45862	---	----	-----
2.	4.1 ± 0.4	9.1 ± 1.3	1.41099	2.20827	0.74965	0.71784	0.744
3.	13.2 ± 1.9	20.2 ± 2.3	2.58022	3.00072	1.54210	1.88707	0.817
4.	26.6	41.3	3.28091	3.72086	2.26224	2.58776	0.874
5.	34.2	58.6	3.53223	4.07073	2.61211	2.83908	0.920
6.	51.4	84.0	3.93964	4.43082	2.97220	3.24649	0.915

P/500

1.	1.8	3.3	0.58779	1.19392	---	----	-----
2.	3.7	6.1	1.30833	1.80829	0.61437	0.72054	0.852
3.	7.0	11.4	1.94591	2.43361	1.23969	1.35812	0.912
4.	10.3	16.0	2.33214	2.77259	1.57867	1.74435	0.905
5.	13.7	25.9	2.61740	3.25424	2.06032	2.02961	1.015
6.	28.9	46.3	3.36384	3.83514	2.64122	2.77605	0.951

As in the case of plants grown at varying levels of nitrogen, the values of $\bar{E}$ were calculated for the plants grown at decreasing levels of P for all the three species. The integrated formula as used previously was also used here, the formula being

$$\bar{E} = \frac{W_2 - W_1}{L_{A_2}^{\alpha} - L_{A_1}^{\alpha}} (L_{A_2}^{\alpha-1} - L_{A_1}^{\alpha-1}) \cdot \frac{\alpha}{\alpha - 1}$$

First of all values of α were calculated and with the aid of this index $\bar{E}$ has been calculated as given in the Table below.

Table 18		Values of $\bar{E}$ at varying levels of phosphorus			
Between harvests	Species	P/10	P/50	P/100	P/500
1 - 2	<u>S.media</u>	2.542	2.042	1.638	1.717
1- 3	do	6.317	5.620	4.052	3.078
1- 4	do	7.323	6.870	5.444	3.145
1- 5	do	8.036	7.495	5.544	4.155
1- 6	do	9.752	7.647	6.094	4.867
1 - 2	<u>S.pallida</u>	2.656	2.280	1.161	0.939
1- 3	do	3.452	2.723	2.248	2.169
1- 4	do	5.707	5.015	6.667	2.712
1- 5	do	6.340	5.410	5.593	3.109
1- 6	do	7.453	6.224	4.858	3.502
1 - 2	<u>S.neglecta</u>	2.590	2.167	1.084	0.979
1- 3	do	4.130	3.699	1.638	1.366
1- 4	do	5.277	4.283	3.111	2.195
1- 5	do	5.773	3.616	3.011	2.909
1- 6	do	6.794	5.015	2.331	3.107

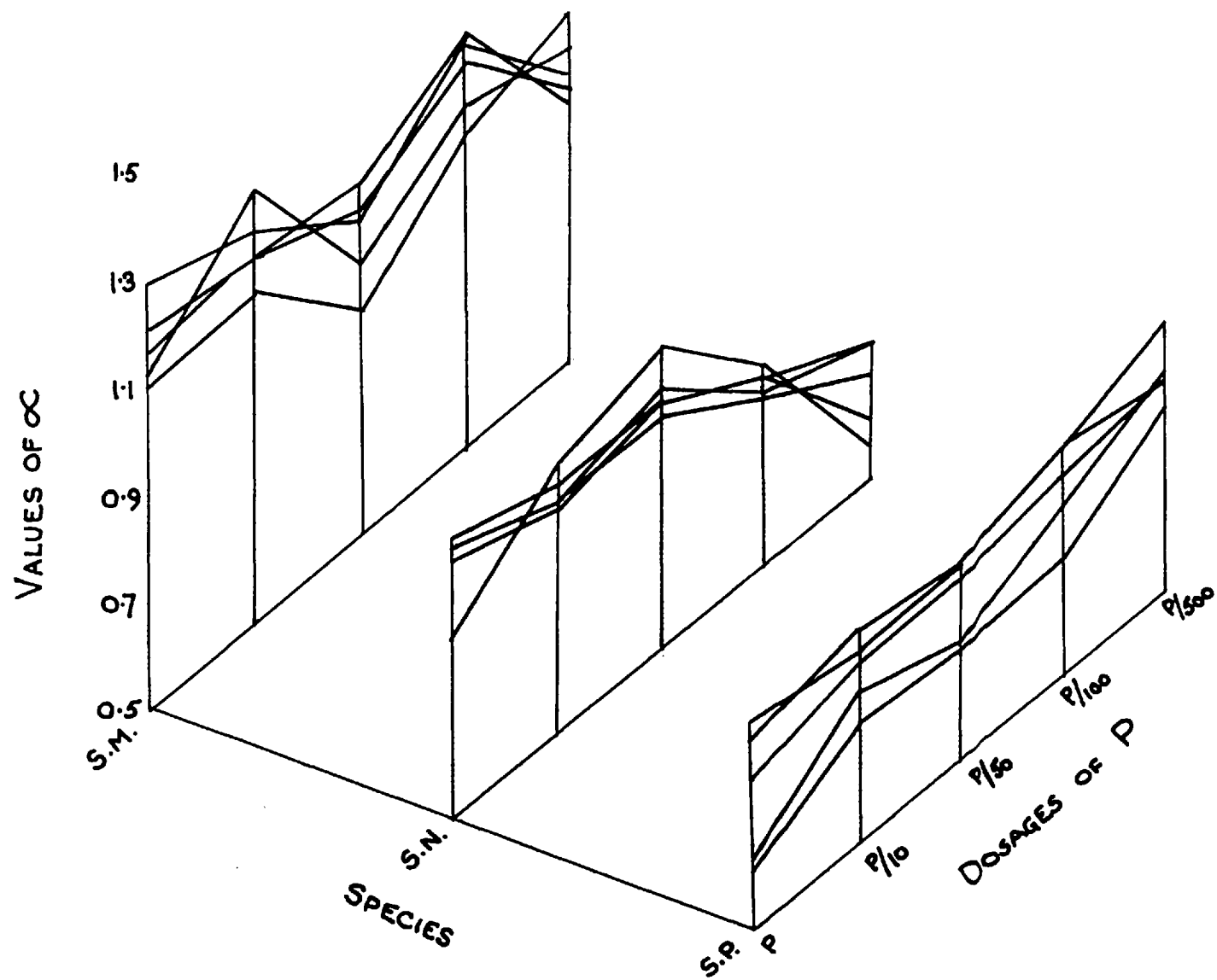


FIG. 21.

PROGRESS CURVE OF DRY WEIGHTS

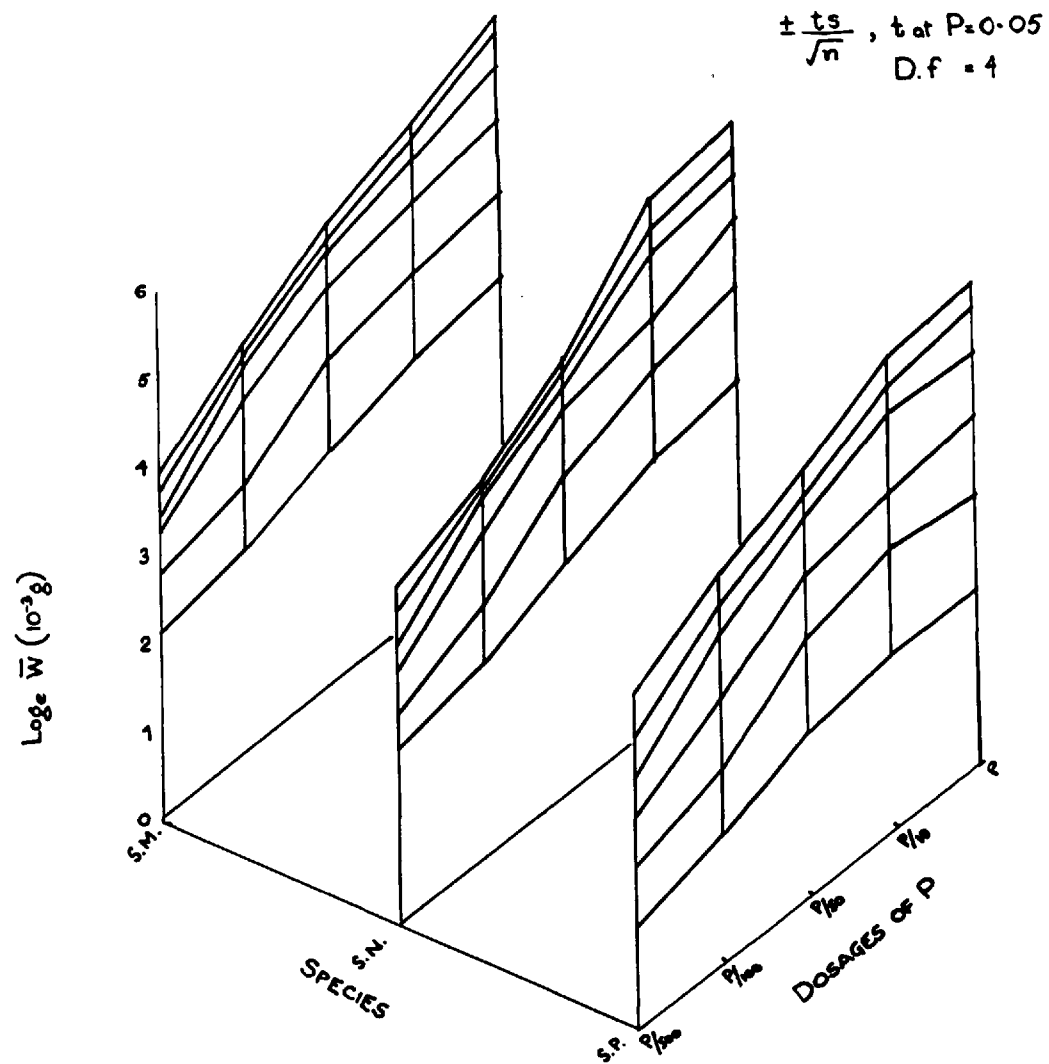


FIG. 22.

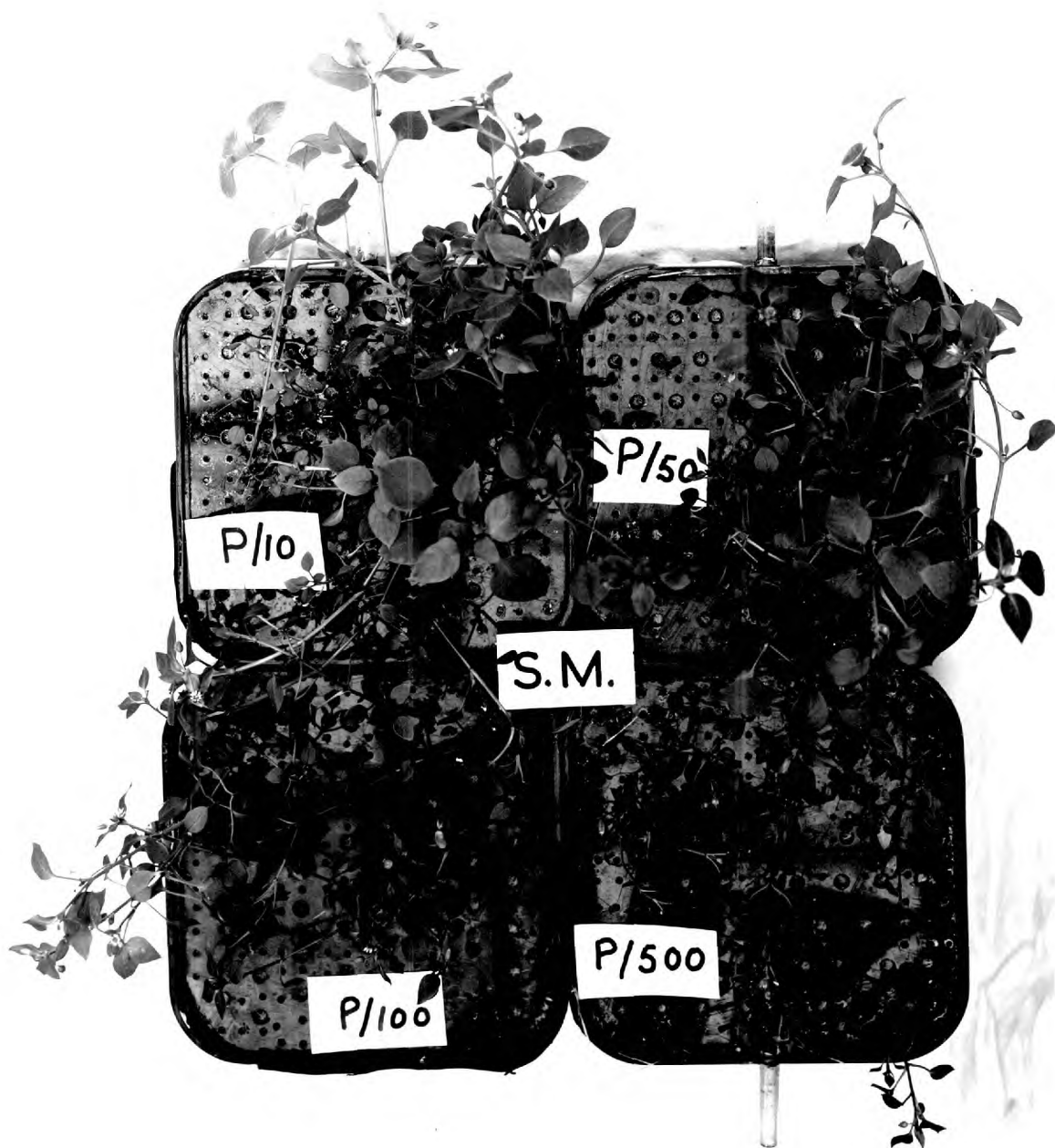
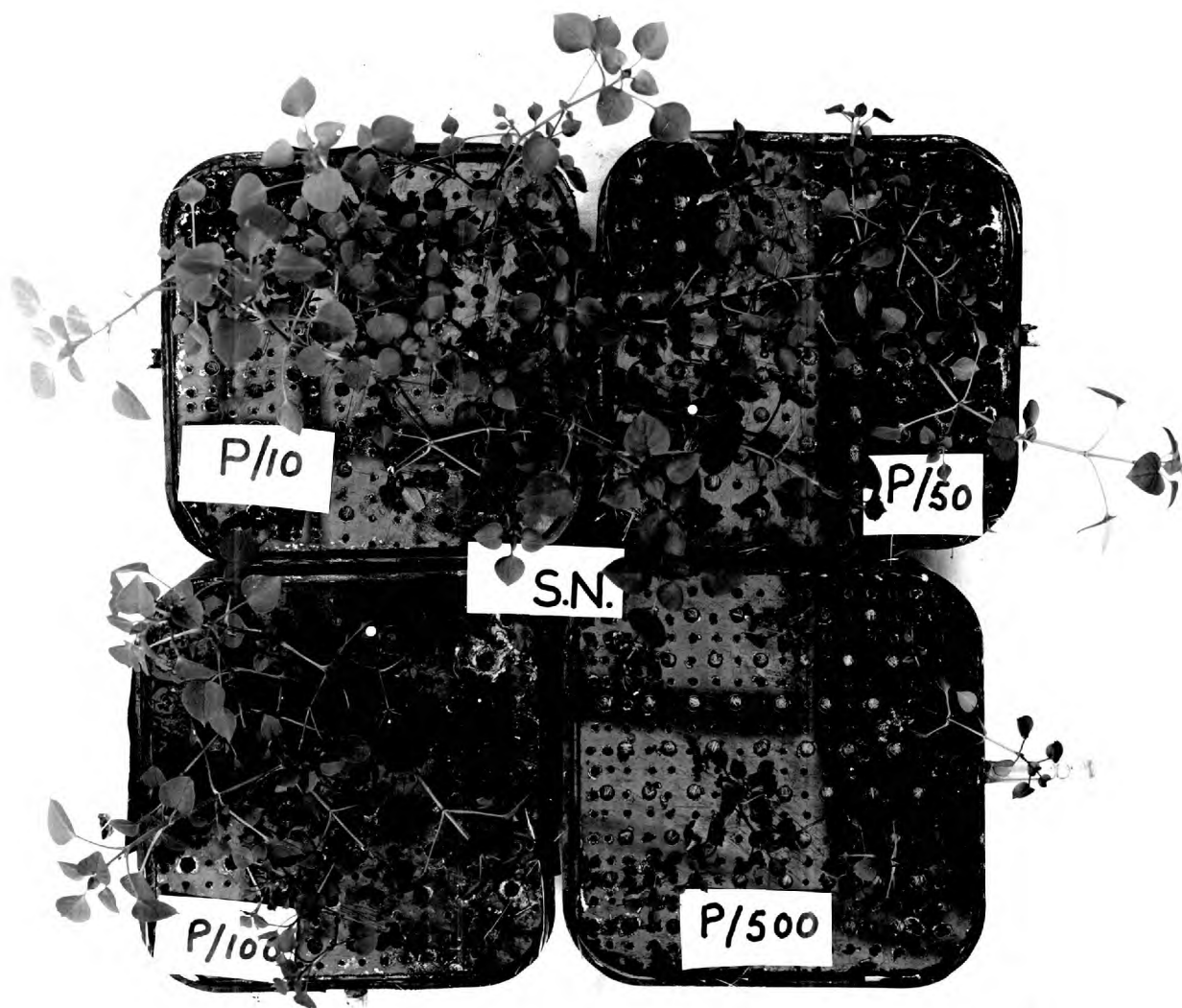




Fig. 23. Plants of *S. media* grown at varying levels of P.



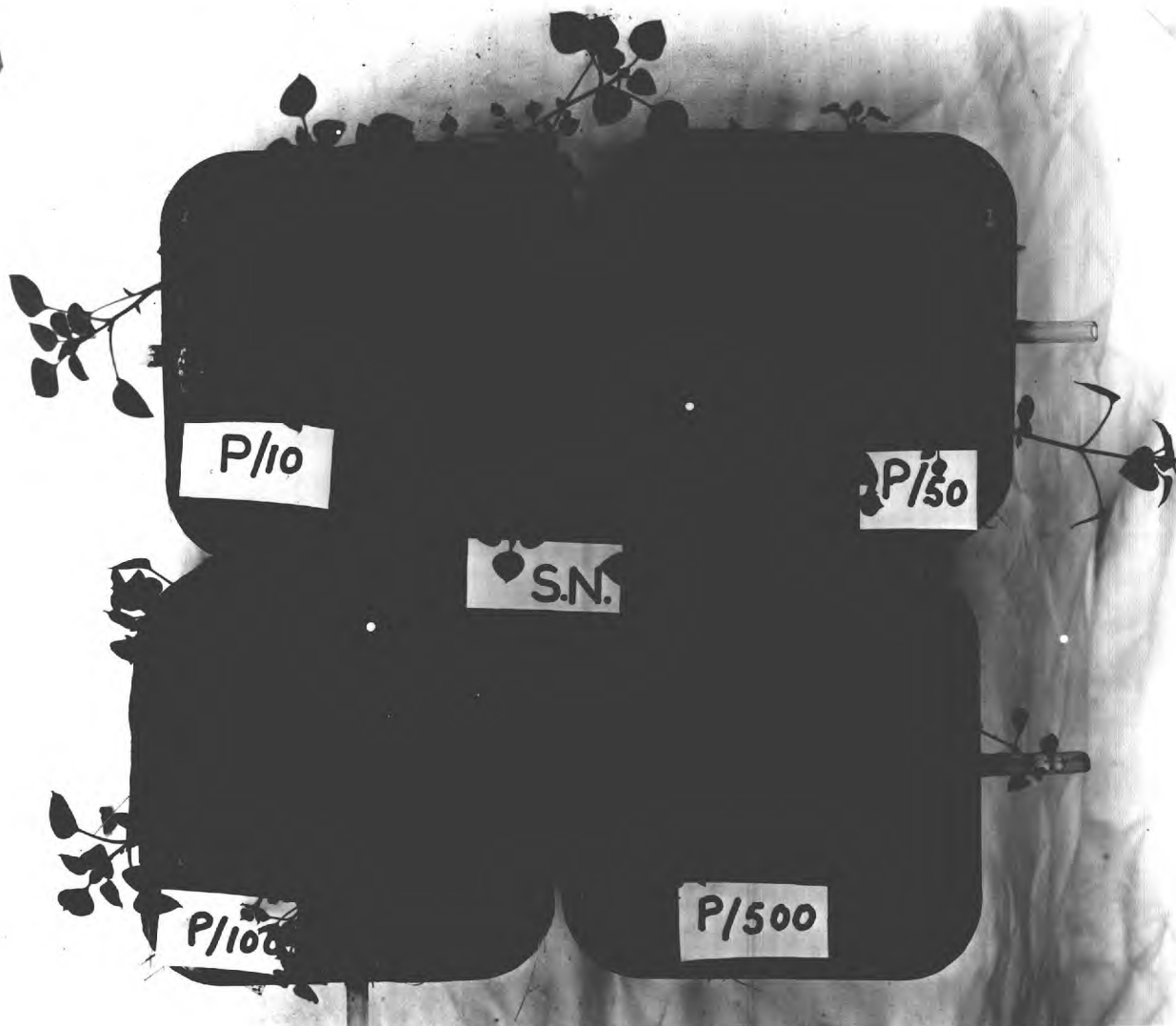
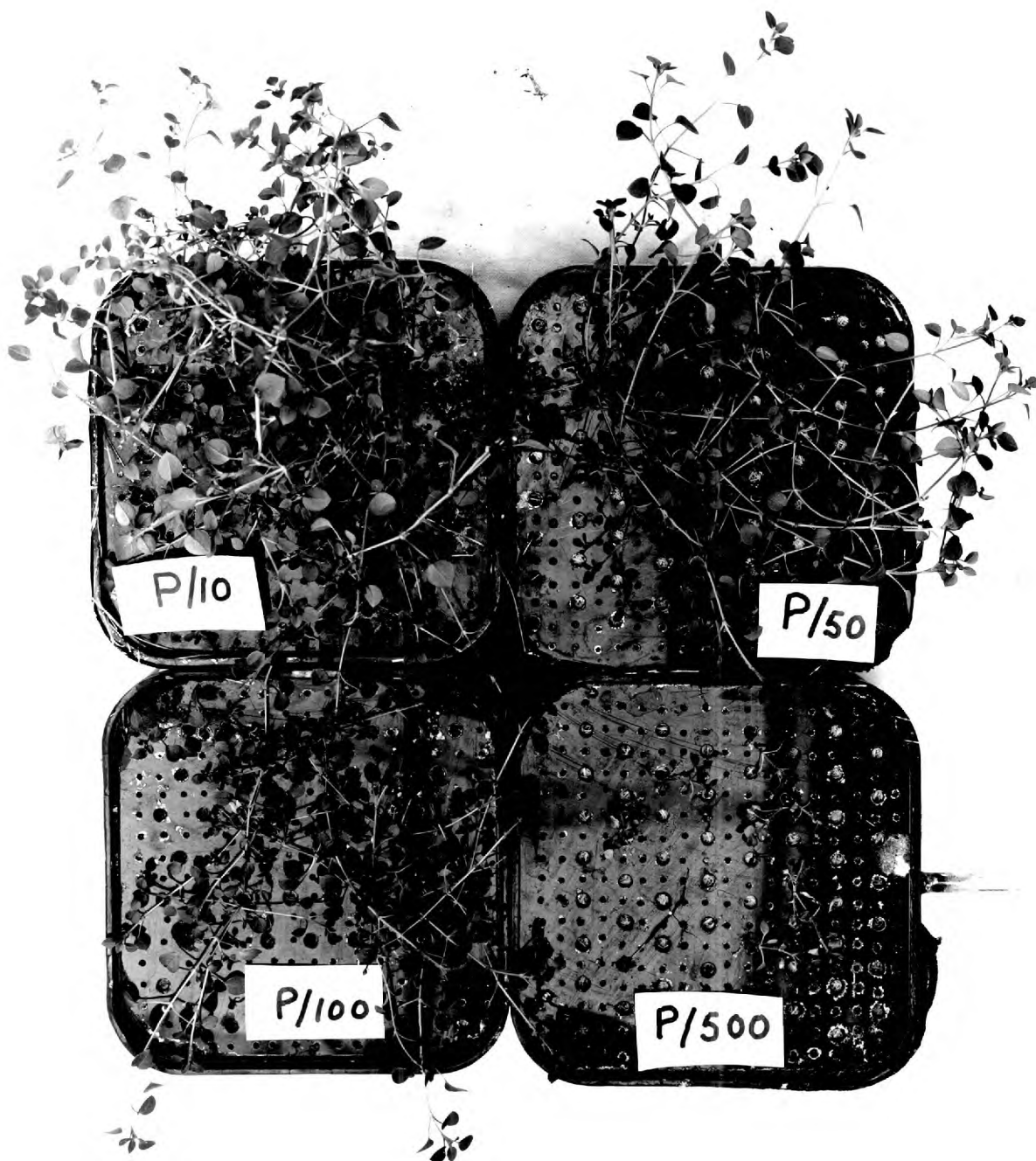


Fig.24. Plants of S.neglecta Weihe grown at varying levels of P.



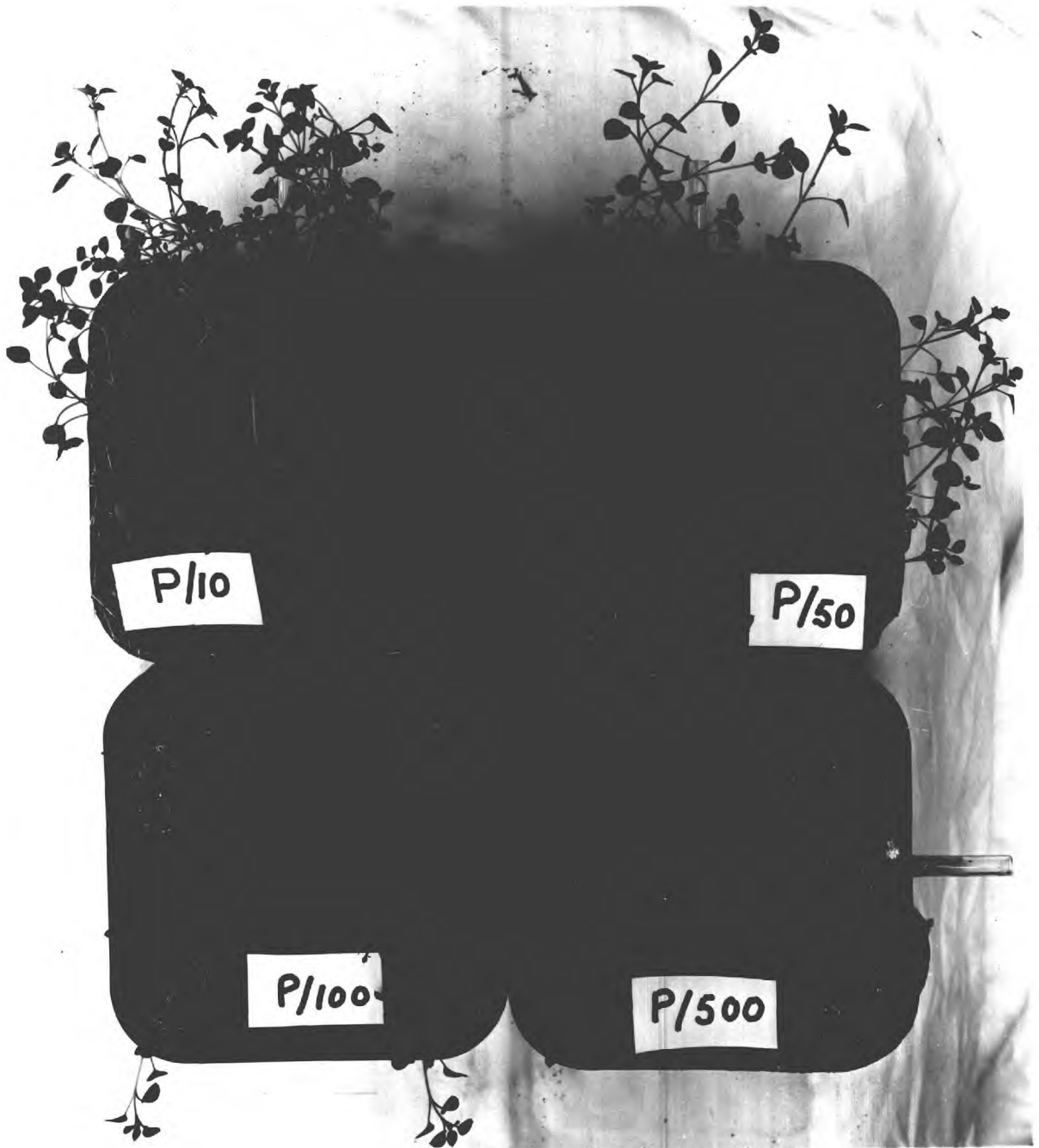


Fig.25.Plants of *Stellaria pallida*(Dumort.)Piré grown at varying levels of phosphorus.

Amounts of P and N in the normal culture solution represent full dosages with respect to both these elements and therefore dry weights of plants of all the three species grown in normal culture solution have been taken to be common both for one N and one P. In all the three species total dry wts. go on decreasing with lowering of dosages of P but this reduction is less marked in extent than the similar dosages of N. For example W for S.media at the sixth harvest in P/10, P/50, P/100 and P/500 are 360.5, 195.6, 100.2 and 51.2 mgs. respectively as against 319.0, 129.0, 72.3 and 42.3 mgs. at the corresponding harvest and dosages of N. This applies to the other species also and therefore it appears that these sps. are more sensitive to nitrogen than to phosphorus as is usual with the most of the plants. With respect to dry weight gain S.pallida appears to be less sensitive than the other two sps. at the lowering levels of both N and P, for example dry weight from 231.6 is reduced to 46.3 at P/500 and to 42.1 at N/500 as against from 428.0 (at N or P) to 42.3 (at N/500) and 51.4 (P/500) for S.media; and to from 446.6 to 44.4 (N/500) and 39.4 (P/500) for S.neglecta.

At lowering dosages of N and P the difference between dry weights and general facies becomes less marked. Let the dry wts. in N/500 and P/500 at the sixth harvest be taken as an example.

	Wts. in mgs.		
	S.m.	S.n.	S.p.
N/500	42.3	39.4	42.1
P/500	51.2	44.2	46.3

This applies to harvest five also. It would seem therefore that under depauperate conditions of growth they produce

phenotypes with matchingly similar facies and there can be much confusion in their identification unless their physiological behaviour and genotypes are studied. This probably has been the main reason which has given rise to confusion in the identification of herbarium specimens. The species, however, even under pressure of nutritional deficiencies remain morphogenetically distinct. The balanced morphogenetic behaviour in S. media is maintained even under extremely poor condition of growth. This as a matter of fact appears to be the inherent biological property which gives the species wider distribution, plasticity and edaphic and phenological tolerance.

Under rich nutritional conditions S. media despite being handicapped with initial low "bonus" of seed weight assumes almost matching dry weights. This is secured by enhanced photosynthetic efficiency coupled with balanced morphogenesis. This leads to earlier sexual maturity and successful completion of life-cycle even under unfavourable combination of ambient factors.

All the three species showed ^{marked} / change in the coloration of leaves and young stems with decreasing dosages of P. This purple coloration of leaves which is due to accumulation of sugars is a sign of phosphorus starvation. Deeper purple colour of leaves in the case of S. pallida is probably an indication that this species is more sensitive to P than the other two species. This can be seen in the sharper fall of $\bar{E}$ values from 8.120 in Normal solution between harvests 1-6 to 3.502 to the corresponding harvests in P/500.

Plants of Stellaria media were also grown in in culture solutions with lowering concentrations of both N and P and their reciprocal combinations. Ten plants of each species (two growth boxes with five plants each were used for each species in each soln.) were grown in each solution for six weeks. Their dry weights, root/shoot ratio, together with mean no. of fruits and number and wts. of seeds are given below

Table 19

Solution.	Dry wt. per plant.in mgs.	Root/shoot ratio	Mean no. of fruits.	No. of seeds	Wt. of seeds
Normal(NP)	387.3(13.7)	0.203(0.014)	15.3(1.9)	98.5(9.8)	39.8(4.2)
I-A(P N/50)	120.5(7.8)	0.267(0.013)	5.7 (0.8)	32.6(6.1)	13.8(2.1)
I-B(PN/50)	28.2(1.2)	0.344(0.017)	2.7 (0.5)	14.3 (2.3)	4.8 (1.0)
I-C(PN/100)	11.7(0.8)	0.428(0.023)	No flowering or fruiting		
I-D(PN/500)	7.7 (1.8)	0.474(0.027)	" "	" "	" "
II-A(P.N/500)	38.2 (2.2)	0.353(0.019)	3.5(0.6)	20.4 (3.2)	7.3 (0.8)
II-B (P/10.N/500)	26.5 (1.5)	0.327(0.023)	2.7 (0.8)	16.6 (2.6)	5.2 (0.4)
II-C (P/100.N/10).	28.3 (2.1)	0.413(0.031)	1.8 (0.45)	9.3 (1.4)	3.0 (0.2)
II-D (P/500.N.)	31.9 (3.2)	0.407 (0.018)	2.2(0.32)	10.5 (2.0)	2.9 (0.5)

From the growth of S. media in varying conc.^{ns} of both N and P and their reciprocal combination it would appear that reduction above NP/50. would disturb the morphogenetic pattern to such an extent that induction of flowering is completely excluded. The seed weight with lowering concentration does not appear to be affected to significant extent. The sols used in the present experiment have been described on pages 33 and 34 in Chapter II. The pH in all of them was adjusted to 5.5.

Uptake of P in the culture solution:

Sps.	Dosages of N or P	P in $\mu\text{g./g.}$ of plant mater- -ial.	P/mg. of plant material.	Total amt./plant
S.m.	NP	5000.000	5.000	428.0×5.000 $=2140.0000$
S.n.	"	4890.000	4.890	446.000×4.89 $=2180.94$
S.p.	"	4750.000	4.750	231.6×4.75 $=1100.1$
S.m.	N/10	4100.000	4.1000	319.0×4.1 $=1307.9$
S.n.	"	3875.000	3.875	308.0×3.875 $=1193.5$
S.p.	"	3775.000	3.775	205.3×3.775 $=775.00$
S.m.	N/50	3400.000	3.4	129.0×3.4 $=438.6$
S.n.	"	3625.000	3.625	112.2×3.625 $=406.725$
S.p.	"	3550.000	3.550	117.2×3.55 $=416.06$
S.m.	P/10	2350.000	2.35	360.5×2.35 $=847.17$
S.n.	"	2500.000	2.5	387.2×2.5 $=968.00$
S.p.	"	2650.0	2.65	221.7×2.65 $=587.5$
S.m.	P/50	1400.000	1.4	195.6×1.4 $=273.84$
S.n.	"	1550.000	1.55	129.2×1.55 $=200.26$
S.p.	"	1675.000	1.675	130.1×1.675 $=217.9$

Uptake of K in the culture solution:

Sps.	Dosages of N or P.	K in $\mu\text{g.}/\text{g.}$ of plant material	K/mg. of plant material.	Total amt. per plant in $\mu\text{g.}$
S.m.	Normal	9175.000	9.175	3926.90
S.p.	"	8795.000	8.795	3922.57
S.p.	"	7880.000	7.880	1825.00
S.m.	N/10	6785.0	6.785	2164.41
S.n.	"	7115.0	7.115	2191.42
S.p.	"	6990.0	6.990	1435.04
S.m.	N/50	6125.0	6.125	793.35
S.n.	N/50	6250.0	6.25	701.25
S.p.	"	5975.0	5.975	700.27
S.m.	P/10	5387.00	5.387	1942.01
S.n.	"	5190.00	5.19	2009.56
S.p.	"	5000.00	5.000	1108.50
S.m.	P/50	3875.00	3.875	757.95
S n.	"	3750.00	3.75	487.87

Following the usual procedure, the amounts of P and N were determined in the plants grown at varying levels of N and P up to dilution 1/10 and 1/50. Amount of these nutrients were not determined in plants grown in solutions referred to on page 144. Uptake of P and N has been given in pp. 146 and 147. So far the amount of P in per gram of plant material is concerned, there does not appear to be any marked difference. So far the total uptake of P is concerned, *S. pallida* markedly falls behind the other two species. This is due to low total dry weight. Amount of P per gram of plant material falls off in all the three species with increasing dilution P or N but the fall for the same degree of dilution of P is more pronounced. Uptake of P does not give any clue to account for the differential morphogenetic behaviour of the species at least in the culture solution. In the case of soil culture, however, the situation was found to be different.

Both in the case of soil from the *S. neglecta* as well as *S. pallida* site, *S. media* was found to have higher capacity to exploit P . The results can be seen in Table 21, pp. 150 - 151. The uptake of this element depends possibly upon p^{11} concentrations. Similar pattern of uptake in culture solutions is probably due to same p^{11} values at all levels of dilution. *S. media* in both the soil types had better growth than either of the species. This can be seen from the table 20 on page 149. The higher weight of all the species in soil from the *S. neglecta* site was an indication that *S. neglecta* grows in nutritionally rich soil.

In respect of uptake of N in culture solution, it was found that there was not much difference in *S. neglecta* and *media* but *pallida* differed markedly from these. In respect of nitrogen uptake *media* was found to be most efficient (see ^{Table} fig. 24 pp. 154-155).

Uptake of N, K and P in soil culture : As described in the foregoing pages plants of all the three species grown in culture solutions at varying levels of nitrogen and phosphorus were assessed in terms of uptake of P and K. For the purpose of this comparison they were also cultured in soils from the original sites of Stellaria pallida (Dum.) Pire' and S. neglecta Weihe . Soil samples for the purpose were collected from the top 6" layer of the respective sites. Soil from the S. pallida site was collected from near Cheltham Gate , O.S.1" Ref. being Clappers' Ford 965619, Surrey (v.-c.17) from the shade of pine trees while that from S. neglecta site was collected from Emmett s' Mill 41/998618. They were sieved through 1/2" sieve to remove the pebbles and bigger stone chips and extraneous root tangles. They were then spread in thin layers in big trays and dried in oven for forty-eight hours at a temperature of 50° C

Seeds were sown in germinating boxes on the 8th of November , 1964 to be transplanted after two weeks. Earthen 3.5" pots were filled with soil 3/4" below the rim of the pots and three hundred pots were thus prepared for transplantation . Fifty seedlings of each species were transplanted in each soil type. After transplantation on the 22nd Nov. '64 the pots were transferred to the section of the greenhouse which was kept warm . Mercury lights just above the bench were used for eight hours. This provided additional light to the plants to help quick growth. The plants were regularly watered everyday just sufficient to maintain their healthy growth. During the growth of the plants it was observed that S. media began to flower by the middle of Dec. while S. pallida began

flowering by the first week of January 1965. It was therefore inferred that light and temperature are probably in combination are limiting factors for induction of flowering in S. pallida.

Harvesting : Plants were harvested on the 30th and 31st of January. Roots and shoots were separately pressed in folders of filter papers and dried in oven for forty-eight hours. After being taken from oven they were stored in desiccators. They were then weighed at later dates. Their average weights with standard errors for each species in each soil type are given below.

Table 20.

Plants in soils from S. pallida site

Sps.	Mean shoot weight in 10^{-3} g.	$\pm \frac{ts^*}{\sqrt{n}}$	Mean root wt. in 10^{-3} g.	$\pm \frac{ts}{\sqrt{n}}$
<u>S. media</u>	2361.6	123.2	723.3	63.2
<u>S. neglecta</u>	2260.7	101.5	621.2	44.5
<u>S. pallida</u>	1162.4	73.5	384.3	36.2
Plants in soils from <u>S. neglecta</u> site				
<u>S. media</u>	2752.2	139.5	1030.3	74.6
<u>S. neglecta</u>	2462.8	126.3	884.5	67.8
<u>S. pallida</u>	1746.5	89.2	607.4	44.7

* t at P = 0.05 , D.F. = 39.

Oven dried plant materials were powdered in grinding mill, sieved through 60 B.S. sieve and ashed in the Muffle Furnace for twenty-four hours. This ash after digestion was used for the determination of P and K following the usual procedure described in Chapter II. These determinations were made separately for the roots and shoots and the values for the total weight were finally combined. These determinations were made on EEL colorimeter and EEL Photometer respectively. Plant material used in each case both for the root and shoot was one gram. These results are given below.

Table 21A Values for the amounts of P in the plants grown in soil from S. pallida site

(A) Shoot				
Sps.	Total amt. of P in $\mu\text{g.}$ in lg. of plant material	Amt. of P/mg. of plant material	Total amount in shoot in $\mu\text{g.}$ per plant.	
<u>S. media</u>	2000.0	2.000	2361.6×2.0	=4723.200
<u>S. neglecta</u>	1350.0	1.350	2260.7×1.35	=3051.945
<u>S. pallida</u>	1362.5	1.362	1162.4×1.362	=1583.188
(B) Root.				
<u>S. media</u>	1000.00	1.000	723.3×1.0	=723.3
<u>S. neglecta</u>	1275.00	1.275	621.1×1.275	=791.902
<u>S. pallida</u>	1275.00	1.275	384.3×1.275	=489.982

(C) Total amount in shoot + root in $\mu\text{g.}$

Sps.	Total amount in shoot in $\mu\text{g.}$	Total amount in root in $\mu\text{g.}$	Total amount in shoot + root in $\mu\text{g.}$
<u>S. media</u>	4723.200	723.200	5446.400
<u>S. neglecta</u>	3051.945	791.902	3843.847
<u>S. pallida</u>	1583.188	489.982	2073.171

Table 21B. Values for the amounts of P in the plants grown in soil from S.neglecta site

(A) Shoot

Species.	Total amount of P in in $\mu\text{g.}$ in 1 g. of plant material.	Amt. of P/mg. of plant material.	Total amt. in shoot in $\mu\text{g.}$ per plant.
<u>S.media</u>	2800.000	2.800	2752.200×2.8 =7706.160
<u>S.neglecta</u>	2575.000	2.575	2462.800×2.575 =6341.71
<u>S.pallida</u>	1350.000	1.350	1746.500×1.35 =2357.775

(B) Root

<u>S.media</u>	1600.000	1.600	1030.5×1.6 =1648.480
<u>S.neglecta</u>	1500	1.500	884.5×1.5 =1326.75
<u>S.pallida</u>	1500	1.500	607.4×1.500 =911.100

(C) Total amount in shoot + root in $\mu\text{g.}$

Species.	Total amount in shoot in $\mu\text{g.}$	Total amount in root in $\mu\text{g.}$	Total amt in $\mu\text{g.}$ in the whole plant.
<u>S.media</u>	7706.160	1648.480	9354.64
<u>S.neglecta</u>	6341.71	1326.75	7668.46 0
<u>S.pallida</u>	2357.775	911.100	3268.870

Table 22A Values for the amounts of K in the plants grown in the soils from S. neglecta site.

(A) Shoot

Species.	Total amount of K in $\mu\text{g.}$ in lg. of plant material.	Amt. of K/mg. in plant mater- ial.	Total amount in the shoot per plant.
<u>S. media</u>	7750.000	7.75	2361.6×7.75 =18302.400
<u>S. neglecta</u>	6750.000	6.75	2260.7×6.75 =15259.725
<u>S. pallida</u>	6125.000	6.125	1162.4×6.125 =7119.700

(B) Root

<u>S. media</u>	1625.000	1.625	723.3×1.625 =1175.36
<u>S. neglecta</u>	do	do	621.2×1.625 =1009.450
<u>S. pallida</u>	do	do	384.3×1.625 =624.487

Total amounts in Shoot + root in $\mu\text{g.}$

Species.	Total amount in in the shoot in $\mu\text{g.}$	Total amount in the root in $\mu\text{g.}$	Total amt. in the whole plant.
<u>S. media</u>	18302.400	1175.362	19477.62
<u>S. neglecta</u>	15259.725	1009.450	16269.175
<u>S. pallida</u>	7119.700	624.487	7744.187

Table 22B Values for the amounts of K in the plants grown from the S. pallida site.

(A) Shoot

Species.	Total amt. of K in $\mu\text{g.}$ in lg. of plant material	Amt. of K /mg of plant material	Total amount in in shoot in $\mu\text{g.}$ per plant
<u>S. media</u>	9875.000	9.875	2752.2×9.875 $= 27177.975$
<u>S. neglecta</u>	8875.000	8.875	2462.8×8.875 $= 21857.350$
<u>S. pallida</u>	10500.000	10.500	1746.5×10.5 $= 18338.25$

(B) Root

<u>S. media</u>	1875.000	1.875	1030.3×1.875 $= 1931.812$
<u>S. neglecta</u>	1625.000	1.625	884.5×1.625 $= 1437.312$
<u>S. pallida</u>	2125.000	2.125	607.4×2.125 $= 1290.725$

(C) Total amounts in shoot + root in $\mu\text{g.}$

Species.	Total amount in the shoot in $\mu\text{g.}$	Total amount in in the root in $\mu\text{g.}$	Total amount in $\mu\text{g.}$ in whole plant
<u>S. media</u>	21177.975	1931.812	$21177.975 + 1931.812$ $= 29109.787$
<u>S. neglecta</u>	21857.350	1437.312	$21857.350 + 1437.312$ $= 23294.662$
<u>S. pallida</u>	18338.25	1290.725	$18338.25 + 1290.72$ $= 19628.97$

Uptake of Nitrogen in the plants cultured in soil: Details of estimation of uptake of N in the plant material have been described in pages 43 - 45 in Chapter II. =. 0.2 g. plant material was taken in Kjahl dahl flask to which 1 g. of Analar (micro) potassium sulphate and 0.01 g. selenium dioxide were added. After proper digestion of the material, the digest solution was titrated against N/50 HCl. 1 ml. of digest solution was in each case taken in the outer chamber of the conway diffusion unit. Calculations of the uptake are based upon ^{mean} reading of the microburette. Using N/50 HCl, one large division of the microburette scale (0.01 ml) represents 2.8016 micrograms of nitrogen. The results are given below.

Table 2, A

A. Soil from the Stellaria pallida site

Shoot. Species.	Mean reading of microburette.	Amount of N /g. in μ g.	Amount of N in the Total shoot wt. in μ g.
<u>S. media</u>	9.6	6723.84	15879.02
<u>S. neglecta</u>	7.6	5323.04	12033.79
<u>S. pallida</u>	6.3	4412.52	5129.11
Root.			
<u>S. media</u>	4.2	2941.68	2124.77
<u>S. neglecta</u>	3.7	2591.48	1609.82
<u>S. pallida</u>	3.2	2241.28	861.32

Total amount of N in μ g. per plant.

Species.	Shoot	Root	Total
<u>S. media</u>	15879.02	2124.77	18003.79
<u>S. neglecta</u>	12033.79	1609.82	13643.61
<u>S. pallida</u>	5129.11	861.32	5990.43

Table 23 B.

Soil from S.neglecta site

Shoot Sps.	Mean reading of microburette.	Amount of N/g. in μ g.	Amount of N in the total shoot weight in μ g.
---------------	----------------------------------	-------------------------------	---

<u>S.media</u>	10.2	7144.08	19661.93
----------------	------	---------	----------

<u>S.neglecta</u>	8.5	5953.4	14662.03
-------------------	-----	--------	----------

<u>S.pallida</u>	6.8	4762.72	8318.09
------------------	-----	---------	---------

Root

<u>S.media</u>	5.8	4062.32	4185.4
----------------	-----	---------	--------

<u>S.neglecta</u>	5.2	3642.08	3321.42
-------------------	-----	---------	---------

<u>S.pallida</u>	4.8	3361.92	2042.03
------------------	-----	---------	---------

Total amount of N in μ g. per plant.

Species.	Shoot	Root	Total
<u>S.media</u>	19661.93	4185.4	20080.47
<u>S.neglecta</u>	14662.03	3321.42	17983.45
<u>S.pallida</u>	8318.09	2042.03	10360.12

Growth of *S.neglecta* and *S.pallida* in soil solutions:

Soils collected from the sites of *S.neglecta* and *S.pallida* were also used for preparing soil solutions and plants of these two species were grown in them. Soils from the top six inches of the field sites were air dried for four days at the temperature of the glasshouse and sieved through 40 B.S.sieve. Weighed samples of each soil with five times their weight of water were shaken on microid flask shaker for one hour and then filtered through Whatman No. 1 filter papers. Each filtrate was passed through the original filter paper for 2-3 times until it ran through clear. Recovery of the liquid was c. 90 % per litre. The solutions were stored in polythene aspirator bottles and used for growing plants in them. Solution from the soil of *S.pallida* had the pH value 5.2 while that from the soil from the *S.neglecta* site was 6.4. Solutions from soils of each site were divided in four parts and their pH's were adjusted to 4, 5, 6 and 7. Ten plants of each species at each pH were grown two culture boxes. Thus sixteen boxes with five plants each were used.

In general growth of the plants was very slow because of poor recovery of nutrients from the soil. The solutions were changed every week and their pH's were checked and adjusted twice a week. The plants were grown from the 14th of May to the 10th of July. It was found that in spite of poor growth plants of *S.pallida* in solutions from both soil types produced flowers. As can be seen from the Table on the next page, dry wts. of plants of both the species in the solution of the soil from the *S.neglecta* was at all pH's higher than in the solution of soil from *S.pallida* site.

It was inferred , therefore that soil of S.nelecta was nutritionally richer than the one from the S.pallida site. This could also have been due to difference in the recovery of nutrients from the soils but this pattern of result was also found in soil culture experiments.

Table Dry wts. of plants grown in soil solutions at different pH's.
(A) (Soil from S.nelecta site)

Sps.	Dry weights at different pH's in mgs.			
	4	5	6	7
<u>S.nelecta</u>	109.2 * ± 8.2	98.3 ± 9.3	103.5 ± 7.6	99.5 ± 6.3
<u>S.pallida</u>	44.3 ± 2.1	40.8 ± 1.9	39.3 ± 2.6	41.9 ± 2.7

(B) Soil from S.pallida site

<u>S.nelecta</u>	72.1 ± 4.9	71.3 ± 3.7	75.7 ± 4.2	77.6 ± 5.8
<u>S.pallida</u>	30.2 ± 2.3	33.8 ± 1.9	35.9 ± 2.8	31.8 ± 2.5

From this it could be inferred that within the range of pH's under reference there is no marked effect on the dry weight gain and morphogenetic patterns of these species. In terms of dry wt. gain S.nelecta has always, under the conditions of experiment, higher values. However, flowering in S.pallida is an indication of differences in the morphogenetic pattern. From the growth behaviour of these species in soils from both sites and their solutions , it appears that S.pallida has , of the two species, wider range of tolerance.

$$t = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}} , t \text{ at } P = 0.05, \text{ d.f. } = 9$$

CHAPTER VIII.
TAXIMETRICAL STUDIES

There are two fundamental questions a taxonomist ought to be asked : what does he do ? Why does he do it ? It would not probably be easy to get a clear answer to these questions. A taxonomist can not easily answer because he is too much involved nor can an outsider because he knows too little about the subject. Taxonomist collects data to extract information from them. The data may be from gross morphology to DNA - RNA base configurations. From all aspects of study he obtains some informations. This again drives back to the same fundamental questions. Why collect informations ? Is it just to satisfy curiosity or to use it to arrange organisms in an array of nomenclatural hierarchy for the convenience of others who may be working with different aspects of plant life ? The answer is no , in at least some cases since taxonomists are caught in an age of hectic experimentation . They want to get at the fundamentals of the working and organisation of life-machinery. Gregor(1963) has rightly pointed out that the aim of experimentation is more to understand the true nature, origin, development, molecular organisation and behaviour of organism rather than to give some name to it. As Walters(1964) has pointed out the present phase of taxonomy may better be known as self-conscious or self-critical rather than a realist phase(sensu Heywood 1964).

Purposes of classification has been one of the most discussed topics. Most of the taxonomists are in favour of phyletic grouping but there has been a growing minority of opinion in favour of

empirical grouping where organisms are grouped on overall similarity shared by their constituent members. Both of them suffer from some imbalance in the sense that former is based upon presumed evolutionary lineages and the latter is subjective in its approach and as such has limited capacity to release information and therefore lacks objectivity and repeatability. The ambitious concept of monophyly is probably a fact but difficult to demonstrate especially at the family or lower levels in higher plants. There are a few instances of "re-creation" at the specific and infra-specific level but prospects in this field are limited.

Palaeontological findings at these levels do not help much. Phylogenetic groupings at the present state of our knowledge appears to be some mental gymnastics and does not offer much to attract a serious experimenter.

This type of classification characterised the first revolution in the post-Darwinian era. During the second phase of revolution in 1940's importance shifted from investigation at the specific or infra-specific level to population, from pure morphology to assessment of groups in terms of cytogenetics, physiology and experimental ecology and engendered the new science of speciation. The effects of all these on practical classification has been much less than what was expected to be at one time. There has been a failure again to distinguish between what is desirable and what is possible.

The third phase of classification the realist or self-critical phase, has been concerned more with the ^{raw} materials and procedures of classification itself rather than something being thrust upon from outside.

The important features of this classification would be as follows:

- (A) An acknowledgement that classifications serve different purposes and that no one will be adequate or ideal for all purposes. From this it follows as a corollary that phyletic and maximum-attribute classifications are different, although it might well be that the two might coincide largely in any particular instance.
- (B) Starting-off point is group making based on certain principles. Such groupings have in the past been known as natural - a term which is highly ambiguous since it is also employed for phylogenetic group - more recently phenetic in the sense that they are based upon all available attributes phenotypes sensu lato. This idea of using the term phenotypic was first put forward by Harlan Lewis in 1959 at the International Botanical Congress in Montreal and later by Cain & Harrison (1960), as phenetic, although with proviso of equal weighting of characters chosen.
- (C) Equal weighting: In the original definition of phenetic all characters employed were supposed to have equal weight. Now the weighting of characters takes several forms (Davis & Heywood 1963, pp. 48 seq.). If the phrase equal weighting means that the characters which are selected (for one reason or another) from those that are available are treated as equal in the value for purpose of making comparisons, then phenetic classification would mean normal, realistic, neo-classical classifications. It would in other words mean making of groups on the basis of available evidence and not favouring a priori any kind of evidence as being more significant.

(D) Characters form the essential fabric of all classifications. Taxonomists have been too much preoccupied with amassing of data without thinking too much about what a character actually is. Vague words like good and bad characters have been used which stem from practical taxonomists experience and are seldom defined or explained adequately. As to the inbuilt correlation of characters and biological and taxonomic significance of such phenomena we are still much in the dark.

(E) Numericalists have been called upon to solve some of the problems about the purpose of classification, character weighting, nature of classification (phenetic, phyletic, natural etc.) etc. and whether they would be absorbed in the community of taxonomists would depend upon their capacity to cope with the task of finding plausible answers to some^{or} of the questions which the revolutionists in the third era in taxonomy are trying hard to drive at.

The challenge of the realist phase of taxonomy is how to improve methodology, conceptual thinking and presentation of data. It would be pertinent to quote Gould (1963) in this connection -

" It would seem that in order not to lose operational control of their science, the very logistic minds in the profession of biology should be devising ways to limit unnecessary taxonomic fragmentation, and to find good methods of dealing with problems posed by the mass of information at hand. "They have to penetrate through the mystique of classification and decide what they have to do. They must cease pretence - the double-think of saying one thing and doing something else. Realism and honesty has to be the key-note to the taxonomic revolution.

Methods in numerical taxonomy

Numerical taxonomy in its conceptual approach has been known to be Adansonian after the name of the French taxonomist Adanson(1763) who practised a method in which characters were not given a priori importance according to their fancied importance in some natural classification. With the advent of electronic digital computers the task of working with those concepts has become easier and less time consuming.. It is possible to test hypotheses on larger numbers of variables drawn from larger numbers of OTU's .Thus as Rogers (1963) has said, taximetrics is a new name for the old Adanscnian concept. This is in a sense extension of natural classification (sensu Gilmour). The natural grouping was based upon gross morphology and recognised the importance of the largest number of possible attributes. It is essential to know the correlation of these characters whether it is done on the fingers or on a computer(Burt 1964). This is based upon community of characters. The phrase "community of character" has been changed to "correlation of characters" to convey in a sense the procedure adopted in taximetrics because correlation is mathematically calculated using electronic digital computers. The phenons and OTU's in cluster analysis of Sokal & Sneath are based upon correlation co-efficients.

Numerical taxonomy according to Sokal & Sneath (1964) has five stages.

- (a) The selection of OTU's (specimens or units to be classified)
- (b) Characters of OTU's (50 - 100 at least) are listed. (c) Each OTU is compared with every other. This gives the overall or phenetic resemblance between OTU's.

(d) The OTU's are now sorted out on the basis of their overall similarities (there are a number of methods available loosely termed as cluster analysis to give the groups called phenons. These are phenetic groups comparable to Gilmour's natural taxa, and their rank relationship can be expressed in numerical terms. (e) Characters of special interest are thus re-examined, such as those which are most constant in the taxa and thus most useful for diagnostic keys.

The time consuming repetitive processes of steps c - e are best done by electronic digital computers. Prior selection of characters is eliminated and many sorts of data pertaining to the group give the same end-results using several statistical methods. In this respect it is claimed that numerical taxonomy is repeatable and more objective. As Sokal(1958) pointed out all characters are taken into account, there can be no selection of characters in the sense that some are accepted and others are rejected. The absolute objectivity of these methods has been challenged by Inger(1958). It is now being realised that in some of the most important applications it does matter which of these methods is used.

Phenetic resemblance plays an important rôle in phylogenetic work. At the moment it seems doubtful if reliable phylogenies can be made without complete records. It has been shown by Cavali-Sforza and Edwards(see MacNeill & Heywood 1964) that one can obtain from phenetic data hypothetical phylogenies that best fit certain evolutionary assumptions. Even evaluation of fossil evidences is based upon phenetic similarities.

Measurement of phenetic relationship can help in the assignment of fossils to their position in phylogenetic trees. In addition problems of parallelism, convergence and evolution rates all require comparison of phenetic changes with phyletic relations.

One approach to the problem of quantifying resemblance has been to consider taxonomic resemblance as a function of distance between taxa in n-dimensional space, using co-ordinates as the characters. Work on these lines led to development of Pearson's co-efficient of racial likeness (Pearson 1926) and to the concept of generalised distance as devised by Mahalanobis (1936) and modified by Rao (1948, 1952).

These statistics have been widely applied in Anthropology where data consist largely of continuous variables and where infra-population variation has to be considered. In numerical taxonomy the application of these methods on the whole is inapplicable, principally because of large number of variables, many discontinuous which have to be taken into account. Recently Sokal (1961) has devised a distance co-efficient which overcomes these difficulties.

Another co-efficient is the Mean Character Difference of Cain & Harrison (1958) which is mathematically related to the concept of distance. In calculating this, the difference without regard to sign in relation to particular character is divided by maximum observed value for that character so that for any feature the difference can range from 0 to 1. A difference of unity will only be obtained in comparisons involving a character valued as 0. Such a value would be given when the

general plan indicates that the character is present but is undeveloped, for example , comparison of horn lengths in cattle ,polled animals would be valued as 0. Finally the sum of individual. character differences is divided by total number of characters used in the comparison to give mean value.

In addition several statistical methods are available for the comparison of the the OTU's as well as sorting out of phenons. With regard to cluster analysis Rao(loc. cit.) has pointed out that cluster is , however, not a well-defined term and only criterion appears to be that any two units belonging to the same cluster , should, at least on average , show a higher co-efficient. Several forms of mutivariate analysis including R-analysis , Q-analysis ,discriminant function and principal component analysis have been , according to the nature of of the data , used for the analysis of the primary data. Distance-coefficient and canonical variate statistics have also been used depending upon the type of available data and information wanted. For the measurement of generalised distance between apparently similar taxa canonical statistic was thought to more suitable. A short account of this method is given below.

Canonical variate analysis : This is a form of "Generalised Distance (D^2) devised by P.C. Mahalanobis (1927 -'36) in relation, to analysis of race-mixture in Bengal (India). The tests and measures used for working out this generalised distance is based upon certain statistical principles. Rao (1948, 1950) used this method in an extended form to determine the constellation group of twenty-two Indian tribes, There have been few successful applications of this method to taxonomical problems.

One example was , however, given by Blackith, Davies & Moy(1963) together with the outline of the biometrical principles involved. The advantage of this over other methods is that it is helpful in extracting out numerically the total variability from in-between and within taxa .The concepts and mathematical principles involved have been described by Rao(1952).The various steps in this process are as follows:

- (a) First of all means of variables for the groups are calculated because further calculation and derivations are based upon them.
- (b) Total variation is derived from the determinantal matrix of in-between and within-taxa sum of squares and their products.
- (c) Canonical variance against each of the variables is then calculated.
- (d) The original variables are then weighted by these variates.
- (e) The significance of the variates is then tested by methods developed by Rao(1950) and Bartlett(1948).
- (e) Values of the significant canonical variates for means of taxa is then calculated. These values have also been known as the vectors of the components.

Principal component analysis : As will be shown later , principal component analysis of the morphometrical data was also done partly to work out the correlation co-efficient of variables and partly to detect the suspected cases of mis-identification. Therefore a brief outline of this method is herewith being given. It is to be noted that just like R- Q-analysis and discriminant function this is also a form of multivariate technique .Rao(1952) and Kendall(1957) have in particular made clear the interrelationships between various types of multivariate

analysis , and have underlined the basic theory upon which these techniques depend. These methods have been found to combine a reasonably simple method of analysis , if an electronic digital computer is available, with an approach sufficiently general to be usefully applied to the widest possible range of experimental procedures. Q-technique forms the basis of many numerical classifications , and lead to setting up of a 'taxonomy' of the treatments (Sneath 1957: Michener & Sokal 1957). It is useful in evaluating closely related groups of plants or animals. In factor analysis , however, attention is paid on the variates themselves and the ways in which they are correlated. The experimenter gains better understanding of the response to his "treatments" and attention is paid to seeking for "dimensions" of variability which are more general than the individual variates. Rao's concept of principal component analysis also followed by Jeffers is based upon total correlation matrix , followed by calculation of new variables defined in the analysis , and an analysis of variance of these variables. The reasons for the choice of this type of multivariate analysis is summarised as follows:

(1) This method of principal component analysis is objective and is free from dubious practices of estimation of communalities and rotation of axes present in some other methods of factor analysis.

(2) Principal component analysis is relatively easy to programme on electronic digital computers , and can be applied to a wide variety of situations .

(3) Although obviously a mathematical artefact , experience in its application frequently suggests meaningful and valuable interpretations.

(4) The method directs attention to wider problem of the "dimensions " which assessed variates , seek to express , and gives guidance to the choice of variates in future experimentation.

The actual method of computation can be described very simply.

Given a matrix of variates

$$\begin{bmatrix} X_{11} & X_{12} & X_{13} & . & . & . & X_{1n} \\ X_{21} & X_{22} & X_{23} & & & & X_{2n} \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ X_{t1} & X_{t2} & X_{t3} & . & . & . & X_{tn} \end{bmatrix}$$

where n is the number of variates , and t is the number of treatments or plots , the co-efficients of correlation between every pair of columns are calculated to form the correlation matrix

$$\begin{bmatrix} r_{11} & r_{12} & r_{13} & . & . & . & r_{1n} \\ r_{21} & r_{22} & r_{23} & . & . & . & r_{2n} \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ r_{n1} & r_{n2} & r_{n3} & & & & r_{nn} \end{bmatrix}$$

where the principal diagonal , composed of elements $r_{11}, r_{12}, \dots, r_{nn}$, consists of 1's. The latent roots and vectors of this symmetric correlation matrix define an orthogonal set of linear combinations of the original

variates

$$\begin{aligned} Z_1 &= a_{11} X_1 + a_{12} X_2 + . . . + a_{1n} X_n \\ Z_2 &= a_{21} X_1 + a_{22} X_2 + . . . + a_{2n} X_n \\ &\vdots \\ Z_n &= a_{n1} X_1 + a_{n2} X_2 + . . . + a_{nn} X_n \end{aligned}$$

such that the first linear combination (component) has, subject to the restraint of statistical independences, maximum variance. Furthermore, the second component is uncorrelated with the first and has^{as} large a variance as possible, and so on. The new linear combinations therefore describe the original variation in as small a number of uncorrelated dimensions as possible, and if the components so obtained have any physical interpretation, may lead to a better understanding of the variates.

The calculations described may be readily programmed for any electronic digital computer which has an efficient sub-routine for the calculation of latent roots and vectors of the matrices. The computation for example for the present thesis was carried out on I.C.T. Sirius computer at the Forestry Commission Research Stn., Alice Holt Lodge, Wrecclesham, Farnham, Surrey.

The present investigations

For the present investigations the OTU's selected were three apparently similar species of Stellaria, i.e. S. media, S. neglecta and S. pallida. The number of individuals (herbarium specimens) used were 72, 108 and 73 respectively. Thus in all 253 plants were used. These species as examined in natural habitats and in herbaria have confusingly similar facies and form a complex knot. The possibility of mis-identification, therefore, is fairly high. Their delimitation on vegetative characters and even on floral presents difficulty. Initially thirteen variables were used all drawn from the floral parts and it was seen that the three groups could come out distinctly. For obvious reasons to be explained later only eleven of the thirteen variables were used for computational work.

The characters chosen were all drawn from floral parts, because they comparatively provide stabler features for comparison. Characters selected were all "size" characters because in mass observations they tend to be normal. The variables selected are being given below :

(A) Seed length: This character has in the past been used in taxonomies of the Stellaria sps. under reference. This variable, like others shows much overlapping. This was measured from the funicle at the base of the groove to the the the opposite point of the seed diameter. Variables drawn from seeds and sepals have been shown in Fig. 26 page 193.

(B) Seed breadth : This is the diameter of seed at right angles to the length. Lengths and breadths were measured from five seeds from each plant and the measures for the individuals given in the appendix are the means of these scorings. For all measurements care was taken to use only fully mature seeds.

(C) Length of the tubercle: The seeds used for (A) and (B) were also used for measuring the lengths of tubercles. Five tubercles were measured from each seed, thus for each plant twenty-five tubercles were measured and the measures given in the appendix are the means of these measurements. Tubercles near the funicle are generally smaller and therefore those from the opposite sides were only used for the purpose.

(D) Breadth of the tubercle : They were measured for the same tubercles as for (C).

(E) Length of sepal : From each specimen measurements were taken on five sepals all taken from the same flower. Measurements were taken from the tip

of the sepal to its point of attachment to the thalamus. This criterion in the past has been used for the delimitation of the species.

(F) Breadth of sepal : The sepals used were the same as those for (E). This measure was taken along the broadest points. Means of five sepals gave the measure for each individual. This has also been in the past used as a subject -ve character

(G) Tip of the scarious tissue of the sepal : Sepals are characterised by the the possession of scarious tissue whose relation to the general. shape of the sepal can be seen in Fig. 26 on page 193. This measurement was made from the tip of the sepal (including the scarious part) to the middle point of the base of the apical notch. Sepals used were the same as for (E) and (F).

(H) Base of the scarious tissue of the sepal : This is the breadth just above the tip of the green part of the sepal. The sepals used were the same as for (E) to (G).

(I) Cleft of sepal : This is the vertical length of the cleft of the green part of the sepal. Same sepals were again used for the purpose.

(J) Length of petal : The petals are bifid, the cleft going almost up to the base. The length of petal here means the length of the undivided basal part + length of the longest arm. The length of the basal portion was measured from the point of attachment of the petal to the thalamus. Five petals were used from the same flower from which the sepals were taken. The means of these measurements for the individuals, like other variables, are given in the appendix.

(K) Cleft of the petal : The same petals were used for this measurement. This is the length of the longer of the two limbs of petal.

(L)Diameter of pollen grain : The pollen grains are round in all the three species .This character has not been used in previous taxonomies.The diameter

was measured from wall to wall.(M).Length of capsule measured in terms of lengths of valves of dehisced fruits.Five valves ~~were~~ measured from each plant.

The length of petal relative to sepals has been in the past used to delimit the species. There are, of course , some difficulties in using this character in the analysis more so in the herbarium specimens. The petals are composed of very delicate tissues and in herbarium specimens they get deformed and crinkled. Another difficulty is that presence/absence or the relative lengths of sepal/petal have been controversial characters used in the delimitation of species. Clapham, Tutin & Warburg (1962) note that there are some forms of Stellaria media which have no petals. In the case of S. pallida , however, petals are from 0 - minute in S. neglecta petals are rarely absent. Therefore, its importance as a single criterion for delimitation has been a matter of opinion. For the taximetical studies the characters of the petals have , however, been eliminated. The methods of canonical variance analysis permit the use of only common variables with respect to whom the generalised distance is measured.

COMPUTATIONS AND RESULTS FROM THE COMPUTER

The data given in the consolidated form in the appendix were used for the canonical variance as well as principal component analysis. All computational work was done on the I.C.T.-Sirius electronic digital computer at the Forestry Commission Research Stn., Wrecclesham, Farnham , Surrey. Algorithm of the programme was set by Mr. J.N.R. Jeffers. Canonical variances and principal component analyses were

done first on eleven variables from A - I , and L & M. For reasons stated earlier the variables J and K were eliminated from the analysis. However, their means for the individuals are given in the appendix at the end of this thesis. For the canonical variance analysis means of the variables for each taxon were needed in the first instance . They are given in a tabular form in Table 25 on page 175 . The total variation was then calculated from the determinantal matrix ^{of} in-between and within-taxa sum of squares. The details of computational figures and the derivation of total variability are shown in Table 26 on page 176 . The total variation calculated from the determinantal matrix derived from the in-between and within-taxa sum of squares and products ^{was} 33,321.8. Canonical variates were then calculated and the significance of the variates was then tested individually and only three of them were found to be significant, the first alone accounts for 96.80 % of the total variability, the second for 2.68 % and the third for 0.52 % . The three canonical variates , thus , account for all of the total variability. The significance of the variates was tested using the methods developed by Rao(1950) and Bartlett(1948) .

The original variates were then weighted against the individual canonical variates. This provided a technique for the weighting of the characters . Components 1 - 11 have been derived and the computational details as given by computer are given in the Table ^{component} page . The first gives maximum weight to seed length and pollen grain diameter , the variables (A) and (L). The second component (and hence second variate) gives maximum weight to length of tubercle (C) as contrasted to pollen grain diameter (L). The third component gives maximum load on

contrast between length of seed (variable A^i) and breadth of sepal (variable F). These weightings can be seen in Table 28 on page 177 against components 1 - 3. Computed values of three canonical variates for the means of three taxa have been given in the Table 29 on page 178 . They give the necessary vectors which can be used to measure the distance between the species in two dimensional space. The three species have been compared in Figs 27 to 29 with respect to these vectors . It can be seen that vectors 1 and two^{give} (see Fig. 27) widest separation between the species indicating that variables seed length , pollen grain diameter and length of tubercle (variables A , L and C respectively) are most important and discontinuities along them can be sought in the present net of the taxa

Viewed as a whole the three taxa come out to be quite distinct from each other . Canonical variance gave significant results so far generalised distances are concerned but there appeared to be another problem for which a combination of canonical statistic with multivariate analysis was considered to be the suitable taximetric method. This is what has been combined in the principal component analysis as understood in the present context. Difficult taxonomy of these species always gives fair chances of mis-identification. In every group there appeared to be some suspected cases of mis-identification. Partly to detect this mis-identification ^{partly} and/to see the correlation of characters in light of this method it was considered desirable to^{do} the principal component analysis of the data . The results will be presented in the following pages.

Data on morphometric measures have been given in the in the appendix. They are the means of primary measurements for individual specimens of all the three species. The means of these means as calculated by I.C.T.-Sirius computer are as follows:

Table 25. Means of variables for each taxon.

Variables	Species		
	<u>Stellaria neglecta</u>	<u>S.media</u>	<u>S.pallida</u>
A	137.07	107.29	81.38
B	140.02	109.76	85.06
C	494.7	23.21	20.71
D	65.21	59.67	47.79
E	579.38	484.00	336.13
F	221.46	211.18	128.75
G	68.64	70.01	54.66
H	86.50	94.45	71.63
I	33.35	27.46	21.62
L	18.80	18.65	15.33
M	600.75	601.82	378.35

Total variation was derived from the determinantal matrix of and their products.
in-between and within-taxa sum of squares/These calculations from computer results are as follows:

Calculation of total variation in-between and within taxa.

+11 (No. of variables)

Table 26

+30403.307000	-107541.330000	+145.653670
-3652.659000	+25769.001000	-2952.645600
-25066.129000	+2508.729600	-3894.348000
+5979.833000	-50037.050000	+4871.933200
+597.140200	-66164.130000	+956.716700
-11706.324000	+83015.710000	+18218.062000
-15455.296000	+16464.358000	+860.347900
+19353.364000	+311689.450000	+4748.264500
+3828.768100	+14680.023000	-1540.963600
+72418.210000	+51734.750000	-3980.405300
+3415.169800	-16693.937000	+978.384200
+31201.951000	-42928.172000	+82.390860
-9950.912000	+10401.060000	-1866.977200
-25742.036000	+949.187600	-2457.955400
+6147.125000	-19860.222000	+3070.587400
+610.815700	-26320.496000	+591.407100
-12033.260000	+33123.681000	+11484.562000
-15879.777000	+6574.932000	+544.055400
+19874.937000	+125058.820000	+144486.160000
+3924.011500	+5880.895000	-46805.532000
+74322.080000	+17388.837000	-120339.180000
+3506.699700	-5651.496000	+29350.339000
+9376.712000	-14580.456000	+2577.589800
-2896.128000	+3588.503200	-55740.080000
-7554.307000	+299.460920	-73817.370000
+1715.724400	-6822.015000	+92837.060000
+218.303800	-8991.083000	+18314.085000
+3557.732500	+11246.838000	+350411.910000
-4685.808400	+2172.251400	+16496.213000
+5842.025000	+42153.310000	
+1178.226900	+1994.931500	
+26611.824000	+22562.266000	
+1018.830600	-7366.427000	
+15728.488000	-18981.075000	
-5073.895000	+4702.017100	
-13110.980000	+376.318290	
+3190.817000	-8869.416000	
+285.126490	-11694.075000	
-6140.392000	+14637.978000	
-8091.887000	+2819.835100	
+10117.070000	+54956.450000	
+1966.506800	+2600.812100	
+37846.991000	+7623.752000	
+1790.158800	-2440.383100	
+130227.280000	-6311.270000	
-41670.749000	+1516.614000	

Total variation

= 33321.800000

Table 27

Eleven components have been derived as follows :

Canonical variates	Total variation 33321.8		
+.0003225488	96.80 %	0	Only first two canonical variates and hence components are significant.
+.0000089299	2.68 %	0	
+.0000017392	0.52 %	0	
-.0000000018			
+.0000000012			
+.0000000004			
+.0000000005			
+.0000000003			
+.0000000000			
+.0000000000			

N.B. Decimals to be read to the eighth place from the left.

Table			
Component 1	Component 3	Component 5	Component 7
+.0411524705	+.1000000000	+.1000000000	-.0139911048
-.0134034291	-.0063212004	+.0798602345	-.0081536814
-.0345525700	-.0621111375	-.0483563980	+.0261677222
+.0085281660	-.0018687408	+.0009788171	+.0418932796
+.0006987469	+.0095549315	+.0148119248	-.0044523464
-.0161487502	-.0704530205	-.0280636326	+.0106603418
-.0212920959	-.0695924909	-.0563915727	+.1000000000
+.0266497348	+.0507034403	+.0473309159	-.0904754943
+.0051455149	-.0027008701	-.0195277656	-.0903929013
+.1000000000	-.0337498713	-.0567997001	+.0839619779
+.0047314700	+.0030012034	-.0017736518	+.0027460338
Component 2	Component 4	Component 6	Component 8
+.0133668111	-.0100030167	-.0866975086	+.0178967662
-.0143534277	-.0271173273	-.0532611941	-.0137287439
-.0340388019	+.0157917771	-.0274661271	+.0059033130
+.0184667220	+.0001994507	+.1000000000	-.0156032671
-.0036832443	-.0040435665	+.0472671215	-.0055817997
-.0173040632	+.0318047321	+.0250143786	+.0206740270
-.0212423784	+.0291255898	-.0294049613	+.0210705553
+.0252883390	-.0211458413	+.0318903391	-.0191759997
-.0000567020	+.0020836036	-.0374073247	-.0016705050
+.1000000000	+.1000000000	-.0160968128	+.1000000000
+.0054082285	+.0086384361	-.0298556482	-.0045969434

<u>Component 9</u>	<u>Component 10</u>	<u>Component 11</u>
+.0200289306	+.0105782975	+.0105782975
-.0248845250	+.0139043062	-.0139043062
+.0157850412	+.0120373358	+.0120373358
-.0129962053	-.0073445828	-.0073445828
-.0074559847	-.0077970397	-.0077970397
+.0391891490	+.0343703188	+.0343703188
+.0426225837	+.0368510803	+.0368510803
-.0226150538	+.0274406984	-.0274406984
-.0043110639	+.0048201979	+.0048201979
+.1000000000	+.1000000000	+.1000000000
-.0104191972	-.0081748682	-.0081748682

Vectors of the canonical variates against

three components are as follows :

Table 29

<u>Species</u>	<u>Vectors</u>		
	<u>1</u>	<u>2</u>	<u>3</u>
<u>Stellaria media</u>	7.747	1.213	-0.437
<u>Stellaria neglecta</u>	7.347	-1.235	0.144
<u>Stellaria pallida</u>	5.906	1.182	0.360

Principal component analysis

Table 30

No. of sets 253

Variables the same as for canonical variate analysis

Species -- -- -- -- -- -- --

Variables	Mean	S.D.	Min.	Max.
A	112.52613	26.98529	63.40000	172.40000
B	115.54921	27.43903	62.20000	175.80000
C	33.69221	16.86395	13.72000	91.60000
D	58.60980	11.79422	33.40000	92.40000
E	482.04605	116.02853	204.25000	681.20000
F	191.78538	46.53336	73.60000	280.80000
G	64.99881	14.73188	35.00000	111.60000
H	84.47115	16.53774	39.60000	133.60000
I	28.29210	9.99132	11.60000	70.80000
L	17.75573	2.04431	14.00000	22.60000
M	536.88320	123.97324	184.00000	751.60000

Table 31.

From these means ,S.D. ,min and max. the correlation matrices for latent

roots and vectors were analysed and are given below.

+11 Co-eff. of correlation		
1.000000 A with A	0.849079	0.460490
0.981759 A with B	0.812924	0.444610
0.658159 A with C, etc	0.549788	0.387714
0.730666	0.640063	0.322369
0.849079	1.000000	0.503439
0.765882	0.842780	0.362757
0.330848	0.423106	0.432955
0.293804	0.404548	0.357713
0.460490	0.503439	1.000000
0.675691	0.753294	0.336574
0.729422	0.808234	0.343058
0.981759 B with A	0.765882	0.675691
1.000000 B with B	0.739766	0.651883
0.646096 B with C etc.	0.444209	0.319527
0.716359	0.613465	0.501209
0.812924	0.842780	0.753294
0.739766	1.000000	0.766919
0.313219	0.322843	0.353920
0.256712	0.439921	0.383911
0.444610	0.362757	0.336574
0.651883	0.766919	1.000000
0.720453	0.852674	0.732629
0.658159	0.330448	0.729422
0.646096	0.313219	0.720453
1.000000	0.109208	0.404676
0.535538	0.284539	0.623582
0.549788	0.423106	0.808234
0.444209	0.322843	0.852674
0.109208	1.000000	0.370007
0.051699	0.734599	0.413177
0.387714	0.432955	0.343058
0.319527	0.353920	0.732629
0.404676	0.370007	1.000000
0.730666	0.293804	
0.716359	0.256712	
0.535538	0.051699	
1.000000	0.257722	
0.640063	0.404548	
0.613465	0.439921	
0.284539	0.734599	
0.257722	1.000000	
0.322369	0.357713	
0.501209	0.383911	
0.623582	0.413177	

Table 32
Components of variability

+.0064746054	58.86 %	only the first two meaningful
+.0015373853	13.98 %	The first component gives weight to
+.0009354166	8.50 %	plant size on the whole .The second
+.0005688284	5.17 %	component gives weight to base of the
+.0005828762		scarious tissue of sepal and tip of
+.0003281845		scarious tissue of sepal.
+.0002640562		
+.0002359829		
+.0001469837		
+.0001110333		
+.0000146477		

Component 1	Component 3	Component 4	Component 7	Component 9
+.0994081538	+.0117574957	+.0007073174	-.0427776107	-.0095694623
+.0971102625	+.0123806695	+.0044777732	-.0502008931	-.0330769776
+.0669261681	+.0759956781	-.0951920297	+.0444643191	-.0124405883
+.0821811519	+.0082653383	+.1000000000	+.0441488825	+.0152415932
+.1000000000	-.0099701100	-.0136042767	-.0141114547	+.1000000000
+.0950381424	-.0489575273	-.0164007313	-.0234927326	+.0459062714
+.0542753524	+.0288025147	-.0076091519	+.0191373217	+.0093336807
+.0536534504	-.0051743667	-.0340584637	-.0186800325	-.0142657270
+.0602085757	+.1000000000	+.0517662222	-.0001238389	-.0129737907
+.0857357778	-.0588628591	-.0086637859	+.1000000000	-.0229591449
+.0928618707	-.0511129920	+.0046634953	-.0262247173	-.0819608277
Component 2	Component 4	Component 6	Component 8	Component 10
-.0301801012	-.0129755326	+.0840665664	+.0434395093	-.0004651207
-.0332704749	-.0142099524	+.0979260278	+.0379714907	+.0104574588
-.0561485578	-.0333774159	-.0571614982	-.0164043796	+.0026235209
-.0272169096	-.0879014341	-.0597365488	+.0102685550	-.0027589085
-.0044136139	+.0268570066	+.0100699424	-.0351466707	-.0767032644
-.0035952452	+.0232435759	-.0813513386	+.0020092096	+.1000000000
+.0965179413	-.0468024464	+.1000000000	-.0902695838	+.0353339582
+.1000000000	-.0388178871	-.0800755639	+.1000000000	-.0319352814
+.0313306485	+.1000000000	-.0429138965	+.0066659807	+.0073439024
+.0061296796	+.0551653146	+.0663175517	+.0458289752	-.0036581760
-.0000772961	+.0119014415	-.0715088110	-.0993345755	-.0332159052

Table 33
Values of components for the individuals

Component 11							
+.1000000000				-0.290	1.888	-1.290	-1.187
-.0883537132				0.217	0.123	-1.238	0.359
-.0018698048				-0.323	0.216	-0.521	0.716
-.0028208141				0.155	0.906	-0.875	-0.170
-.0140475644				-1.136	-1.014	-0.341	-0.849
-.0012366101				1.643	2.718	1.029	1.387
+.0028045485				1.365	0.693	-1.837	0.084
-.0045573362				0.379	2.412	-0.459	-0.621
+.0007517819				0.000	0.321	-1.604	0.581
-.0012585387				0.386	-1.037	-1.907	0.460
+.0072516595				1.185	1.322	-1.318	-0.089
				0.288	0.566	-0.158	0.763
				0.613	0.645	-1.207	0.645
				0.621	1.320	-0.246	-0.016
-3.285	0.704	0.293	-0.546	-0.511	-0.967	-0.458	-0.259
0.067	2.154	0.060	1.500	0.166	0.893	-0.778	-0.433
-1.044	0.793	-1.484	1.151	1.435	1.285	-1.751	-0.071
-0.422	1.151	-0.912	-0.077	1.413	1.727	-0.460	0.156
-0.199	2.552	-0.443	-0.667	0.595	0.032	-1.555	-0.593
0.692	3.117	0.124	-0.288	0.050	-0.048	-1.214	0.055
-1.107	-1.249	-1.811	1.416	0.593	0.001	-1.580	0.636
0.196	2.768	-0.554	-0.097	1.539	1.315	-0.708	-0.715
-0.367	0.185	-1.439	0.914	1.467	-0.355	-1.638	0.592
-1.094	0.161	-0.609	0.455	-0.023	0.281	-1.188	0.528
-1.132	-0.764	-0.704	0.488	1.719	2.128	1.553	0.460
0.178	2.266	-0.931	0.074	0.489	-1.101	-0.466	0.550
-2.962	0.095	0.015	0.699	1.465	-0.0833	-1.346	-0.068
0.158	-0.761	-2.483	-0.020	2.119	0.617	0.076	1.437
-0.383	1.866	-0.041	-1.056	0.803	1.396	-0.613	0.804
-0.333	2.659	0.056	-0.930	2.093	2.651	0.951	0.760
-0.442	-1.158	-0.977	-0.254	0.082	0.045	-0.520	-1.084
0.168	1.135	-1.379	-0.049	0.253	1.600	0.501	0.326
0.590	1.303	-1.160	-0.885	1.669	-0.462	-1.328	-0.559
-0.031	-0.762	-1.414	-1.977	0.782	1.609	-0.352	-0.595
-0.977	2.536	-0.091	-1.017	1.800	-1.487	-0.990	0.105
-0.478	0.436	-1.556	-0.018	-2.648	-0.836	-0.407	0.350
-0.110	1.035	-1.434	0.402	3.041	0.727	-0.289	-1.147
-0.222	1.639	-1.239	-0.393	2.589	2.019	-0.141	0.082
1.042	1.477	-0.497	-0.637	0.428	-0.074	-1.167	-1.101
0.763	3.056	0.592	-0.642				
-0.561	-0.224	-1.061	0.618				
0.656	1.374	-0.906	-0.540				
0.249	1.432	-1.372	0.185				
-0.758	-0.884	-1.162	-0.729				
0.991	2.262	-0.864	-0.754				
0.409	2.277	-0.615	-0.626				
0.756	2.094	-1.600	-0.846				

Table 34

<u>Stellaria neglecta</u>		Weihe					
I	II	III	IV	I	II	III	IV
2.515	0.704	2.606	2.038	2.527	0.578	-0.936	-0.742
4.090	0.282	1.617	0.413	2.991	1.363	-0.105	-0.144
3.226	0.216	1.515	-0.003	2.715	-1.473	0.253	-1.193
1.773	1.609	0.266	1.454	2.162	-0.659	-0.162	-0.385
-3.135	1.780	0.862	-0.082	2.705	-1.006	0.015	-0.224
1.521	-0.587	0.920	0.570	0.293	-1.518	0.606	-0.942
1.974	1.773	0.385	0.384	1.389	-1.913	-0.749	-0.288
1.959	0.984	-0.403	-0.068	3.361	0.552	-0.941	-1.017
2.673	1.555	0.481	0.161	1.332	-0.759	0.211	-0.372
1.075	-0.647	0.391	0.041	2.320	0.480	0.274	1.150
2.406	0.362	0.227	0.391	3.272	0.349	-0.765	0.235
1.206	-0.668	0.732	-0.586	1.453	-0.450	-0.753	0.232
1.538	-0.268	-0.061	0.123	2.464	-0.609	0.400	-0.882
0.926	-0.147	1.947	0.885	3.331	-0.716	-1.124	0.518
1.202	1.230	0.619	-0.156	2.063	-0.455	2.369	1.500
0.726	-0.560	2.137	0.522	2.809	-1.907	0.268	-0.465
1.752	0.720	0.792	0.100	4.549	0.102	0.856	-0.674
2.406	0.527	2.049	-0.592	2.878	-1.498	0.925	-1.079
2.788	0.350	2.585	-0.538	2.872	0.205	1.809	0.584
1.804	1.050	1.374	-1.635	0.473	-1.248	-0.628	-0.621
2.327	-1.380	0.507	0.150	1.529	1.657	-0.837	0.756
1.934	1.547	1.485	-0.463	2.742	-1.439	0.291	-1.753
-0.119	1.020	0.150	-0.968	4.828	-0.173	0.324	-1.941
2.283	0.200	1.018	0.103	2.842	-0.143	1.370	1.448
2.037	3.608	0.328	-1.230	2.580	0.922	1.908	1.637
2.369	0.514	0.228	-0.368	2.725	-0.482	-0.776	-0.351
3.689	0.072	4.257	0.425	0.503	-0.234	-0.645	-0.315
3.689	1.263	1.808	-1.162	1.180	-0.751	-0.906	0.712
0.515	-0.795	2.323	2.046	3.823	-0.416	-0.526	-0.691
2.065	-1.203	0.887	0.392	2.311	-0.055	-0.611	0.318
1.486	0.207	0.806	-0.086	2.434	-0.763	-0.908	0.704
0.317	0.615	0.281	-0.721	2.818	-1.733	-0.075	0.758
1.297	-0.616	-0.276	0.888	2.784	0.123	0.284	-0.336
3.117	1.152	1.089	0.643	2.587	-0.606	0.282	-0.365
1.826	-0.562	1.650	2.074	4.354	0.083	0.056	-0.519
2.377	-0.963	0.432	-0.140	2.681	-0.695	0.384	0.210
0.170	-0.572	1.091	0.067	2.060	-1.513	-0.008	0.906
1.182	-0.143	0.001	0.454	2.017	-1.076	0.373	-0.327
-1.120	0.464	0.109	0.506	2.424	-0.673	-0.085	-0.173
1.943	-0.782	-1.153	0.117	1.378	-0.578	-0.347	1.110
2.879	0.225	-0.945	0.202	1.009	-0.396	-0.147	0.202
3.010	-1.396	-0.373	-0.621	2.716	-2.339	-0.600	-0.638
0.227	-0.836	-0.345	0.701	3.881	-2.072	0.658	-0.464
0.417	0.036	-0.428	-0.191	2.222	-2.500	0.109	0.554
1.640	-0.884	-0.218	-0.857	2.215	-1.855	-0.230	1.028
0.874	-0.116	0.475	-1.409	1.200	-2.919	-0.429	0.828

I	II	III	IV
3.903	-1.326	0.306	-0.676
0.835	0.470	-0.765	1.530
0.820	-0.275	-1.190	-0.930
1.358	-0.991	-0.528	0.584
0.596	-1.780	-1.885	1.643
1.900	-2.920	-0.865	-0.177
3.184	-2.309	0.444	-0.548
3.068	-1.343	-0.098	-0.781
2.598	-0.550	-0.176	-0.093
2.190	-0.951	0.125	-0.879
1.503	-1.298	-0.532	0.023
2.543	-0.990	-0.336	0.456
2.910	-2.872	-0.134	-0.335
1.810	-2.276	-0.856	0.347
2.016	-3.018	0.303	0.690
2.096	-2.568	0.053	0.486

Table 35

Stellaria pallida (Dumort.) Pirá

I	II	III	IV	I	II	III	IV
-4.502	-0.076	0.242	0.345	-2.671	0.723	-0.220	-0.207
-4.595	-0.359	0.337	0.608	-3.451	0.312	-0.008	-0.306
-0.672	0.206	-0.863	0.311	-2.759	0.913	0.039	-1.201
-3.336	0.102	0.358	0.356	-4.120	0.268	-0.179	-0.042
-4.799	-0.704	-0.100	0.744	-3.943	-0.184	-0.360	0.242
-4.235	-0.525	-0.264	0.771	-4.437	-0.211	-0.223	0.593
-2.890	-0.445	-0.762	1.059	-3.554	0.468	0.162	-0.107
1.508	0.881	0.553	0.173	-2.710	0.551	0.002	-0.786
-3.644	-0.625	0.144	0.552	-4.077	0.541	0.022	0.219
-2.849	2.189	1.773	0.324	-3.491	-0.408	-0.064	-0.404
-3.196	1.506	0.880	0.363	-3.348	0.115	0.693	0.061
-3.355	1.008	0.170	0.508	-3.000	-0.718	0.482	-0.970
-3.838	-0.051	0.378	0.228	-4.046	-0.482	-0.058	0.398
-4.134	0.236	0.390	0.680	-3.578	-0.211	-0.056	-1.013
-3.598	0.122	0.505	-0.292	-4.487	-0.629	0.357	0.133
-3.916	0.160	0.693	0.256	-4.635	-0.620	0.210	-0.488
-4.061	0.401	0.427	0.095	-3.977	-0.340	-0.213	0.336
-3.607	-0.303	-0.187	0.054	-4.535	-0.599	0.289	-0.321
-4.469	-1.188	0.650	-0.824	-3.579	-1.350	0.131	-0.656
-3.895	-0.168	-0.268	-0.403	-3.550	-0.239	0.032	-1.338
-3.933	-0.551	0.939	-0.161	-3.486	-1.150	-0.334	-0.266
-5.182	-0.978	-0.224	0.166	-3.102	-0.019	0.317	-0.108
-3.644	-0.303	-0.117	-0.028	-2.421	2.230	1.001	-0.106
-4.884	-0.122	0.684	0.232	-3.376	-0.807	-0.215	-0.722
-1.875	-1.082	-0.315	-0.006	-3.827	-0.724	0.699	0.313
-4.388	-1.774	0.019	-0.479	-2.507	0.907	1.497	1.418
-3.242	0.551	0.329	-0.242	-3.644	-1.253	0.945	-0.494

-3.404	-0.897	0.499	0.002
-3.890	-0.672	0.259	0.526
-2.447	0.476	1.993	0.806
-2.208	-3.102	4.118	-1.920
-1.799	0.962	0.584	-1.070
-2.885	0.886	0.232	-0.623
-2.617	0.599	0.497	0.024
-4.208	-0.725	-0.062	-0.112
-4.115	-0.447	0.464	0.501
-3.449	-0.574	0.387	-0.489
-4.475	-0.108	0.315	0.812
-3.080	0.920	0.324	-0.791
-4.079	-0.297	0.015	0.827
-3.910	-0.977	0.398	0.157
-2.733	-2.319	-0.116	-1.338
0.229	-1.763	-0.104	-1.687
-1.897	0.405	0.984	-1.822
-3.585	-1.069	0.625	-0.510
-2.761	-1.028	0.405	-0.992

One additional variable seed weight was introduced into the component analysis and the results are given below. It can be seen that separation between the species is better than before when only eleven variables were used. The mean and s.d. pertain to 253 specimens of all the three species.

Table 36.

Variable	Mean	S.D.
A	112.53	26.9836
B	115.55	27.4379
C	33.70	16.8640
D	58.61	11.7930
E	482.05	116.0800 116.0800
F	191.79	46.5334 46.5334
G	65.00	14.7319
H	84.47	16.5377
I	28.29	9.9913
L	17.76	2.0443
M	536.88	123.973
Seed wt.	4.56	2.7446

Table 37

+ 12

Coefficients of correlation

1.000000 A with A

0.981755 A with B

0.805467 A with C etc.

0.730598

0.849071

0.765885

0.330440

0.293788

0.460495

0.675668

0.729412

0.884331

Correlations greater than

0.126 significant at 0.05

0.158 " " 0.01

0.981755	B with A	0.730598	0.765885	0.293788
1.000000	B with B	0.716300	0.739761	0.256714
0.794600	B with C , etc.	0.628068	0.560857	0.095636
0.716300		1.000000	0.613362	0.257730
0.812915		0.639912	0.842784	0.404545
0.739761		0.613362	1.000000	0.439921
0.313226		0.284561	0.322843	0.734599
0.256714		0.257730	0.439921	1.000000
0.444603		0.322311	0.362757	0.357718
0.651867		0.501110	0.766919	0.383911
0.720455		0.623462	0.852676	0.413179
0.853869		0.633169	0.763670	0.298999
0.805467		0.849071	0.330440	0.460495
0.794600		0.812915	0.313226	0.444603
1.000000		0.679287	0.159311	0.465828
0.628068		0.639912	0.284561	0.322311
0.679287		1.000000	0.423105	0.503439
0.560857		0.842784	0.322843	0.362757
0.159311		0.423105	1.000000	0.432955
0.095636		0.404545	0.734599	0.357718
0.465828		0.503439	0.432955	1.000000
0.421129		0.753298	0.353920	0.336574
0.494635		0.808241	0.370009	0.343057
0.748176		0.852348	0.310803	0.498500

0.675668	0.729412	0.884331
0.651867	0.720455	0.853869
0.421129	0.494635	0.748176
0.501110	0.623462	0.633169
0.753298	0.808241	0.852348
0.766919	0.852676	0.763670
0.353920	0.370009	0.310803
0.383911	0.413179	0.298999
0.336574	0.343057	0.498500
1.000000	0.732627	0.677381
0.732627	1.000000	0.679789
0.677381	0.679789	1.000000

Values of components for individual specimens

Stellaria media

I.	II.	III.	IV.	I.	II.	III.	IV.
-3.486	0.615	0.309	0.493	-0.898	-0.839	-1.170	-0.753
-0.142	2.198	0.063	-1.535	0.819	2.365	-1.004	0.549
-1.309	0.735	-1.496	-1.299	0.118	2.390	-0.732	0.529
-0.590	1.186	-0.963	-0.035	0.534	2.204	-1.739	0.604
-0.477	2.608	-0.474	-0.769	-0.534	1.951	-1.381	1.020
0.444	3.210	0.034	0.221	-0.034	0.226	-1.291	-0.354
-1.290	-1.220	-1.796	-1.413	-0.464	0.236	-0.493	-0.686
-0.036	2.830	-0.617	-0.063	-0.025	0.964	-0.900	0.160
-0.582	0.240	-1.462	-1.000	-1.096	-1.064	-0.321	0.933
-1.258	0.163	-0.602	-0.471	1.352	2.850	1.029	-1.182
-1.225	-0.779	-0.670	-0.427	1.087	0.860	-1.954	-0.167
-0.162	2.372	-1.014	-0.206	0.159	2.475	-0.504	0.541
-3.205	0.030	0.055	0.711	-0.244	0.403	-1.665	-0.700
0.045	-0.688	-2.544	-0.044	0.587	-1.090	-1.849	-0.566
-0.620	1.926	-0.135	0.989	1.215	1.357	-1.366	-0.079
-0.521	2.677	0.019	0.822	0.396	0.519	-0.085	-0.754
-0.489	-1.133	-1.010	0.311	0.731	0.605	-1.155	-0.807
-0.117	1.239	-1.457	-0.027	0.626	1.321	-0.235	-0.040
0.328	1.400	-1.183	-0.926	-0.606	-0.948	-0.443	0.407
-0.292	-0.680	-1.375	-1.894	-0.108	0.977	-0.804	0.450
0.521	2.718	-0.258	1.050	1.399	1.349	-1.795	-0.098
-0.575	0.444	-1.583	-0.198	1.395	1.771	-0.467	-0.205
-0.287	1.076	-1.462	-0.576	0.398	0.147	-1.658	0.556
-0.424	1.681	-1.283	0.248	0.361	-0.174	-1.124	-0.247
0.750	1.632	-0.620	0.692	0.433	0.082	-1.607	-0.674
0.394	3.195	0.505	0.760	1.356	1.453	-0.814	0.749
-0.767	-0.176	-1.068	-0.599	1.149	-0.156	-1.743	-0.518
0.428	1.487	-1.017	0.484	-0.243	0.350	-1.207	-0.553
-0.061	1.540	-1.444	-0.301	1.497	2.261	1.514	-0.196
				0.282	-0.995	-0.472	-0.318

1.267	-0.665	-1.448	0.188
2.108	0.698	0.108	-1.270
0.879	1.354	-0.530	-0.957
1.760	2.833	0.888	-0.562
-0.163	0.140	-0.577	1.207
0.076	1.634	0.535	-0.240
1.745	-0.385	-1.417	0.499
0.556	1.705	-0.398	0.641
2.039	-1.479	-0.945	0.001
2.325	-0.571	-0.542	-0.074
3.278	0.773	-0.314	1.165
2.449	2.156	-0.185	-0.027
0.706	-0.173	-1.091	0.989

Stellaria neglecta

2.626	0.743	2.692	-1.721	0.233	0.653	0.229	0.691
4.387	0.326	1.675	-0.262	1.731	-0.733	-0.168	-1.032
3.535	0.239	1.521	0.086	3.244	1.215	1.093	-0.605
1.912	1.575	0.393	-1.463	2.375	-0.716	1.860	-1.904
-3.345	1.675	0.914	0.013	3.272	-1.194	0.594	-0.021
1.903	-0.678	1.043	-0.485	0.694	-0.781	1.241	-0.167
2.258	1.733	0.384	-0.622	1.365	-0.175	0.055	-0.491
2.194	0.948	-0.337	-0.045	-0.839	0.254	0.316	-0.593
2.893	1.571	0.475	-0.242	2.165	-0.796	-1.094	-0.258
1.493	-0.763	0.485	-0.095	3.025	0.280	-0.939	-0.320
2.932	0.252	0.321	-0.545	3.211	-1.297	-0.463	0.648
1.426	-0.693	0.757	0.674	0.412	-0.906	-0.327	-0.655
1.756	-0.294	-0.017	-0.167	0.519	0.009	-0.397	0.182
1.170	-0.217	2.043	-0.753	1.832	-0.849	-0.306	0.776
1.270	1.218	0.674	0.176	1.049	-0.131	0.430	1.360
1.061	-0.665	2.248	-0.361	2.752	0.610	-0.963	0.697
2.061	0.660	0.845	-0.171	3.063	1.452	-0.161	0.046
2.756	0.479	2.115	0.704	2.894	-1.376	0.145	1.260
2.902	0.433	2.545	0.820	2.383	0.632	-0.189	0.334
1.931	1.078	1.312	1.648	2.801	-0.891	-0.076	0.286
2.463	-1.319	0.512	0.006	0.544	-1.599	0.677	1.007
2.059	1.548	1.519	0.514	1.819	-1.972	-0.765	0.122
0.077	0.902	0.263	0.950	3.681	0.603	-1.066	0.707
2.908	0.046	1.135	-0.233	1.759	-0.840	0.217	0.239
2.285	3.546	0.346	0.946	2.420	0.531	0.253	-1.273
2.506	0.579	-0.302	0.302	3.553	0.371	-0.748	-0.395
4.061	0.085	4.334	0.038	1.694	-0.458	-0.779	-0.383
3.976	1.342	1.683	1.208	2.715	-0.572	0.362	0.957
1.164	-1.051	2.542	-2.167	3.539	-0.633	1.094	-0.400
2.431	-1.244	0.939	-0.356	2.517	-0.562	2.535	-1.338
1.609	0.227	0.780	0.088	3.078	-1.838	0.202	0.554

4.911	0.186	0.801	0.763	1.658	-0.600	-0.243	-1.173
3.004	-1.383	0.851	1.318	1.342	-0.495	-0.023	-0.183
3.022	0.288	1.766	-0.395	3.083	-2.304	-0.645	0.673
0.599	-1.258	-0.067	0.714	4.410	-2.028	0.548	-0.437
1.461	1.718	-0.834	-0.727	2.763	-2.562	0.124	-0.647
3.011	-1.371	0.196	1.849	2.466	-1.837	-0.199	-1.006
4.969	0.026	0.161	2.092	1.575	-2.985	-0.346	-0.816
3.171	-0.151	1.436	-1.302	4.322	-1.259	0.204	0.651
2.632	0.993	1.943	-1.401	0.771	0.494	-0.707	-1.597
2.906	-0.412	-0.834	0.281	1.058	-0.332	-1.155	0.808
0.555	-0.243	-0.604	0.341	1.547	-0.992	-0.508	-0.604
1.269	-0.738	-0.871	-0.753	0.733	-1.809	-1.896	-1.795
4.020	-0.298	-0.613	0.676	2.191	-2.889	-0.912	0.184
2.573	-0.044	-0.621	-0.426	3.499	-2.232	0.391	0.766
2.735	-0.777	-0.849	-0.809	3.212	-1.224	-0.196	0.854
3.325	-1.789	0.018	-0.744	2.790	-0.497	-0.196	0.112
2.952	0.197	0.200	0.262	2.404	-0.914	0.094	0.930
2.740	-0.518	0.209	0.481	1.818	-1.348	-0.466	-0.049
4.432	0.263	-0.061	0.577	2.871	-0.994	-0.303	-0.485
2.879	-0.648	0.397	-0.112	3.532	-2.930	-0.085	0.398
2.234	-1.458	-0.051	-0.917	1.964	-2.21	-0.871	-0.294
2.401	-1.117	0.407	0.349	2.266	-2.983	0.321	-0.480
2.507	-0.577	-0.153	0.220	2.625	-2.641	0.126	-0.448

Stellaria pallida(Dumort.)Pire

-4.685	-0.253	0.376	-0.370	-5.288	-1.197	-0.083	-0.269
-4.766	-0.532	0.473	-0.604	-3.861	-0.407	-0.057	-0.025
-0.885	0.239	-0.854	-0.295	-5.004	-0.336	0.849	-0.217
-3.521	-0.010	0.456	-0.325	-1.964	-1.141	-0.242	0.108
-4.881	-0.917	0.049	-0.839	-4.509	-1.934	0.143	0.595
-4.408	-0.669	-0.163	-0.819	-3.541	0.489	0.372	0.279
-3.055	-0.539	-0.662	-1.119	-2.730	0.587	-0.127	0.084
1.796	0.802	0.648	-0.246	-3.670	0.219	0.037	0.275
-3.899	-0.707	0.220	-0.455	-3.039	0.886	0.014	1.236
-3.152	2.119	1.853	-0.184	-4.319	0.142	-0.121	-0.015
-3.461	1.416	0.939	-0.413	-4.134	-0.314	-0.270	-0.311
-3.603	0.915	0.236	-0.560	-4.635	-0.359	-0.123	-0.645
-4.061	-0.162	0.454	-0.200	-3.794	0.365	0.238	0.103
-4.337	0.085	0.509	-0.704	-2.990	0.518	0.007	0.812
-3.840	0.030	0.561	0.342	-0.4.257	0.399	0.099	-0.298
-4.133	0.032	0.798	-0.203	-3.729	-0.491	-0.011	0.433
-4.243	0.250	0.532	-0.113	-3.596	-0.066	0.764	0.058
-3.837	-0.401	-0.114	-0.064	-3.194	-0.767	0.473	1.087
-4.586	-1.355	0.747	0.888	-4.228	-0.614	0.035	-0.389
-4.106	-0.271	-0.232	0.379	-3.745	-0.308	-0.047	0.978
-4.056	-0.706	1.047	0.222	-4.665	-0.783	0.461	-0.105

-4.765	-0.785	0.279	0.467	-2.147	0.994	0.543	1.150
-4.192	-0.464	-0.120	-0.374	-3.205	0.848	0.244	0.624
-4.651	-0.763	0.360	0.307	-2.914	0.564	0.531	0.023
-3.701	-1.456	0.168	0.711	-4.351	-0.862	-0.000	0.101
-3.719	-0.333	0.024	1.285	-4.271	-0.605	0.598	-0.468
-3.618	-1.263	-0.269	0.244	-3.605	-0.670	0.423	0.540
-3.304	-0.102	0.369	0.134	-4.599	-0.292	0.451	-0.839
-2.789	2.212	1.012	0.121	-3.386	0.871	0.340	0.820
-3.572	-0.883	-0.181	0.788	-4.286	-0.435	0.137	-0.844
-3.991	-0.855	0.823	-0.147	-4.076	-1.104	0.500	-0.060
-2.815	0.856	1.610	-1.241	-2.940	-2.338	-0.119	1.638
-3.778	-1.364	1.010	0.658	-0.192	-1.571	-0.207	2.053
-3.622	-0.965	0.535	0.124	-2.170	0.442	0.878	1.963
-4.087	-0.787	0.350	-0.466	-3.748	-1.172	0.691	0.648
-2.668	0.417	2.087	-0.536	-3.017	-1.041	0.394	1.196
-4.403	-0.369	0.250	0.287				

Just as principal component analysis , canonical variances were also worked out with an additional variable seed weight. Weight of ten seeds in milligrams for each specimen has been taken for the purpose of this analysis. The means for other variables for each species are the same as given on page . However, the means for seed weight for each taxon are given below.

<u>Species</u>	Mean seed wt. for ten seeds in mgs.
<u>Stellaria media</u> (L.)Vill	3.97
<u>Stellaria neglecta</u> Weihe	7.14
<u>Stellaria pallida</u> (Dum.)Pire	1.33

The twelve canonical variances were calculated again from the determinantal matrix of in-between and within-taxa sum of squares and their products. Using the methods of Rao(1950) and Bartlett(1948) only first two were found to be significant. Their values along with original variables weighted against them are given below.

Table 38

Canonical variates

.0001558249 7

.0000518585 7

Figure 7 against the variates indicates that decimal points are to be read to the seventh place from the left.

Component 1
(weights for the first
canonical variate)

+ .0026659410
+ .0020862519
+ .0060046885
- .0057836071
+ .0012942732
+ .0041157093
+ .0053466422
- .0021887387
+ .0004169423
- .0045823870
- .0002635650
+ .1000000000

Component 2
(Weights for second canonical variate)

+ .0044477197
- .0101799423
- .0246742101
+ .0140138618
- .0033217973
+ .0083786531
+ .0009346927
+ .0076137349
+ .0083096239
+ .1000000000
+ .0032975438
- .0658464006

Only two of the variates were found to significant, the first accounting for 75 % of the variability contained by the original variables and the second for almost all of the remaining variability. The weights of the original variables suggest that the first variate is almost entirely a measure of seed weight, while the second is almost entirely a measure of the diameter of the pollen grain (variable L), but with some contrast with the seed weight.

Computed values of the two canonical variates for the means of the three taxa were calculated and the values are given below.

Table 39

Species	Vectors	
	1	11
<u>Stellaria media</u>	8.037	11.252
<u>S. neglecta</u>	10.907	8.207
<u>S. pallida</u>	4.945	7.918

These vectors for each species when used as co-ordinates give better separation between the species. It can be seen in Fig. on page as compared to Fig. on page. Fig. on page gives the distribution of the species (individual specimens) with regard to two variates. The symbols used are as before, i.e. 0 for S. neglecta, + for S. media and X for S. pallida. This distribution diagram is complete and better than those with only eleven variables. There are still some individuals for S. neglecta which tend to form a cluster with the points for S. media which is an indication of the dominance of the complements of alleles from S. neglecta.

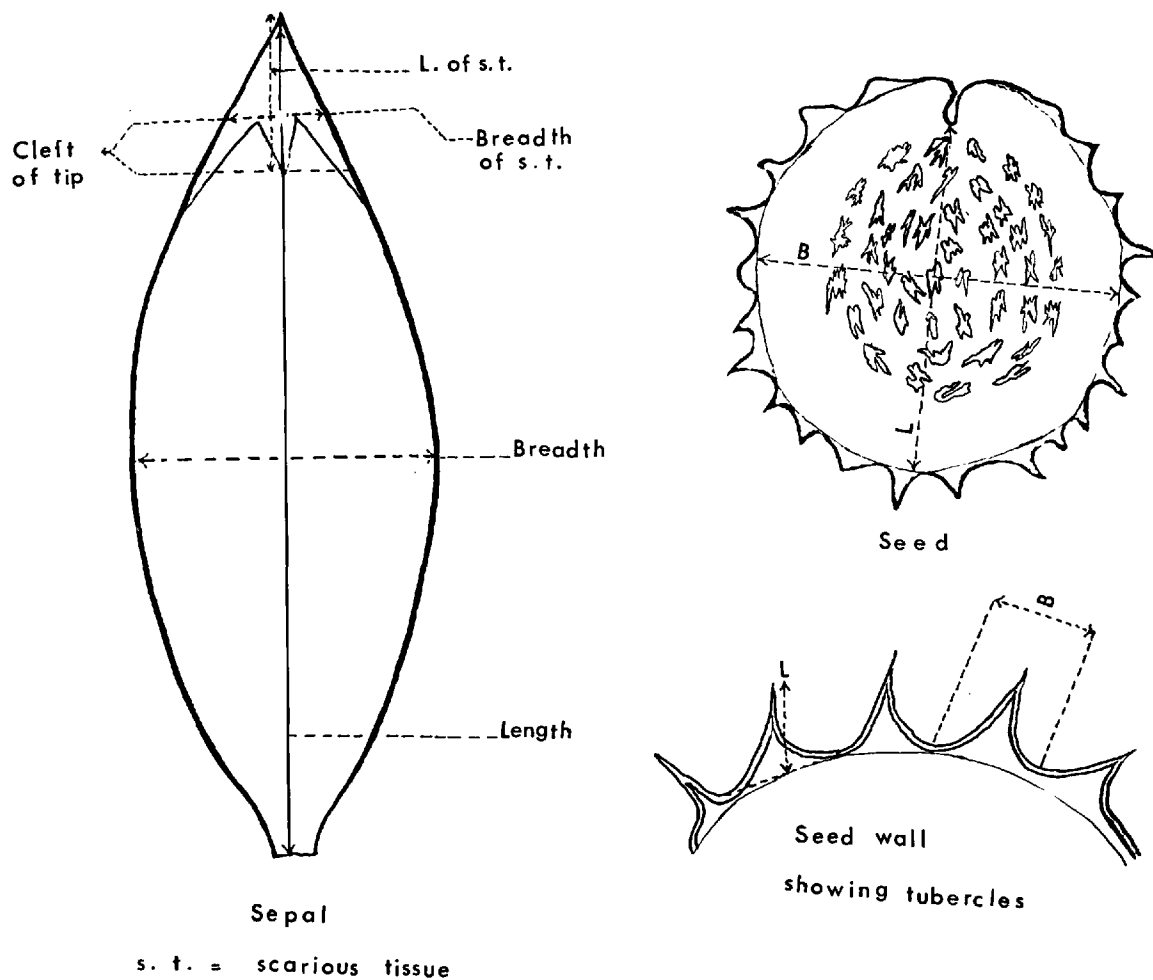


Fig.26. Sepal and seed showing the variables used from them.

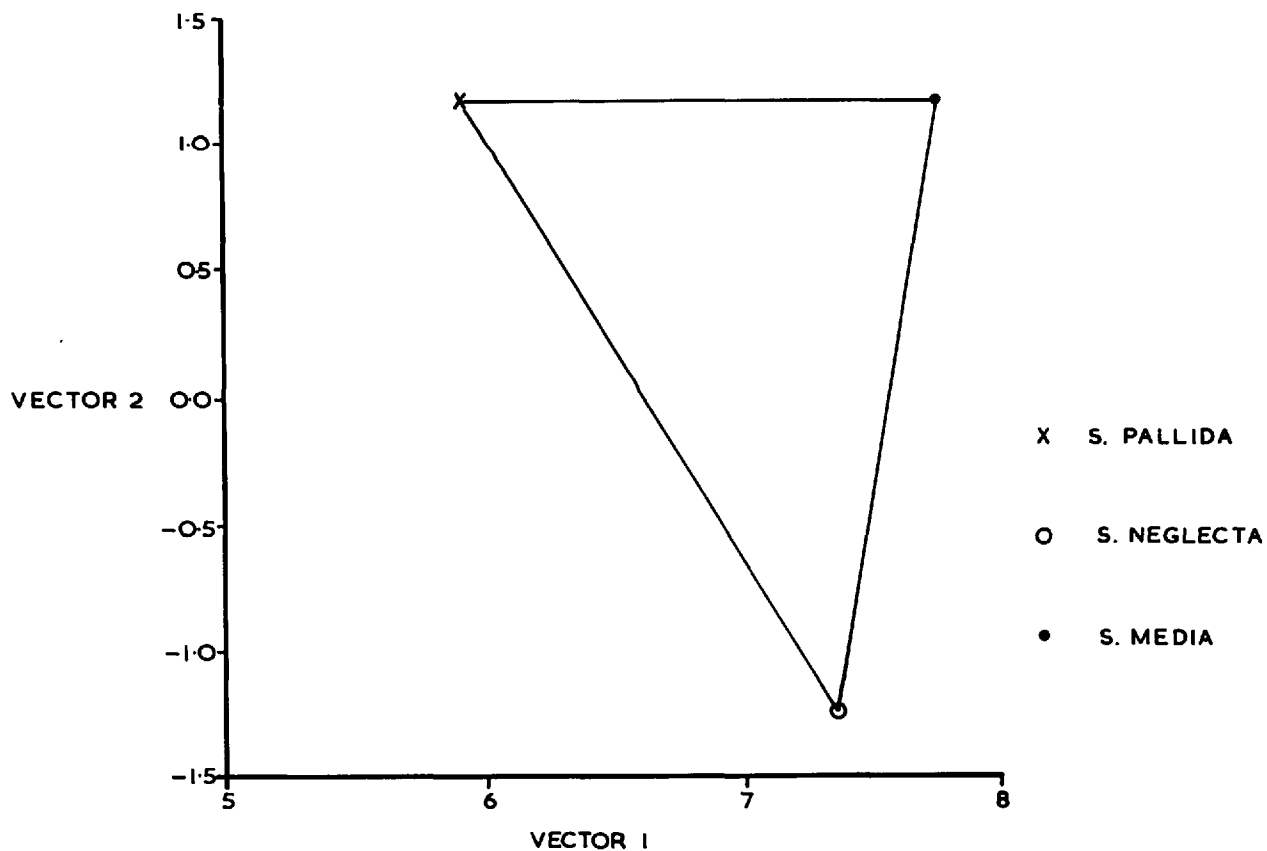


Fig.27. Plots for computed values of canonical variates 1 and 2 for the means of taxa against eleven variables(A - I, L & M). Vector 1 is the first canonical variate which gives maximum weight to seed length and pollen grain diameter(variables A & L). Vector 2 is the second canonical variate which gives maximum weight to length of tubercle (C) as contrasted to pollen diameter (L).

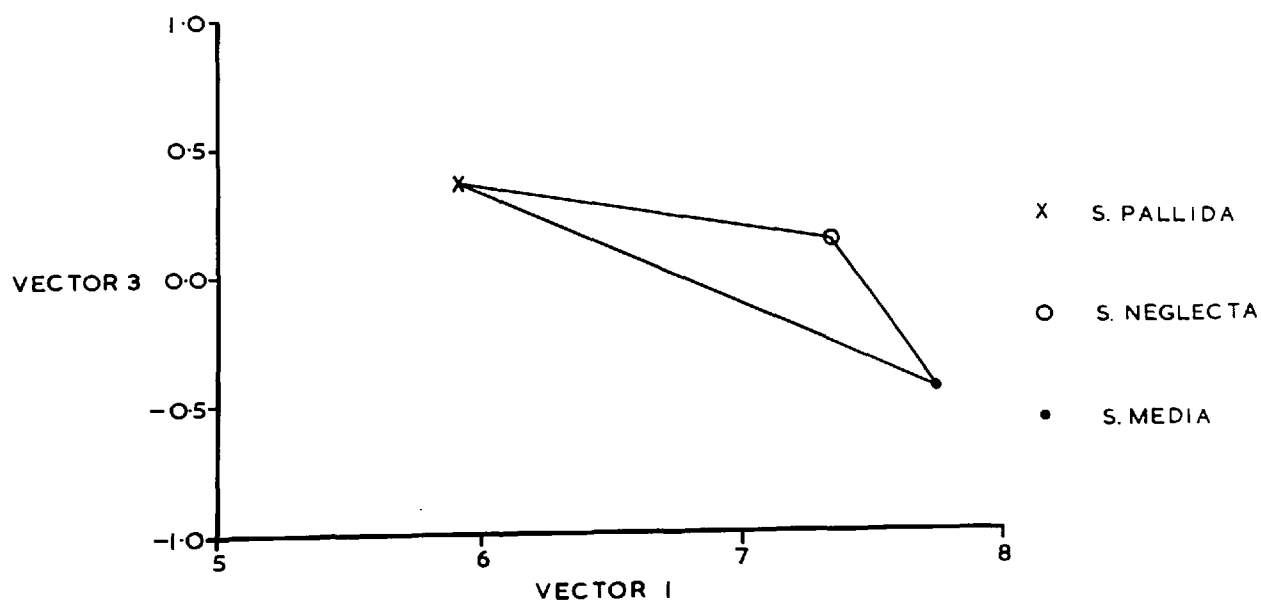


Fig.28. Plots for the computed values of canonical variates 1 and 3 for the means of taxa against eleven variables(A - I, LAM).
 Vector 1 is the first canonical variate which gives maximum weight to seed length and pollen grain diameter.
 Vector 3 is the third canonical variate which gives maximum weight to contrast between length of seed (A) and breadth of sepal(F).

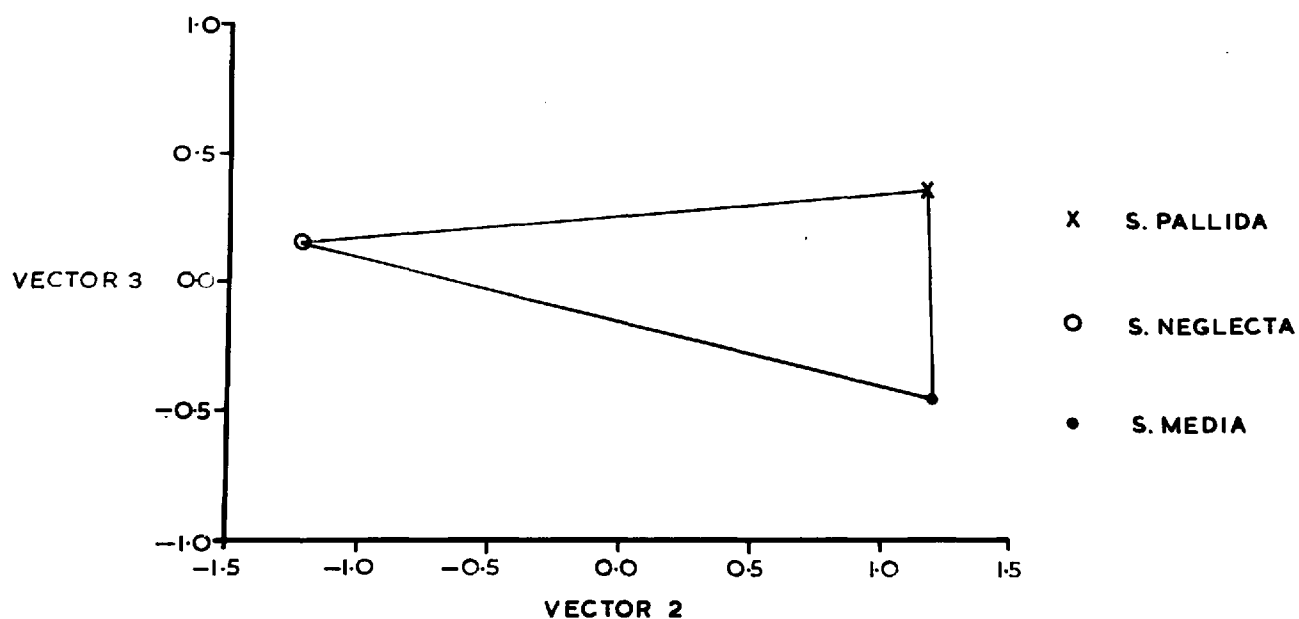


Fig. 29. Plots for the computed values of canonical variates 2&3 for the means of three taxa against eleven variables (A - I , LMI).

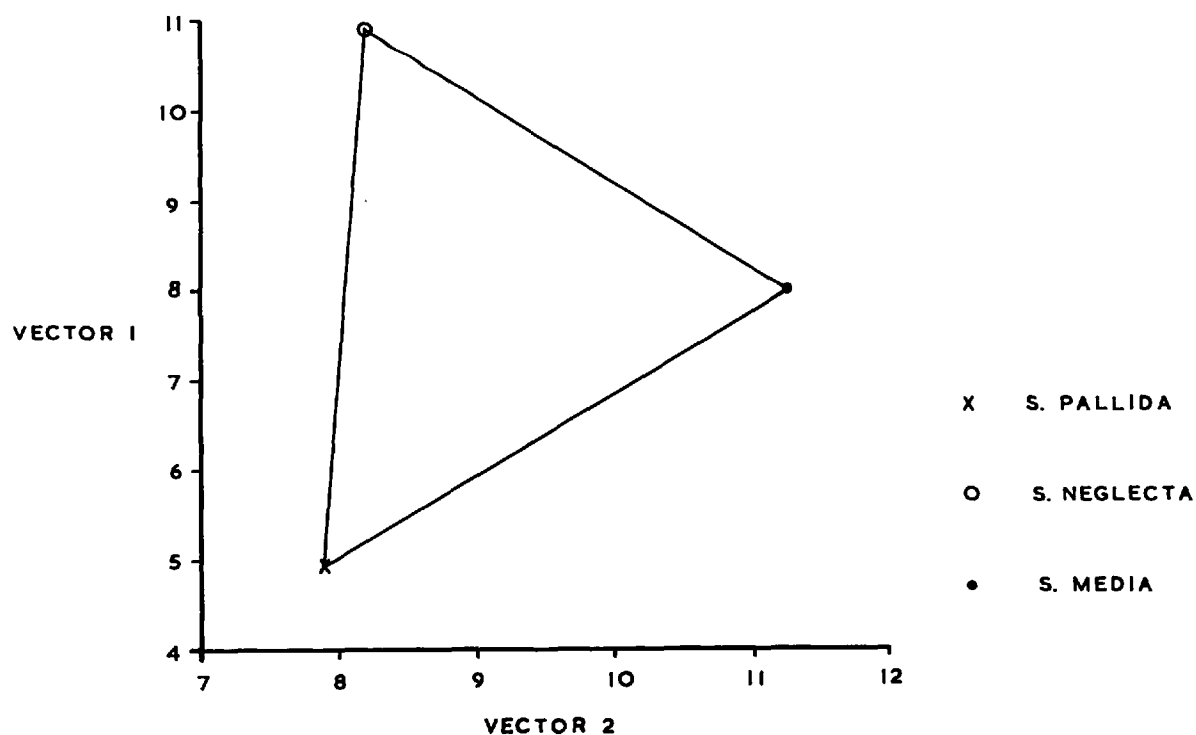


Fig.30. Plots of computed values of canonical variates 1 and 2 for the means of three taxa against twelve variables (additional variable being seed weight).
 Vector 1 is the first variate which is entirely a measure of seed weight.
 Vector 2 is the second variate which is a measure of pollen grain diameter but with some contrast with the seed weight.

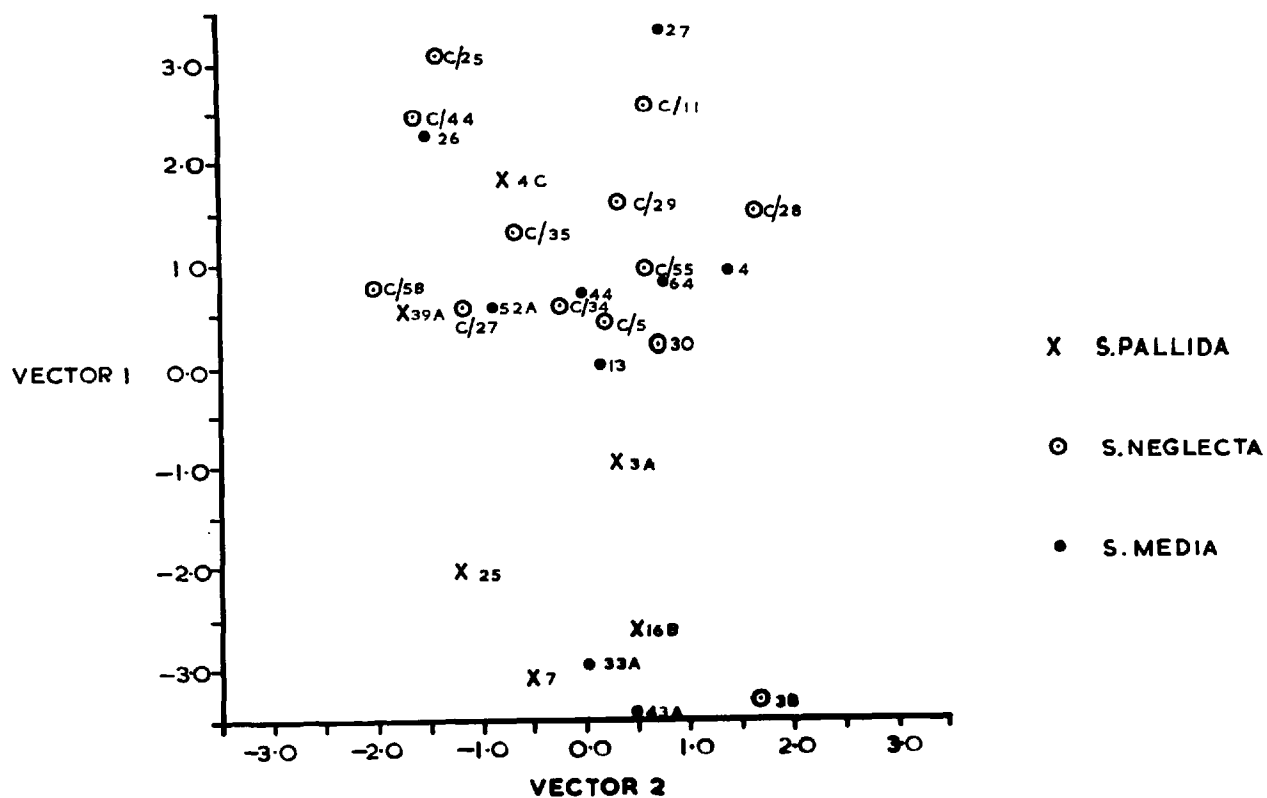


Fig. 31. Plots of computed values of some of the doubtful individuals with respect to variates 1 and 2.

PLOTED VALUES OF COMPONENTS 1 AND 2.

VERTICAL SCALE, 1ST COMPONENT, 1 UNIT = 0.1
 HORIZONTAL SCALE, 2ND COMPONENT, 1 UNIT = 0.1

STELLARIA NEGLECTA 0
 STELLARIA MEDIA +
 STELLARIA PALLIDA x

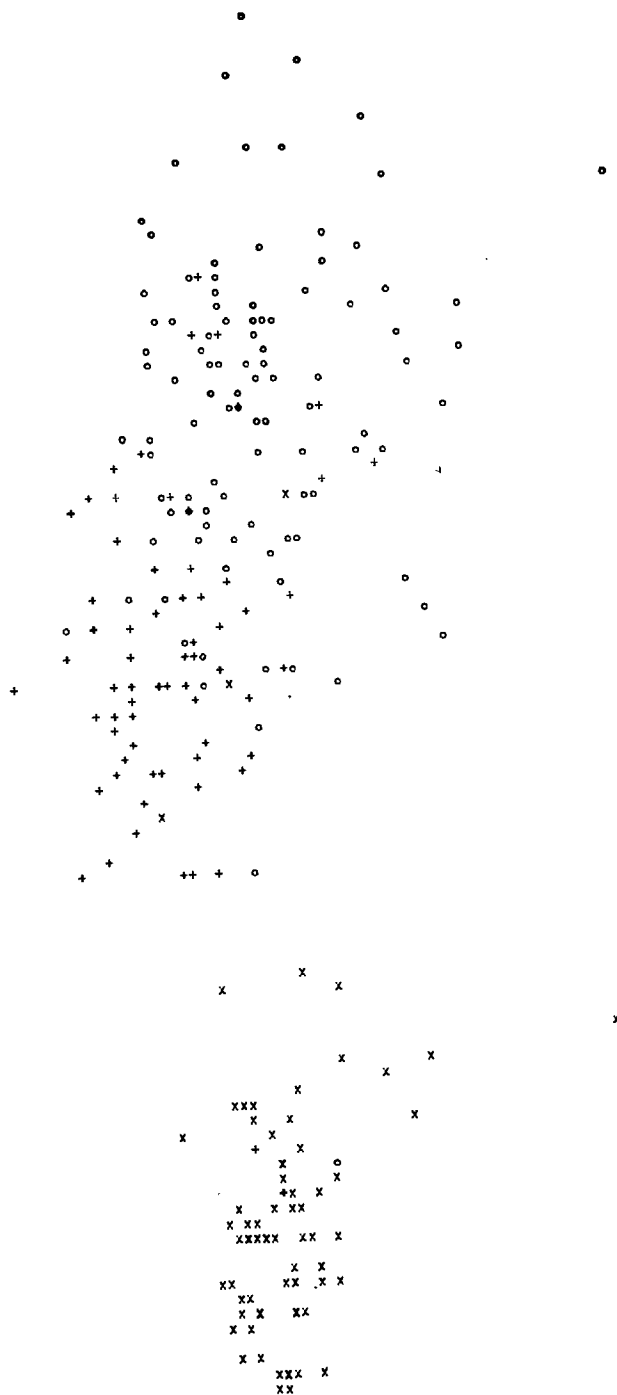


Fig. 32. Distribution of individual points for plants of *S. media* (+), *S. pallida* (x) and *S. neglecta* (0) with respect to components 1&2 against eleven variables.

PROGRAMME TO PLOT VALUES OF PRINCIPAL COMPONENTS AND CANONICAL
VARIATES

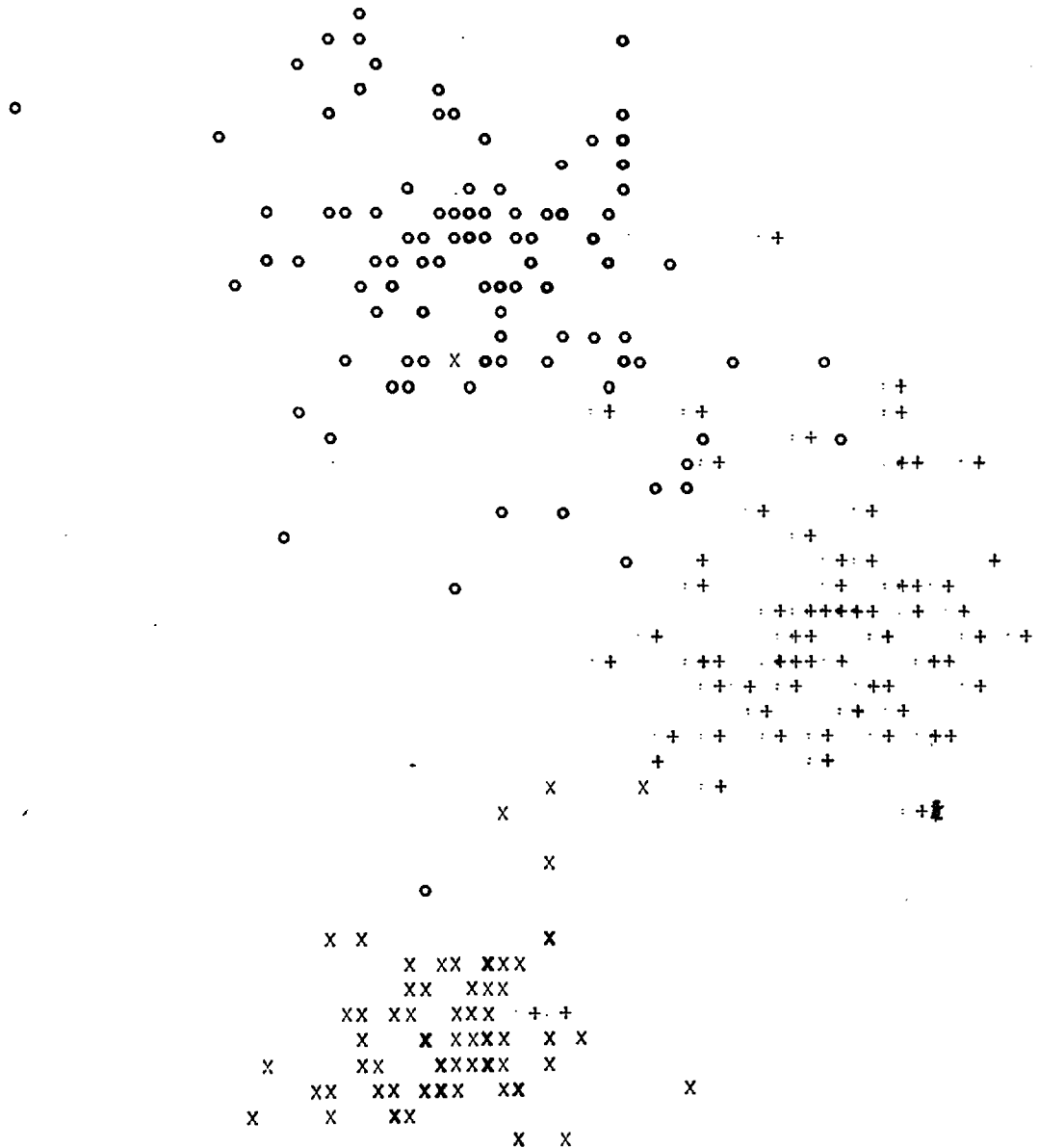


Fig.33. Distribution of points for the individual plants of *S. media*(+), *S. pallida*(X) and *S. neglecta*(O) with respect to components 132 against twelve variables.

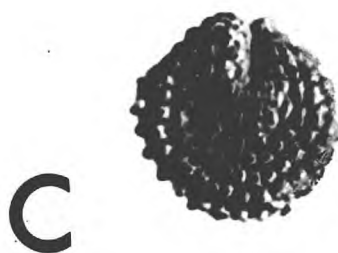


Fig.34. Size of seeds from plants under comparative culture
(A)Stellaria neglecta Weihe (B)S. media (L.)Vill.
(C)S. pallida(Dumort.)Piré

The additional character seed weight: In the initial stages of taximetric investigation, importance of this variable was not realised until the summer of 1964 when the plants were grown in the green house for raising some seeds. Live plants of S.pallida and S.nelecta were collected at the initial stage of flowering and grown in the greenhouse with the plants of S.media. The soil used for the purpose was loam with requisite amount of John Innes fertiliser. Seeds raised from this plants were weighed for the purpose of comparison and it was found that they differed markedly in this respect. Twenty samples of 100 seeds each were taken for this comparison and the results are follows:

Species.	Mean seed weight per 100 seeds.	$\pm \frac{ts}{\sqrt{n}}$
<u>Stellaria media</u> (L.) Vill.	36.26 mgs.	1.15
<u>Stellaria neglecta</u> Weihe	77.21 "	1.93
<u>Stellaria pallida</u> (Dumort) Fire	13.13	0.61

From this it is seen that under standard conditions of culture S.neglecta has the highest wt. of seeds, next in order is S.media and S.pallida has the lowest seed wt. This was therefore introduced as an additional character. The photographs of typical seeds from the sample are given on page 201. Confusion with regard to this character as well others pertaining to seed arises when plants growing in different parts of tolerance are examined in relation to other characters.

As has been shown in Fig. 27 and also in table 26, the distinctness of the species works out quite well in terms of eleven variables used. However, when the question of assignment of unknown plants to their respective taxa is faced, difficulty is experienced.

of unnamed plants to their respective taxa is faced, difficulty is experienced in critical cases with respect to S.media and S.neglecta. This can be seen from Fig.27 on page 197 where the relative position of species is shown with regard to vectors 1 and 3 in the two dimensional space. The points for S.media and S.neglecta show some intermingling. Morphometrical features as well as general facies of S.neglecta draw it nearer to S.media than to S.pallida.

Computation of the data therefore was done with the additional variable seed weight and it was found that separation of species both in terms of canonical variates and principal components is better than with eleven variables. This can be seen in Fig.30 on page 197 and Fig. 33 on page 200. Therefore, seed weight of all the morphological characters used appears to be the most important feature. It may be noted this connection that where genotypes with some commonness in gene-pool are involved, differences in the morphological attributes may be concealed to take place of differences in physiological behaviour and morphogenetic patterns.

In case of plants with such genotypes, gross morphology, may always present some difficulty unless discontinuities are worked out in terms of physiological behaviour. The low and high seed weight of S.neglecta and S.pallida appears to have been combined in S.media with release of enhanced vigour, wider tolerance and balanced morphogenesis. Any misidentification of S.pallida for S.neglecta or S.neglecta is readily sorted out by computer results (see Fig 31 to 33 pp 198 - 200) but difficulty is faced with respect to the other two species.

This type of situation where two different genotypes show such converging morphological attributes can be better explainable in terms genetic lines of speciation , specially hybridisation followed by polyploidy. As Löve (1961) has pointed 30% of the origin of angiosperms has been through this process. As Baker(1964) has pointed this phenomenon is more accentuated in the ^{forms} μ where efficient biology is needed for high potentiality of competition , wide phenological adaptation and shorter life-cycle.

Workability of the some of the variables selected for the present investigation has been shown in the foregoing pages and significance of some of the results have been explained in the next chapter. It can from all aspects of study of these species be inferred that S. media with efficient biology but morphological features quite akin to the other two species has probably been derived from them by polyploidisation and and hybridisation.

In such cases computer taxonomy gives valuable informations to ^{be} μ correlated with other aspects of study.

GENERAL DISCUSSION AND CONCLUSION

Speciation as understood in the experimental field of biology deals with the study of origin, development and structure of reproductively isolated gene-pools. Experimental investigation of isolating forces operating at the specific and infra-specific level is a prerequisite to any meaningful grouping of organisms with maximum content of information retrieval. What Darwin pointed out about a century ago was the possibility of making a generally-agreed classification of organisms depending upon the process of evolution. Darwin's acceptances have since then been subjected to test of time in the light of experimental techniques. As Walters(1963)^{has}/pointed out Darwinian concepts can not be extended to imply that natural classifications must necessarily be phylogenetic. The relationship between actual course of evolution and patterns of organic variation to which it is the aim of taxonomy is to provide a map is a fascinating but complex study. Those who equate "natural" with "phylogenetic" classification merely obscure the problem. In the development of post-Darwinian taxonomy there has always been a wide gap between what is desirable and what is possible.

It has been in most cases mental gymnastics^a based only upon observed differences and similarities in the plants growing in their ecological niches and their phenological behaviour. Plants as they grow in nature are the products of interaction between genotypes and a number of interacting variables. A number of variables are involved in the environmental complex and therefore it is very difficult to say what would the reaction in a given set of combination of these factors. The problems of variation can be studied by modern methods of biometry but this does not

give a solution in itself rather it opens up avenues for ^a number of newer investigations.

Computer taxonomy is quicker and is capable of using larger number of variables. It readily works out the matrix of similarity and by various methods of character weighting points out the discriminatory ^s importance of variables. It thus helps to evaluate taxa in terms of discontinuities, of course it has the advantage of objectivity and repeatability and is free from personal error in the sense that these findings can be extended to study other groups of plants of similar taxonomic status. Morphological attributes are not randomly acquired but they represent the adaptational fitness of the plant. It is not enough to know the essential morphological attributes of the plants.. What is more important to know is how these attributes have been acquired.

Experimental taxonomy focusses attention first upon differences between plants growing in different range of their tolerance and to correlate them to ^{their} physiological and biological attributes. That is how gene ecology, comparative culture for growth analysis and relationship between genotype and phenotype have all become inseparably linked into one discipline in the modern phase of taxonomy known as experimental taxonomy. So long as the discontinuities along taxa are sharp and steep, the morphological concept of taxa at the specific and infra-specific level appears to work and to have provided a workable system but when the question of inter-play of complex isolating processes and thus intergradation ^{on} and sometimes convergence comes into play, it becomes manifest that we can not rely only on observations made on plants as they

grow in their natural habitats. Some groups of plants are more plastic than the others. The plasticity again in its response to individual ambient factors shows differential pattern.

All the genotypic changes (from chromosomal aberration and polyploidy to genic mutation) provide one of the essential ^{to} keys the process of speciation. Taxonomist is not content with providing certain keys to identification of plants and revising floras and manuals based upon certain morphological discontinuities, howsoever small and artificial that may be. What he wants to get at is the basis of these differences. Characters provide cardinal keys to all taxonomic analyses. They determine the fitness of organisms to environmental complex and its individual factors. All changes in an organism arise first at the genotypic level and tend to be heritable to an extent as its surroundings permit it to be.

It is fortunate that taxonomists have begun realising that understanding of genomic make-up and biological properties vis-a-vis ambient factors is more important than mere creation of categories or lumping them on the basis of certain individual fancies.

The present investigation: To this end the present investigations were undertaken and the results have shown how investigations based only on one aspect may sometimes lead to fallacious conclusions and may render it difficult to decide where a plant is to be put in the hierarchy of taxonomic nomenclature. The three species of Stellaria have always been confused one for the other despite their having different gene-pools.

Applicability of taxometrics to taxonomical problems has been one of the debated subjects in taxonomy. Some of the taxonomists are very critical about the promising future of this branch although they implicitly welcome some of the conclusions of numericalists. Backwelder (1964) has raised a number of points pertaining to this and he advocates for an omnispersive classification as against phyletic and phylogenetic classifications. Any classification, as he says, takes into consideration all available data and it is futile to talk of any data which can claim universal acclamation.

Numerical taxonomy in its approach at least, if not in concept is quite recent and some of the critics including Prof. Williams are doubtful whether ^{numericalists} will be assimilated in the community of taxonomists. Many of its concepts and procedures need revision and modification but its precision, subjectivity and repeatability is unquestionable. If taxonomy has to progress to suit the challenge of the age it has to devise ways and means to give precision and specificity to its concepts. Taxonomists can not afford to play with vague words like "good" and "bad" characters the implication of which is confined to the mind of an individual worker. True it is that blind application of statistical methods and principles may sometimes lead to biological conclusions which are no better than mathematical artefacts. A careful understanding of the suitability of methods suited to the problem at hand in its proper perspective gives valuable informations.

Biometrical treatment of morphometrical variables
from Stellaria species : The three species of Stellaria have always confused herbarium workers so far their identification at the specific level

is concerned. Whether a particular herbarium specimen will be assigned to one or other of the three sps./is in critical cases all a matter of opinion. As a result of this it has been found difficult to provide a key based upon one or a few morphological characters and these sps. have been usually lumped into one Stellaria media group. That the three subjective groups are really objective could have never been known without the present statistical treatments. One of the various methods of cluster analysis as devised by Sneath, and the group of numerical taxonomists at Kansas (headed by Michener, Sokal and others) could have been applied to the present problem to test the objectivity of the groups but in the case of taxa which form a knot like the ones under reference something more than this has to be known. Generalised distance between the taxa give further clue to new lines of investigation. Polythetic groups or phenons could have been formed by various methods of cluster analysis but how these phenons in the multi-dimensional space could be reduced to two dimensional space so as to release information about their relative distances is difficult to obtain.

statistic
Canonical variance in relation to the present

investigation: This has the advantage of extracting total variability from in-between and within taxa which in the present investigation was worked out to be 33321.8 based upon eleven variables and 253 individuals. This total variation was derived from the determinantal matrix of sum of squares and their products. Canonical variates were then calculated against each of the variables and each of the variates were then weighted against the variables and in this way eleven components were derived and significant test on these components (using the methods of Bartlett 1948 and Rao 1950)

suggested that only two (first and second) of the components accounted for for c. 99.5 % variability. The first component gave maximum weight to seed length and pollen diameter, variables A and L respectively. The second component gives maximum weight to length of tubercle as contrasted to pollen diameter, variables C and L respectively. The third component accounts for 0.52 % variability only but is statistically significant. This gives maximum weight to contrast between length of seed and breadth of sepal, variables A and F respectively. From this it would appear that seed length, length of tubercle, diameter of pollen and breadth of sepal are the most important characters along which discontinuities can be sought. As can be seen in Fig. 27, factors 1 and 2 when used as ordinate and abscissa give widest separation between the taxa indicating the highest discriminatory importance of seed length, pollen diameter and length of tubercle. The three taxa come out to be quite separate and it appears that they deserve specific rank as assigned to them.

Thus it can be seen that their taxonomic ranks in terms of variables selected is quite distinct. In mass observation of morphometrical characters the three species are quite distinct.

Morphometrics as an aid to check of mis-identification: There was then the problem of having a taximetric method whereby individual cases of doubtful identifications could be checked and verified. To this end in view principal component analysis of the data was undertaken where the individual points representing the specimens have been shown in a two dimensional space in Fig. 32. It can be seen that with respect to the

eleven variables used, S.pallida comes out quite separately from the other two species except for some stray cases of mis-identification. This can be seen from the distribution of points in the Fig. 32. So far the other two species S.media and S.neglecta are concerned ~~there~~ is tendency to separation but some of the individual points for the species lump together and form an intergrading zone. A numericalist without proper training in taxonomical methods might have under such circumstances been tempted to conclude that they are probably varieties of the same species sharing to a greater extent same gene-pool. In such cases of confusion comparative culture and cytological investigations would help resolve the problem. Analysis of growth and morpho-genetic patterns in terms of some of the standard parameters coupled with genome analysis and study of breeding behaviour would provide an answer. Thus numerical taxonomy should not be regarded as an end in itself. In critical cases of convergence it may and does fail to give understanding of taxa in their proper perspective.

Results with an additional variable seed weight : As pointed earlier, the significance of seed weight was realised later during comparative culture of the species and therefore it was decided to do the principal component and canonical variance analysis of the same individuals with twelve variables now, the additional variable being wt. of seeds. The distance between the taxa now is more pronounced as can be seen in Fig. 30 in which vector 1 has been plotted against 2. These two variates account for the total variability. The first accounts for 75 % variability contained by the original variables and the second for almost all of the remaining variability. The weights of the original variables suggest that the first variate is entirely a measure of seed weight while the second is a measure of pollen

diameter , but with some contrast with seed weight.As can be seen from the computed values of the two canonical variates for the means of three taxa given on page in chapter , S.media has lower values of the first variate than S.neglecta . S.pallida has lower values of first variate than either S.media or S.neglecta , but values of the second of the same order as S.neglecta .It can be seen from the values of the first variate that S.neglecta with highest seed weight has a correspondingly higher value, then comes in order S.media and last comes S.pallida (the values being 10.907, 8.037 and 4.945 respectively).

The values of the second variate would,however, suggest that contrast between seed weight and pollen diameter is highest in S.media (11.252) and this contrast in the case of S.neglecta and S.pallida almost of the same order(8.207 and 7.918 respectively).

Respective positions of individuals in the group can be seen in the Figs. 32 and 33. Fig. 32 is the plot for the individuals from the computer with respect to vectors 1 and 3 with eleven variables. The same picture emerges with various combinations of vectors 1 to 3 (1-2 & 2 - 3) and therefore plots based on vector 1 and 3 are given in Fig.32.In the cluster of points for S.pallida(Dumort.)Pire two clear cases of mis-identification of S.pallida for S.media can be seen in Fig.32. It is interesting to note that these two specimens , as will be seen subsequently , are 33A and 43A (for the measurements of variables see appendix) which on the basis of absence of petals have probably taken as S.media. Mixed with X's can also be seen an open circle(O) which is a mis-identification of S.pallida for S. neglecta .This specimen is 38 in the S.neglecta

lot of specimens. These specimens 33A and 43A from S.media and 38 from S.neglecta are sorted out to their respective positions in the species S.pallida also with respect to twelve variables. It can therefore be noted that so far separation of S.pallida from either S.media or S.neglecta is concerned, eleven as well as twelve variables give equally well results. Difficulty is experienced only with respect to S.media and S.neglecta.

It can be seen in Fig. 32 that the points for these two species have a tendency to separate but there is an intergrading zone on the graph where they merge into each other. However, almost complete distinction is possible when an additional variable seed weight is included in the computation for canonical variance and principal component analysis. This separation with respect to vectors 1 and 2 can be seen in plots from computer shown in Fig. 33. Individuals of all the three species with critical values have been plotted in Fig. 31. It can be seen that specimens 33A and 43A from S.media are clear cases of mis-identification which go with S.pallida now. and so does the specimen 38 from S.neglecta. Points for specimens 7, 25 and 3A from S.pallida have been drawn to show the positions of typical S.pallida specimens.

The specimen 4C from S.pallida goes to S.neglecta which in the herbarium is a case of again mis-identification. The anomalous position of this specimen can be seen in Fig. 33 also. The position of specimen 39A from S.pallida appears to be doubtful. The values for variables A and B suggest it to be with S.media or S.neglecta but variable A₁ suggests its inclusion with S.pallida. It has therefore been included in S.pallida.

So far the specimens for S. neglecta are concerned, specimen C/5, C/27, C/28, C/29, 30, C/34, C/35, C/55 and C/58 appear to be critical with respect to values of vectors. 1 and 2 against twelve variables. From their position on Fig. 31 it can be seen that they are assignable to S. media. Computer values as well as values of Δ_1 (variable seed weight) would suggest this conclusion.

Specimens 26 and 27 (see page 4 in the appendix) appear to belong to S. neglecta. Their position can be seen on the Fig. 31. It can be seen now that seed weight in combination with length of seed, pollen diameter, length of tubercle and breadth of sepal are the characteristics along which discontinuities can be sought in these species.

Cytological investigations: Despite critical morphology, the species are quite distinct cytologically. Chromosome complements have been shown in Figs. 4 - 6 (pp. 74 - 76) and Figs. 7 - 11 (pp. 81 - 85) from which it would appear that $2n = 44$ for S. media and $2n = 22$ for Stellaria pallida and S. neglecta. In respect of number S. media stands out quite distinct from the other two species. Size of somatic chromosomes did not permit karyotypic studies but the pairing behaviour of chromosomes at different ^{prophase} stages was investigated and the results have been discussed in Chapter IV. From the number and sizes of the chromosomes it ^{was} concluded that S. media may be an allotetraploid with S. pallida and S. neglecta as putative ancestors and this is supported by the dimorphic nature of the bivalents in S. media. Peterson's claim to have produced an autotetraploid of S. neglecta for the Swedish forms was not found to be true, at least so far as British material is concerned. Such a wide range of tolerance, ubiquity, aggressiveness without

being seriously restricted in its distribution can not possible without one or more acts of hybridisation as pointed out by Baker(1964). Such an increase in vigour can be released as a result of heterosis. Cytological attributes in relation to adaptational capability has been described in Sinha and Whitehead (1965) in New Phytol. 64, 2 (under publication).

Growth behaviour of the species: In respect of growth and morphogenesis also from rich to depauperate nutritional conditions, S. media appears to be most efficient. The behaviour of the species has been studied in comparative way in respect of some of the parameters of growth, namely progress curves of dry wts., α , E and leaf area ratio and it has been found that under varying conditions of light and concentrations of N and P, S. media is more efficient and this accounts for its success as a weed and ruderal under all sorts of edaphic and climatic conditions. These results have been discussed in the appropriate chapters of this thesis.

Thus from morphometrical features, cytological behaviour and growth and morphogenetic patterns it was concluded that despite morphological similarity of herbarium specimens, the three forms under reference are quite distinct entities biologically. This type of relationship is due to partial commonness in gene-pools. Further work in these species with respect to their breeding and cytogenetic behaviour is desirable to extend the concept of these species.

These species were also investigated in terms of their capacity to exploit N, P and K and the results have been discussed in findings in the appropriate chapters. In this respect also S. media appears more efficient than the other two species.

REFERENCES

- ANDERSON, E. (1940).
The concept of the genus. II. A survey of modern opinion. Bull. Torrey Bot. Club., 67, 363-369.
- IDEM (1949)
Introgressive hybridisation, New York.
- IDEM (1953).
Introgressive hybridisation. Biol. Rev., 28, 280-307.
- ARNEY, S. E. (1952).
Some effects of nitrogen nutrition on the morphology and anatomy of marrow-stem kale. Ann. appl. Biol., 39, 266-276.
- ARNON, D. I. & HOAGLAND, D. R. (1940).
Crop production in artificial culture solutions in soils with special reference to factors influencing yields and absorption of inorganic nutrients. Soil Sci., 50, 463.
- ARNON, D. I. & JOHNSON, C. M. (1942).
Influence of hydrogen ion concentration on the growth of higher plants under controlled conditions. Plant Physiol., 17, 525-537.
- ASPINALL, D. & PALEG, L. G. (1964).
Effects of daylength and light intensity on growth of Barley. III. Vegetative development. Aust. J. Biol. Sci., 17, 807-822.
- BAIG, N. A. (1965).
Cytotaxonomy of Cerastium species. Ph.D. Thesis, Univ. of London.
- BAKER, H. G. (1953b).
Race-formation and reproductive methods in flowering plants. Symp. Soc. Exp. Biol., 7, 114-143.
- IDEM (1959a).
Reproductive methods as factors in speciation in flowering plants. Cold Spring Harb. Symp. Quant. Biol., 24, 177-191.
- IDEM (1961).
Rapid speciation in relation to changes in the breeding system of plants. Recent Advances in Botany. 881-885, Toronto Univ. Press.
- IDEM (1964).
Hybridisation in the evolution of weeds.
Xth Int. Bot. Congr., Pt. I, Abstr. 305, p. 134.

- BEAUDRY, J.R. (1960).
The species concept: its evolution and present history.
Rev. Canad. Biol. 19, 219-240.
- BEERS, R.J. & LOCKHART, W. (1962).
Experimental methods in computer taxonomy.
J. gen. Microbiol. 28, 633.
- BEERS, R.J. et al. (1962)
A comparison of methods for computer taxonomy.
J. gen. Microbiol. 28, 641 et seq.
- BELL, C.R. (1964).
Incidence of polyploidy correlated with ecological gradients. Evolution, 18, 510-511.
- BENNETT, ERNA (1964).
Historical perspective in Genecology.
Record Scott. Pl. Br. Sta., pp. 49-115.
- BLACKBURN, K.B. & MORTON, J.K. (1957).
The incidence of polyploidy in the Caryophyllaceae of Britain and Portugal. New Phytol., 56, 344-351.
- BLACKITH, R.E., DAVIES, R.G. & MOY, E.A. (1963).
A biometric analysis of development in Dasydercus faciatus Sign.
Growth, 27, 317.
- BLACKMAN, V.H. (1919).
The compound interest law and plant growth. Ann. Bot., 33, 353-360.
- BLAIR, W.F. (1943).
Criteria for species and their subdivisions from the point of view of genetics. Ann. New York Acad. Sci., 44, 179-188.
- BLUFF, MATH. JOS. & FINGERHUTH, CAROL. ANT. (1825).
Compendium Flora Germania, I, 560.
- BRADSHAW, A.D. ; LODGE, R.W. & CHADTICK, G. J. (1958).
Experimental investigation into the the mineral nutrition of several grass species. I. Calcium level.
J. Ecol., 46, 749.
- BRADSHAW, A.D. (1962).
The taxonomic problem of local geographic variation in plant species. Publ. Syst. Assoc. 4, 7-16.
- IDEM (1964).
Inter-relationship of genotype and phenotype in a varying environment. Record Scott. Pl. Breed. Sta.

- BREMEKAMP, C.E. (1939).
Phylogenetic interpretations and genetic concepts in taxonomy.
Chron. Bot., 5, 398-403.
- BRIGGS, G.E., KID, F. & WEST, C. (1920).
A quantitative analysis of plant growth. Pts. I & II.
Ann. appl. Biol., 7, 103 & 202.
- BUTLER, R.D. (1963).
Effect of light intensity on stem and leaf growth in Broad Bean seedlings. J. exp. Bot., 14, 142-152.
- CAIN, A.J. (1958).
Logic and memory in Linnaeus' system of taxonomy.
Proc. Linn. Soc. Lond. 169, 144-163.
- IDEM (1959a).
Deductive and inductive methods in post-Linnaean taxonomy.
Ibid., 170, 185-217.
- CAIN, A.J. & HARRISON, G.A. (1958).
An analysis of taxonomists judgement of affinity.
Proc. Zool. Soc. London, 131, 85-98.
- CALLAHAN, R.Z. (1959).
Experimental Taxonomy — more than seed source studies.
Rec. Adv. Bot. II. 1695-1696.
- CAMP, W.H. (1951).
Biosystematy. Brittonia, 7, 113-127.
- & GILLY, C.L. (1943).
The structure and origin of species. Brittonia, 4, 323-385.
- CHETVERIKOV, S.S. (1961).
On certain aspects of the evolutionary process from the standpoint of modern genetics.
Proc. Amer. Phil. Soc., 105, 167-195.
- CLAUSEN, J. & HIESEY, W.M. (1958a).
Experimental studies on the nature of species. IV.
Genetic structure of ecological races. Publ. Carnegie Inst. Washington, 615, 1-312.
- & HIESEY, W.M. (1958b).
Phenotypic expression of genotypes in contrasting environments.
Report Scott. Pl. Breed. Sta. pp. 41-51.
- CLAUSEN, J., KECK, D.D. & HIESEY, W.M. (1945).
Experimental studies on the nature of species. II.
Plant evolution through amphidiploidy and autopolloidy with examples from the Madiineae. Publ. Carnegie Inst. Washington. 564, 1-174.
- CLAUSEN, R.T. (1941).
On the use of terms sub-species and variety,
Rhodora, 43, 157-167.
- COLE, L.C. (1949).
Measurement of interspecific association.
Ecology, 30, 411-424.
- IDEM (1957). The measurement of partial interspecific association,
Ibid., 38, 226-233.

- CONSTANCE, L. (1957).
Plant taxonomy in an age of experiment.
Amer. J. Bot., 44, 88-92.
- COOPER, J. P. (1963).
Species and population differences in climatic response.
The Environmental Control of Plant Growth.
New York, pp. 381-403.
- IDEM (1964).
Climatic variation in forage grasses. I. Leaf development in climatic races of Lolium and Dactylis. J. appl. Ecol., 1, 45-61.
- CHATER, A. O. & HEYWOOD, V. H. (1964).
In Flora Europaea ed. TUTIN, T. G. et al., 1, 134-135.
- CLAPHAM, A. R. ; TUTIN, T. G. & WARBURG, E. F. (1962).
Flora of the British Isles, C.U.P.
- CROCKER, W. (LATE) & BARTON, L. V. (1957).
Physiology of Seeds. Publ. Chronica Bot. Comp. Mass., U.S.A.
- CYRILLO, DOMINICI (1784).
Characteribus Commentarius, p. 36.
- DANDY, J. E. (1958).
List of British Vascular Plants, 133. Publ. B.S.B.I.
- DALY, H. V. (1961).
Phenotypic classification and typology. Systematic Zool., 10, 176 - 179.
- DANSER, B. H. (1929).
Über die Begriffe Komparium, Kommiscuum und Konvivium und über die Entstehungsweise der Konvivien. Genetica, 11, 339-450.
- IDEM (1950).
A theory of systematics. Bibl. Biotheor., 4, 113-180.
- DAVEY, V. McM. & LANG, J. M. S. (1939).
Experimental taxonomy. III. Correlation of characters within populations. New Phytol., 38, 32-61.
- DAVIS, P. H. & HEYWOOD, V. H. (1963).
Principles of Angiosperm Taxonomy, Oliver & Boyd, Edin. & Lond.
- DAUBENMIRE, R. F. (1959).
Plants and Environment - A textbook of autecology, Wiley, N.Y.
- DAWSON, M. D. & HENREICHS, D. H. (1952).
The effects of various germination techniques to overcome dormancy in green stipa grass seed. Sc. Agric., 32, 266-271.

- DU RIETZ , G.E.(1930).
The fundamental units of biological taxonomy.Svensk.Bot.Tidskr.,
24,338-428.
- EHRENDORFER,F.(1964).
Differenzierungs - Hybridisierungszyklen bei Sampepflanzen.
Xth Int. Bot. Congr. Abstr. 300 , pt. I ,p.132.
- EWING ,C.(1943).
Taxonomy and genonomy. Science , 98 , 515-516.
- EVANS , G.C. & HUGHES , A. P.(1961). artificial.
Plant growth and aerial environment. I.Effect of shading on
IMPATIENS PARVIFLORA .New Phytol.,60 , 150-180.
- IDEM(1962). aerial
Plant growth and / environment.III.On computation of unit
leaf rate.Ibid. , 61 .322 sqq.
- EVANS , L.T. ed. (1963).
Environmental Control of Plant Growth. publ.Acad. Press,N.Y.&Lond.
- FEIN,L. (1961).
The computer-related sciences (synnoetics) at a university in
the year 1975 .Amer. Scientist ,49 ,149-168.
- FISHER, R.A.(1936).
The use of multiple measurements in taxonomic problems.
Ann. Eugen. , 7 , 177- 188.
- FORSBERG, F.R.(1942).
Sub-species and variety. Rhodora ,44 , 153 - 157.
- FRIEND,D.J.C. ; HELSEN ,V.A. & FISHER , J. E. (1962a).
The rate of dry weight accumulation in Marquis wheat , as
affected by temperature and light intensity.
Canad. J. Bot. , 40 , 939 - 955
- IDEM (1962b).
Leaf growth in Marquis wheat regulated by temperature,
light intensity and day length. Ibid.,40 , 1299 - 1316.
- GILMOUR,J. S. L.(1951).
The development of taxonomic theory since 1851.Nature,168 ,400-404
- IDEM(1958).
The species : yesterday and tomorrow. Ibid.,181 ,379-380.

- GILMOUR, J. S. L. & HESLOP-HARRISON, J. (1955).
The -deme terminology and units of micro-evolutionary change. Genetica , 27 , 147-161.
- & WALTERS, S.M. (1964).
Philosophy and classification.
In Vistas of Botany IV. ed. TURRILL, W.B. , 1-22, Pergamon, London.
- GRANT, V. (1957).
The plant species in theory and practice.
publ. Amer. Assoc. Adv. Sci. , 50 , 39-80.
- GREGOR, J. W. (1956).
Adaptation and ecotypic components.
Proc. Roy. Soc. B. 145 , 333 - 337.
- IDEM (1956).
Genecological(biosystematic) classification : the case for special categories. Regn. Veget. , 27 , 24 - 26.
- HARLAND, S. G. (1936).
The genetical conception of species. Biol. Rev. , 11 , 83-112.
- HARRIS, T.M. (1964).
Inflation in taxonomy. Proc. Linn. Soc. London , 175, 1 - 7.
- HASKELL, G. (1949).
Variation in the number of stamens in the common chickweed.
J. Genetics , 49 , 291-301.
- HEATH, O.V. J. & GREGORY, F.G. (1938).
The constancy of mean assimilation rate and its significance.
Ann. Bot. N.S. , 2 , 811 sqq.
- HENEEN, W.K. and RUNEMARK, H. (1962).
Chromosome polymorphism and morphological diversity in Elymus rechingeri . Hereditas , 48, 545-564.
- HEISER, C.B. (1964).
Natural hybridisation , biosystematics and numerical Taxonomy. Xth Int. Bot. Congr. Abstr. 299, pt. I. p.132.
- HESLOP-HARRISON, J. (1952).
Statistical methods in plant taxonomy. Taxon , 1. 53 - 59.
- IDEM (1955).
The conflict of categories . In Species Studies in the British flora . ed LOUSELEY, J.E. , 160-172. , B.S.B.I., London.
- IDEM (1959).
Variability and environment. Evolution , 13, 145-147.

- IDEM(1960).
New concepts in Flowering - Plant Taxonomy.Heinemann Ltd., Lond.
- IDEM(1962a).
Purposes and procedures in taxonomic treatment of organisms.
XIIth Symp.Soc.gen.Microbiol. , 12 , 14-36.C.U.P.
- IDEM(1964).
Plant taxonomy seen as a science. Nature, 203 ,332-333.
- HEWITT, E.J.(1952).
Sand and Water Culture Methods used in the study of Plant Nutrition . Commonwealth Agric.Bur. ,Reading,England.
- HEYWOOD, V.H.(1963).
Biosystematics and classification. Rec. Scott. Pl. Br. Sta.
- HUGHES ,A.P. & EVANS ,G.C.(1962).
Plant growth and aerial environment II. Effect of light intensity on Impatiens parviflora. New Phytol., 61 ,150 sqq.
- IDEM(1963).
Plant growth and aerial environment. IV.Effects of day length on Impatiens parviflora , New Phytol. ,62 , 367-388.
- JAHN, (L.(1962).
The use of computers in systematics .J.Parasitol., 48, 656-663.
- JEFFERS, J.N.R. & GARDINER , A.S.(1962).
Analysis of the Collective Species Betula alba L. on the Basis of Leaf Measurements. Silvae Genetica, 11 ,156-161.
- JEFFERS, J.N.R. & BLACK ,T.M.(1963).
An Analysis of Variability in Pinus contorta.
Forestry, 36 , 199-218.
- (1964).
Principal Component Analysis in Taxonomic Research.
Xth Int. Bot. Congr. Abstr. 292,p.129.
- IDEM(1965).
Canonical variate analysis applied to three problems of plant and insect taxonomy. (under publication)
- IDEM (1965).
Principal component analysis of designed experiment.
(unpublished).
- JOHNSTON, E.S. and HOAGLAND ,D.R. (1929).
Minimum potassium level required by tomato plants grown in water culture. Soil.Sci. 13, 297 et seq.

- JORDON , ALEXI & FOURREAU , JULIO (1868).
Breviarum Plantarum Novarum , II. , 19-20.
- LAM, H.J. (1959).
 Taxonomy : general principles. In Vistas in Botany . I.
 (ed. TURRILL, W.B.) , 3 - 75 , Pergamon, London.
- LEWIS, H. (1964).
 The evolutionary potential of interspecific hybridisation
 as a function of chromosome arrangement.
Xth Int. Bot. Congr. Abstr. 303 , p.134.
- LINNAEUS (1737).
Flora Lapponica , p.137.
- IDEM (1753).
Species Plantarum I.P. 272.
- LÖVE , A. (1951).
 Taxonomical evaluation of polyploids. Caryologia, 3 , 263-284.
- LÖVE, A. & LÖVE, D. (1956b).
 Cytotaxonomical conspectus of the Icelandic flora.
Acta. Hort. gothoburg , 20 , 65-290.
- IDEM (1957).
 Arctic Polyploidy. Proc. Gen. Soc. Canada , 2 , 23 - 27.
- IDEM (1958).
 An unusual Polyploid Series in Triglochin maritimum Agg.
Ibid. 3 . 3 . 2, 19 - 21.
- IDEM (1961).
 Chromosome numbers of Central and Northwest European
 Plant Species. , Opera Botanica , 5 , 141.
- IDEM (1964).
 The biological species concept and its evolutionary
 structure. Taxon , 13, 33-45.
- LÖVE , A. (1964).
 Personal communication.
- LÖVKVIST , B. (1963).
 In H. WEIMARCK'S Skånes flora . Lund . p. 268.
- LUBISHEV, A.A. (1959).
 Use of mathematical statistics in general taxonomy
 and evolution. Vest. Leningrad Stat. Univ., 9 , 128 - 136.

- IDEM(1963).
On some contradictions in general taxonomy and evolution.
Evolution, 17, 414 - 430.
- LEJEUNE , A. L. S. & COURTOIS , R.(1828).
Compendium Flora Belgicae ,II. , 90.
- McNEIL , J. & HEYWOOD , V.H.(Ed.) . (1964).
Phenetic and Phylogenetic classification . publ. Syst. Assoc.
- McWILLIAM , J. R. & COOPER , J.P.(1963).
Genotype environment interactions - Phalaris .
Ann.Rep. C.S.I.R.O. Div. Pl. Ind. ,19..
- MASON,H.L.(1950).Taxonomy,systematics and biosystematics.
Madrono , 10 , 193 - 208.
- MAYR , E.(1957).
Difficulties and importance of the biological species.
In "The Species Problem" ed. MAYR,E. , publ.Amer.Assoc. Adv.Sci.
Washington.
- MICHENER , C.D. & SOKAL , R.R.(1957).
A quantitative approach to a problem in classification.
Evolution , 11 , 130- 162.
- MOHR , H. (1962).
Primary effects of light on growth. .
Annu. Rev. Pl. Physiol. , 13 , 465 - 488.
- MULLIGAN , G.A.(1961).
Chromosome numbers of Canadian weeds. III. J.
Canad. J. Bot. , 39 ; 1057-1066.
- MYERSCOUGH , PETER JAMES (1963).
Autecology of some plants of pioneer communities ,
D.Phil. Thesis , Bodleian Library, Univ. of Oxford.
- NEGODI , G. (1935).
Reperti cariológicos su fanerogame.
Atti Soc. Nat. Mat. Modena , 67 , 7 - 9.
- IDEM(1936e).
Contributo alla cariológia di Stellaria media (L.)Cir.
Nuovo gior. bot. ital. , N.S. , 43 , 416 - 424.
- NEWMAN , E.I.(1963).
Factors controlling the germination date of winter annuals.
J. Ecol. , 51 , 625-638.

- NEWTON , PETER(1963).
Studies on the expansion of leaf surface.II.The influence of
light intensity and daylength. J. exp. Bot. , 14 , 458-482.
- NIGHTINGALE , G.T.(1948).
Nitrogen nutrition in green plants. II. Bot. Rev. ,14,185 et seq.
- PERRING ,F.H. & WALTERS , S.M. ed. (1962).
Atlas of the British Flora . publ. Nelson & Sons Ltd. on
behalf of B.S.B.I.
- PETERSON , D.(1933).
Stellaria media L. X Stellaria neglecta Weihe ,
Bot. Notiser , 1933 , 500-504.
- IDEM (1935).
Some chromosome numbers in the genus Stellaria .Ibid.1935,409-410.
- IDEM(1936).
Stellaria --- studien .Zurzytologie ,Genetic , Okologie
und Systematic der Gattung Stellaria , insbesondere der media.
Gruppe. Ibid. , 1936 , 281 - 419.
- PIMENTEL , R.A.(1958).
Taxonomic methods , their bearing on subspeciation.
Systematic Zool. 7 ,139-156.
- PORTER , R.H.(1949).
Recent developments in seed technology. Bot. Rev.
- RAO , C.R.(1948).
The utilisation of multiple measurements in problems of
biological classification.J.Roy.Stat.Soc. ,Ser. 10,159-173.
- IDEM. (1952).
Advanced Statistical Methods in Biometric Research,John Wiley.
- ROGERS , D.J. and TANIMOTO ,T.T.(1960).
Computer programme for classifying plants. Science,132,1115-1118.
- ROGERS , D.P.(1958).
The philosophy of taxonomy. Mycologia ,50,Rapp.VIII.
Int.Bot.Congr. Paris.,Sec.4 ,67 - 74.
- ROHLF ,F.J. and SOKAL,R.R.(1962).
The description of taxonomic relationship by factor analysis.
Systematic Zool. ,11, 1 - 16.

- IDEM (1963).
Co-efficients of correlation and distance in numerical taxonomy. Univ. Kansas Sci. Bull.
- RORISON, I.H.(1956).
Some ecological aspect of calcicole-calcifuge concept.
D.Phil. Thesis , Bodleian Library, Univ. of Oxford.
- REES ,A.R. & TINKER ,P.B.H.(1963) .
Dry-matter production and nutrient content of plantation oil palms in Nigeria.I.Growth and dry-matter production.
Plant and Soil , 19 , 19-32.
- RUSSELL ,N.H.(1961).
The development of an operational approach in plant taxonomy.
Systematic Zool. 10,157-167.
- RUSSELL , E. W .(1961).
Soil conditions and Plant Growth .Ninth Ed. ,Longmans,London.
- RUSSELL,P.F. and RAO , T.R.(1940).
On habitat and association of species of Anopheline larvae in south-eastern Madras. J.Malar. Inst. India. ,3, 153-178.
- SALISBURY ,E.(1962).
Biology of garden weeds. J.Roy. Hort. Soc.,87 , 390-404.
- SILVESTRI ,L.G. et al.(1962).
A quantitative approach to the systematics of actinomycetes based on overall similarity. In AINSWORTH,G.C. and Sneath , P.H.A. (eds.) . Microbial Classification ,XIIth Symp. Soc. gen. Microbiol.,pp.333 - 360. , C.U.Press.
- SIMPSON , G. G. (1940).
Types in modern taxonomy.Am. J. Sci. , 238- , 413 - 431.
- SHEALS , J.G. (1965).
The application of computer techniques to Acarine taxonomy: A preliminary examination with species of the Hypoaspis - Androlaelaps complex (Acarina) .
Proc. Linn. Soc. Lond.,176 , 11 - 21.
- SNAYDON , R.W. & BRADSHAW , A.D. (1961).
Differential response to calcium within species of Festuca ovina L. New Phytol.,60 ,219 - 234.
- IDEM (1962).
Differences between natural populations of Trifolium repens L. in response to mineral nutrients. I. Phosphate.
J. exp. Bot. 13 , 422 - 434.

- SNEATH, P.H.A. (1957b).
The application of computer to taxonomy. J. gen. Microbiol., 17, 201 - 226.
- IDEM (1958).
Some aspects of Adansonian classification and of taxonomic theory of correlated features. Ann. Microbiol. Enzymol., 8, 261 - 268.
- IDEM (1961).
Recent developments in theoretical and quantitative taxonomy. Systematic Zool., 10, 118 - 139.
- IDEM (1962).
The construction of taxonomic groups. Microbial Classification. XIIth Symp. Soc. gen. Microbiol. pp. 289 - 332.
- SNEATH, P.H.A. & SOKAL, R.R. (1962).
Numerical taxonomy. , Nature, 193, 855 - 860.
- SOKAL, R.R. (1959).
Comments on quantitative taxonomy, Evolution, 13, 420 - 423.
- & MICHENER, C.D. (1958).
A statistical method of evaluating systematic relationship. Univ. Kansas Sci. Bull., 38, 1409 - 1438.
- SOKAL, R.R. and SNEATH, P.H.A. (1963).
Principles of Numerical Taxonomy, publ. W.H. Freeman & Co. San Francisco and London.
- SIBTHORP, JOANNE (1794).
Flora Oxoniensis, pp. 140 - 141.
- STAFFORD, H.A. & MAGALDI, A. (1954).
A developmental study of D-glyceric acid Dehydrogenase. Plant Physiol., 29, 504 - 508.
- SPRAGUE, T.A. (1940).
Taxonomic Botany with special reference to Angiosperms. In New Systematics (ed. HUXLEY, J.S.), 435 - 454.
- STEBBINS, G.L. (1950).
Variation and evolution in plants. Columbia Univ. Press.
- IDEM (1958).
Longevity, habitat and the release of genetic variability in higher plants. Cold Spring Harbour Symp. Quant. Biol., 23, 365-378.
- SUMNER, F.B. (1924).
The stability of subspecific characters under changed conditions of the environment. Am. Nat., 58, 481 - 505.

IDEM (1930).

Genetic and distributional studies of three sub-species of Peromyscus . J.Genet., 23 , 275 - 376.

SYLVESTER - BRADLEY , P.C.(1952).

Classification and co-ordination of infra-specific categories. Memorandum to Systematics Association. Taxonomic Principles Committee.

THODAY, J.M.(1953).

Components of fitness. Symp. Soc. exp. Biol. , 7 , 96 - 113.

IDEM(1959).

Effects of disruptive selection. I. Genetic flexibility. Heredity, 13, 187-203.

TURRESSON, G.(1925).

The plant species in relation to habitat and climate. Hereditas., 6 , 147 - 236.

TURRILL, W.B. (1942).

Taxonomy and phylogeny. Bot. Rev. , 8 , 247 - 270 ; 655 - 707

Idem (1946).

The ecotype concept. A consideration with appreciation and criticisms , especially of recent trends. New Phytol. 45, 34 - 43.

IDEM (1954).

Synthetic taxonomy as illustrated by studies on some species of the British Flora. Rapp. VIII. Int. Bot. Congr. Paris. , sect. 10 , 181 - 184.

VALENTINE, D.H.(1949).

The units of experimental taxonomy. Acta Biotheoretica , 9 , 75-86

----- & LOVE, A.(1958).

Taxonomic and biosystematic categories. Brittonia , 10 , 153 -166.

WALTERS, S.M.(1961).

The shaping of Angiosperm taxonomy. New Phytol. , 60 , 74-84.

IDEM (1964).

Improvement versus stability in Botanical classification. Xth Int. Bot. Congr. Edinburgh. Abstr., 274 , pp. 121 - 122.

WATSON , E.V.(1943).

The dynamic approach to plant structure and its relation to modern taxonomic Botany, Biol. Rev., 18 , 65-77.

- WARBURG, E.F. (1949).
Cytology and critical groups. In *British Flowering Plants and Modern Systematic methods.* (ed. WILMOTT, A.J.), 11-16, B.S.B.I., London.
- WHITEHEAD, F.H. (1954).
An example of taxonomic discrimination by biometric methods.
New Phytol. , 53, 496 - 510.
- & MYERSCOUGH, P.J. (1962).
Growth analysis of plants . The ratio of mean relative growth rate to mean relative rate of leaf area increase.
New Phytol. , 61 , 314-321.
- IDEM (1964).
The importance of phenotypic plasticity in competition.
Xth Int. Bot. Congr. Abstr. 589 , pp.254-255.
- WILLIAMS, R.F. (1946).
Physiology of plant growth with special reference to the concept of net assimilation rate. *Ann. Bot. N.S.* , 10 , 41 et seq.
- WILLIAMS, W.T. and LAMBERT, J.M. (1961).
Multivariate methods in taxonomy. *Taxon* , 10 , 205 - 211.
- WILMOTT, A.J. (1950b).
A new method for identification and study of critical groups.
Proc. Linn. Soc. Lond. , 162 , 83 - 98.
- WINGE, O. (1917).
The chromosomes. Their number and importance.
Compt. rend. trav. lab. Carlsberg , 13 , 131 - 275.
- WEIMARCK, HENNING (1963).
Skanes Flora , Bokforlaget Corona AB. , Lund.
- WATSON, D.J. , THORNE, GILLIAN, N. & FRENCH, S.A.W. (1963).
Analysis of growth and yield of winter and spring wheats. *Ann. Bot. N.S.* , 27 , 1 - 22.
Addendum
- MOHR, H. (1964). The control of plant growth and development by light *Biol. Rev.* , 39 , 506 - 536.
- VINCE, DAPHNE, (1964). Photomorphogenesis in plant stems. *Ibid.* 425 - 486.
- ANDERSON, MARGARET C. (1964). Light relation of terrestrial plant communities.
Ibid. , 425 - 486.

APPENDIX

GROUP 1.

Stellaria media (L.) Vill.

Explanation to symbols:

- A_1 = Weight per 10 seeds in milligrams
A = Length of seed.
B = Breadth of seed.
C = Length of tubercle.
D = Breadth of tubercle.
E = Length of sepal.
F = Breadth of sepal.
G = Tip of scarious tissue of sepal.
H = Base of scarious tissue of sepal.
I = Cleft of sepal.
J = Length of petal.
K = Cleft of petal.
L = Diameter of the pollen grain.
M = Length of capsule.

For all measurements except in pollen grains and tubercles of seeds 80 divisions = 700 μ

For pollen grains and tubercles of seeds
50 div. = 90 μ .

Spec. No.	A ₁	A	B	C	D	E	F	G	H	I	J	K	L	M
43A	1.4	73.0	82.0	24.0	49.4	287.4	156.2	57.6	91.8	21.8	-	-	15.0	355.2
8	3.5	82.0	87.0	22.0	49.0	504.2	232.2	73.0	104.8	44.0	356.2	283.0	18.2	580.2
57	2.4	87.4	84.2	18.0	43.2	469.6	224.2	60.0	86.0	23.6	315.8	219.8	19.2	548.01
59	3.5	90.0	95.0	22.0	54.5	500.4	208.0	67.2	100.0	24.0	424.0	327.4	17.0	620.4
37	3.0	91.0	89.0	18.0	49.0	433.0	199.8	82.4	109.0	34.2	299.2	222.6	19.4	565.0
33	3.6	93.0	98.0	25.0	61.0	424.4	237.0	88.0	127.6	37.6	342.01	263.0	18.0	545.0
12	2.8	93.4	97.0	19.0	52.0	397.4	207.6	40.4	61.6	23.2	297.4	225.0	20.0	637.0
47	3.6	93.6	94.8	19.6	49.2	535.8	198.2	92.6	111.0	28.0	449.2	352.4	17.6	637.6
15	3.0	94.0	100.0	22.0	50.0	505.2	216.0	57.2	84.0	23.8	364.4	278.4	19.4	597.4
56	3.0	96.4	91.0	21.6	52.1	459.2	212.0	56.2	83.4	26.6	322.8	207.8	16.4	561.2
32	3.4	97.0	103.0	23.0	58.0	406.4	182.6	55.8	63.6	25.0	341.4	254.8	18.4	556.0
53	2.6	98.8	97.4	20.3	51.6	487.0	208.2	82.2	111.4	26.0	367.0	273.4	19.6	550.0
33A	1.3	99.4	107.0	19.1	46.8	275.6	137.4	56.4	85.2	17.4	-	-	15.2	395.8
54	4.3	100.0	100.2	16.8	68.0	489.6	254.8	49.8	77.0	15.4	306.8	222.8	19.2	673.6
18	2.8	100.0	93.0	28.0	57.0	471.8	198.6	90.0	100.4	23.4	367.0	285.4	15.8	560.2
19	3.6	100.0	102.2	20.0	51.0	492.4	177.8	102.8	102.6	24.6	305.8	240.8	16.0	568.0
24	4.0	100.4	98.0	28.0	69.4	508.8	209.2	47.6	72.0	21.4	307.8	220.6	16.8	617.6
58	3.0	100.8	106.4	18.5	57.4	442.2	241.2	67.6	102.4	23.4	361.4	271.0	18.6	597.6
3	3.5	101.0	105.0	16.0	54.0	554.8	214.6	73.6	93.8	30.0	347.2	247.4	20.2	609.0
9	2.9	101.0	109.0	15.0	50.0	575.6	226.6	47.0	66.2	31.0	350.2	266.2	19.4	635.4
67	2.4	101.5	104.5	26.1	67.2	469.2	212.2	86.2	123.4	31.6	341.2	263.0	17.0	638.8
61	4.0	101.6	99.1	21.0	51.5	480.4	238.2	55.8	97.6	18.4	431.4	359.8	17.2	597.0
42	3.6	102.0	100.0	21.0	49.0	552.4	181.6	68.4	96.6	20.4	320.0	249.6	20.0	589.6
43B	3.6	102.0	103.0	16.2	55.6	457.2	187.6	74.8	106.6	20.2	341.6	262.0	19.2	560.4
23	3.2	102.0	106.6	26.3	71.6	527.2	205.0	82.8	101.6	28.8	346.8	259.6	19.1	600.0
45	2.8	103.4	100.2	19.8	68.7	453.2	175.6	104.0	110.0	38.4	291.2	238.4	18.8	543.0

Spec. No.	A ₁	A	B	C	D	E	F	G	H	I	J	K	L	M
39B	2.9	103.0	102.0	22.0	57.0	426.2	204.2	56.2	77.4	25.2	323.4	258.8	19.6	541.6
68	3.5	104.2	103.7	25.9	64.7	474.6	231.0	70.0	111.8	25.8	364.4	274.0	18.2	609.4
21	2.8	104.0	109.0	20.0	49.0	504.4	192.8	83.4	92.2	21.0	312.2	233.0	20.0	638.4
40	3.0	104.0	100.6	29.0	55.0	417.2	214.0	44.0	77.2	23.2	378.8	285.8	19.4	529.0
62	4.0	104.6	101.8	34.4	60.0	486.0	201.8	88.6	117.6	22.8	366.4	270.8	20.4	594.6
38	3.0	105.0	106.0	25.0	55.0	429.8	195.0	90.0	110.2	25.4	329.2	271.0	18.2	661.4
63	3.8	105.2	103.2	24.5	56.3	490.0	239.8	82.0	118.6	17.4	316.8	234.0	18.6	644.4
55	3.2	105.4	105.1	18.2	56.5	420.8	169.8	88.0	104.2	14.0	319.4	224.0	19.0	588.0
10	3.0	106.0	110.0	23.0	56.0	505.2	215.8	70.0	76.0	23.2	296.6	244.0	19.0	643.6
49	3.6	106.0	110.0	22.0	54.0	453.6	191.6	62.6	81.2	30.0	391.8	298.2	18.8	565.2
60	3.8	106.0	113.4	18.7	60.4	471.2	195.0	75.2	90.4	24.6	358.4	267.4	19.0	580.6
29	4.4	106.8	105.4	25.6	70.0	403.0	180.0	49.2	75.4	21.4	291.2	233.0	15.6	549.0
5	3.8	107.0	106.0	21.0	62.0	530.4	193.6	91.8	105.0	56.0	400.2	322.2	20.0	611.2
17	3.5	107.0	120.0	24.0	61.0	591.0	237.0	63.0	104.6	21.6	435.9	337.4	20.0	670.0
20	3.8	108.0	112.0	18.0	55.0	479.2	183.4	101.0	100.4	25.0	313.8	252.8	18.6	584.2
50	3.0	108.0	108.0	21.3	51.4	471.0	268.0	36.6	115.4	24.4	350.8	261.6	17.6	574.0
52A	6.8	108.4	111.0	20.5	64.8	497.6	280.6	47.0	74.4	21.4	304.8	223.2	18.8	596.4
65	6.0	108.5	104.5	24.75	62.0	508.8	247.2	72.8	106.4	26.4	367.9	277.0	19.0	685.6
11	6.0	109.0	114.0	24.0	60.0	398.8	198.0	62.0	91.4	37.8	301.6	209.6	19.1	614.6
64	6.4	110.3	113.6	21.3	52.0	523.2	235.8	69.4	88.4	26.8	360.4	270.8	18.8	651.4
36	5.4	111.0	114.0	25.0	60.0	460.8	227.4	73.6	104.0	32.4	308.0	219.0	18.0	563.4
39A	3.6	111.0	113.0	26.0	71.2	404.2	184.0	59.2	65.6	24.0	301.8	218.2	19.4	455.2
16	3.0	111.0	117.0	18.0	60.0	508.2	229.4	84.0	84.2	21.4	360.8	272.0	18.6	445.6
6	5.8	112.0	118.0	19.0	60.0	563.6	231.4	77.6	101.8	22.2	346.8	263.6	20.0	696.4
2	5.8	113.0	122.0	23.0	62.4	513.4	195.6	77.4	110.6	34.6	335.4	239.0	19.8	653.0
66	3.6	113.0	110.0	25.5	65.2	493.6	250.8	65.8	87.8	17.8	376.0	295.0	18.0	637.0

Spec. A ₁ No.		A	B	C	D	E	F	G	H	I	J	K	L	M
13	7.5	113.0	120.0	24.0	54.0	445.2	207.6	70.0	75.6	20.4	348.4	258.0	18.6	652.8
28	4.0	113.0	112.0	21.6	59.0	448.4	268.0	56.0	88.6	25.8	333.4	265.4	19.8	587.4
31	4.4	113.4	115.4	26.0	73.0	506.6	218.0	84.4	100.0	28.2	412.6	312.2	19.4	647.6
34	3.0	114.0	120.0	26.5	65.0	596.4	216.6	60.2	81.0	25.2	371.4	229.2	21.0	705.0
14	3.2	114.0	119.0	21.0	49.0	406.0	210.4	68.2	80.6	24.2	350.6	255.6	19.0	658.0
46	4.0	115.2	112.6	30.8	72.3	487.4	202.0	77.2	117.6	55.8	298.0	224.4	17.8	594.2
25	3.2	115.6	125.2	26.3	65.5	561.6	168.8	62.8	57.6	29.2	373.0	275.0	19.2	639.0
30	3.8	115.0	128.0	30.4	73.0	540.4	228.0	60.4	75.6	24.2	444.0	298.0	19.8	700.0
48	6.0	117.8	113.0	25.4	67.7	607.4	247.4	69.4	86.2	48.6	483.4	380.8	19.0	696.6
4	6.2	118.0	125.0	21.0	47.0	529.8	217.8	75.6	100.6	31.4	342.4	256.8	19.4	564.6
22	3.5	118.0	119.0	27.0	64.0	491.2	203.4	89.2	116.2	52.8	368.0	265.0	19.4	655.6
52B	3.0	118.4	126.0	21.3	69.5	469.6	198.2	61.4	94.6	21.8	313.8	232.6	16.4	547.5
51	3.8	120.0	121.0	20.9	54.2	408.6	187.6	78.4	101.2	38.6	293.0	223.6	17.8	543.2
7	6.0	126.0	128.0	37.4	71.0	500.2	231.0	52.8	99.6	22.6	344.0	278.6	18.8	746.6
41	3.8	122.0	122.0	20.0	65.0	428.0	181.4	82.4	105.6	29.0	317.0	235.6	19.4	569.6
26	7.6	131.8	124.8	27.74	79.8	681.2	193.6	51.2	70.6	27.8	317.6	197.0	19.4	696.0
35	3.0	132.0	145.0	41.0	74.0	595.8	232.0	62.0	80.6	35.0	434.2	294.6	20.0	707.2
27	8.4	139.0	149.0	32.1	79.8	597.0	255.0	78.0	108.6	31.6	311.6	231.8	17.2	705.6
1	5.4	133.0	139.0	25.2	65.0	522.4	221.4	87.2	114.8	39.4	350.2	240.6	20.0	672.8
44	7.6	133.4	132.6	19.4	71.2	438.4	181.0	54.4	103.2	17.6	298.4	213.6	19.2	519.0

Total number of plants examined = 72.

GROUP 2.

Stellaria pallida (Dumort.)Piré

Notations and scales of measurements the same
as in S. media (L.)Vill.

Spec. No.	1	A	B	C	D	E	F	G	H	I	J	K	L	M
1	1.2	75.6	74.2	14.3	40.1	310.2	105.4	45.2	74.4	21.2	-	-	15.4	296.0
2	1.0	70.6	67.8	15.8	40.2	330.6	116.8	44.4	66.0	23.0	-	-	15.0	303.3
3A	3.0	102.4	97.8	16.8	58.2	546.4	166.4	56.4	87.0	24.2	266.6	193.6	18.6	522.5
3B	1.6	79.0	87.0	17.2	43.4	384.4	130.4	54.6	74.0	25.2	-	-	15.0	393.6
3C	1.5	69.6	73.8	17.7	33.5	331.8	110.8	35.6	68.0	18.4	-	-	15.0	345.3
4A	1.2	64.4	68.2	16.3	38.2	391.2	127.6	44.6	61.8	20.0	-	-	15.0	422.1
4B	2.0	82.6	89.2	17.3	41.8	394.0	126.0	49.2	66.0	20.4	284.0	204.8	19.4	397.8
4C	7.6	140.0	134.0	38.9	58.7	536.6	181.2	77.8	100.6	35.4	297.2	226.6	20.2	482.6
5	0.8	74.0	71.0	16.9	48.8	414.8	131.2	43.2	65.0	24.8	-	-	15.0	394.3
6	1.2	71.6	74.0	16.1	46.5	365.0	118.0	92.2	78.0	39.8	-	-	15.0	382.3
7	1.0	78.6	77.0	22.4	35.6	385.4	123.0	69.4	91.0	29.0	-	-	15.0	384.5
8	1.3	68.6	68.6	15.2	41.2	420.0	127.0	60.6	83.8	26.0	-	-	15.6	411.5
9A	0.9	77.4	75.0	20.0	44.8	340.0	109.8	49.2	75.0	23.6	-	-	15.4	369.1
9B	1.1	77.0	72.8	16.8	36.3	321.4	118.8	50.2	75.6	25.2	-	-	15.2	354.4 ^o
10A	0.9	84.0	80.0	20.3	48.1	330.4	113.8	57.6	75.2	22.0	-	-	15.0	361.6
10B	1.0	82.0	77.8	17.7	43.2	318.0	107.8	53.2	74.8	26.0	-	-	15.0	345.0
10C	1.3	78.0	73.6	16.2	43.4	311.8	114.2	52.0	81.6	23.2	-	-	15.4	302.8
11	1.1	84.4	90.2	16.3	41.7	339.4	134.2	49.4	72.8	18.0	-	-	15.0	403.5
12A	1.0	89.4	87.6	27.1	51.4	241.8	106.4	46.2	62.6	14.8	-	-	15.0	208.8
12B	1.1	71.8	72.2	17.5	49.4	333.6	124.8	50.4	73.8	16.0	-	-	15.0	407.0
12C	1.3	89.8	88.4	27.4	46.1	291.2	102.6	50.8	69.2	22.4	-	-	15.4	265.2
12D	1.0	72.2	75.4	19.1	36.8	204.2	166.5	41.2	60.0	12.8	-	-	15.2	184.0
13	1.0	79.4	80.2	21.2	41.9	419.4	142.4	52.6	70.6	15.8	-	-	15.0	334.0
14	1.3	73.6	75.8	14.6	40.1	290.8	73.6	50.6	66.8	22.0	-	-	15.2	278.0
15A	2.9	102.8	100.0	23.1	63.7	368.4	161.0	50.4	64.4	21.8	332.4	236.6	19.2	322.4
15B	1.3	87.0	90.8	17.5	55.5	272.8	109.6	38.0	53.2	13.8	-	-	15.8	241.6
16A	0.8	79.2	83.4	17.2	47.6	362.4	144.6	64.2	78.0	22.4	-	-	15.0	350.4
16B	3.2	89.8	86.8	15.8	45.5	394.2	164.8	66.4	83.0	19.2	292.8	194.2	16.0	362.4
17	1.3	74.0	80.6	18.0	46.6	419.4	103.4	58.6	78.2	17.8	-	-	15.4	405.8

No.	Dec.	A	B	C	D	E	F	G	H	I	J	K	L	M
C/1	1.4	81.0	83.2	16.5	60.8	296.2	132.2	65.2	92.0	20.2	-	-	15.4	438.8
C/2	1.2	67.2	66.0	15.5	45.3	298.2	114.2	53.6	75.2	19.0	-	-	15.6	414.4
C/3	1.3	78.0	75.6	14.8	39.0	354.8	139.2	53.4	66.6	16.6	-	-	15.2	388.8
C/4	1.0	63.4	62.2	13.7	40.0	370.8	128.0	44.0	68.8	20.0	-	-	15.0	371.6
C/5	1.2	83.2	88.2	14.4	41.5	322.4	123.6	62.2	76.4	20.6	-	-	15.0	397.6
C/6	1.3	89.2	103.4	17.4	49.0	311.4	123.8	66.4	83.4	18.8	-	-	15.0	497.2
C/7	1.4	87.6	64.0	15.6	41.1	318.4	130.0	55.6	77.6	21.8	-	-	15.0	400.8
C/8	1.0	86.6	98.0	18.6	46.3	306.2	129.0	52.4	72.0	16.6	-	-	15.0	397.4
C/9	1.0	78.0	100.0	19.8	48.4	265.0	128.0	51.8	78.0	28.0	-	-	15.0	392.6
C/10	1.2	81.5	95.0	31.0	60.8	284.4	137.6	54.2	70.0	20.0	-	-	15.0	397.0
C/11	1.2	73.7	78.00	16.7	42.9	308.8	128.6	44.6	67.4	21.2	-	-	15.2	400.4
C/12	1.4	77.2	81.2	24.2	52.0	322.8	141.2	56.4	75.0	13.6	-	-	14.2	395.2
C/13	0.8	73.0	77.5	20.6	43.6	274.4	126.4	46.6	63.6	20.2	-	-	15.0	291.8
C/14	1.0	68.7	65.2	24.5	97.7	271.2	126.2	57.2	55.6	14.4	-	-	15.0	293.0
C/15	1.0	75.0	85.0	16.0	37.8	356.0	134.6	50.2	66.8	17.6	-	-	15.0	382.2
C/16	1.2	66.2	65.0	24.1	48.9	296.6	122.0	46.8	65.8	17.8	-	-	14.4	330.0
C/17	1.4	82.6	86.6	29.8	54.9	330.4	134.0	47.2	59.2	15.0	-	-	15.0	357.6
C/18	1.2	76.4	83.6	29.1	55.8	327.4	139.6	52.8	83.0	11.6	-	-	15.0	292.8
C/19	1.6	89.3	94.6	23.8	44.8	359.8	140.4	47.0	62.2	12.8	-	-	15.0	398.4
C/20	1.4	79.6	92.6	22.9	47.0	357.8	145.0	56.8	75.2	22.4	-	-	15.0	387.4
C/21	0.8	80.2	89.75	19.8	40.7	358.6	136.4	87.8	93.0	31.0	-	-	15.0	443.2
C/22	1.4	77.6	93.3	19.0	57.3	329.4	135.6	47.2	69.4	15.8	-	-	15.0	400.0
C/23	1.4	81.7	88.5	17.1	49.0	292.0	104.8	50.6	57.2	27.0	-	-	15.0	396.2
C/24	1.0	86.0	98.0	20.4	38.6	328.4	154.4	63.8	79.0	43.6	-	-	15.4	402.4
C/25	1.2	84.0	94.0	31.1	57.1	284.2	107.4	45.8	61.8	22.8	-	-	15.0	325.0
C/26	0.8	79.0	87.75	28.3	52.1	314.2	115.6	45.8	65.4	24.0	-	-	15.4	421.6
C/27	1.0	74.6	84.8	20.7	42.3	281.6	140.0	49.2	59.2	24.0	-	-	15.0	410.0

Spec. No.	A ₁	A	B	C	D	E	F	G	H	I	J	K	L	M
C/28	1.5	80.0	90.0	26.6	54.0	341.6	136.4	63.2	73.4	45.2	-	-	15.2	378.6
C/29	1.2	66.6	66.8	17.4	50.9	296.6	116.6	50.6	67.8	20.6	-	-	14.4	408.8
C/30	1.0	101.0	108.8	25.2	52.5	397.6	115.8	75.2	92.0	22.2	-	-	15.0	492.0
C/31	0.8	86.6	95.0	19.4	45.2	337.2	135.6	74.4	81.0	19.2	-	-	15.4	394.8
C/32	1.0	95.6	90.6	22.2	44.2	360.4	126.4	66.8	79.8	25.6	-	-	15.8	432.8
C/33	1.2	69.4	71.2	23.2	47.7	311.6	106.0	49.8	60.0	16.4	-	-	15.8	389.4
C/34	1.3	80.6	83.6	17.4	38.4	327.8	134.6	47.6	65.6	23.8	-	-	14.0	354.2
C/35	1.4	82.6	80.2	27.4	51.1	334.0	122.0	62.8	57.2	18.6	-	-	15.0	414.0
C/36a	1.5	68.0	72.0	16.0	35.0	278.4	131.4	48.8	65.4	25.4	-	-	14.2	415.0
C/36	0.9	84.0	92.0	17.4	49.4	296.6	122.2	72.8	82.2	20.2	-	-	15.4	399.2
C/37	1.0	80.0	85.0	16.0	33.8	289.8	128.4	48.8	65.6	22.4	-	-	15.6	390.6
C/38	1.2	84.0	86.4	20.5	45.8	303.2	131.6	48.2	56.8	22.0	-	-	14.4	379.6
C/39	1.4	90.5	100.0	21.9	76.2	370.4	139.0	43.8	46.0	15.0	-	-	14.2	463.6
C/39A	1.0	147.0	145.4	30.9	78.1	459.6	181.4	51.8	75.8	17.6	-	-	16.0	484.6
C/40	1.1	85.0	95.0	38.0	69.0	337.0	137.0	74.4	84.6	22.6	-	-	14.6	454.0
C/41	1.2	85.0	95.0	26.2	55.6	291.2	121.0	46.4	62.6	20.8	-	-	15.0	328.4
C/42	0.9	85.0	98.3	27.8	66.6	313.2	133.8	54.0	63.6	20.2	-	-	15.6	383.4

Total number of specimens examined = 73

GROUP 3.

Stellaria neglecta Weihe

Notations and scales of measurements the same
as in S. media (L.) Vill.

Spec. No.	<u>S. neglecta Weihe.</u>													
	A ₁	A	B	C	D	E	F	G	H	I	J	K	L	M
1	6.2	127.6	129.0	51.04	66.00	585.8	189.4	75.0	88.2	67.4	424.4	356.8	20.0	553.3
1A	8.4	171.2	175.8	56.52	64.80	640.6	218.6	93.6	87.4	47.6	456.8	352.0	20.0	607.5
2	7.8	146.0	154.0	63.00	71.46	610.6	197.6	80.4	97.8	44.0	426.0	345.0	20.4	544.6
3A	7.2	115.8	118.4	22.08	56.68	673.4	230.6	84.2	93.2	45.0	493.8	380.6	20.0	513.1
3B	1.6	171.0	75.0	21.64	39.20	383.0	130.6	87.3	75.6	26.3	-	-	15.0	389.3
5	8.0	134.6	139.4	44.56	69.12	533.0	179.0	57.2	87.2	41.6	389.0	308.4	20.0	496.3
6	7.6	113.8	116.4	50.80	53.64	619.6	209.2	88.2	109.2	36.4	459.6	375.4	20.0	599.6
7	7.8	135.2	138.2	29.88	61.56	607.2	204.6	82.0	99.4	29.0	470.2	379.6	20.4	547.2
8	7.6	128.0	121.6	45.80	64.68	640.0	219.2	94.2	101.0	39.0	456.4	357.4	20.4	593.6
9	8.0	124.0	125.8	46.82	65.24	595.0	206.4	70.0	73.8	30.2	472.2	396.8	19.0	471.6
10	9.8	136.2	130.8	42.62	63.04	650.8	217.6	74.4	95.4	36.0	515.0	411.6	20.0	583.4
11	6.4	133.2	133.2	47.24	69.96	572.0	190.0	72.0	76.6	30.2	413.2	312.8	17.6	521.2
12	6.8	137.8	133.2	42.24	64.58	570.0	212.8	57.2	98.6	30.6	320.0	228.4	20.0	473.6
13	6.3	126.2	123.4	51.40	60.64	555.2	183.8	57.0	92.4	49.0	552.4	363.0	17.0	490.6
14	6.0	128.2	132.0	29.34	58.66	604.6	194.8	82.4	100.2	34.8	314.4	248.0	17.0	531.6
15	6.8	124.4	128.2	53.80	64.92	504.2	187.6	69.4	82.8	47.6	486.4	339.2	16.6	464.4
16	7.6	126.4	130.6	47.76	60.92	597.4	205.4	81.4	95.0	36.6	451.8	373.2	19.0	521.0
17	8.0	151.6	156.4	53.80	68.56	576.2	188.2	83.0	101.0	43.2	483.0	396.25	17.0	511.4
18	6.0	140.8	142.2	62.60	75.20	633.2	226.0	87.4	91.4	49.8	578.4	462.0	15.0	583.0
19	6.0	131.6	136.0	52.80	67.84	631.2	204.8	94.6	102.2	30.2	509.2	418.6	15.0	543.2
20	6.0	148.0	152.4	53.80	70.92	590.8	221.4	61.6	76.2	34.2	501.2	412.0	20.0	506.8
21	6.4	141.2	141.2	43.08	61.08	575.6	182.2	98.6	100.0	39.0	-	-	18.0	504.2
22A	6.8	124.4	128.6	15.76	59.56	464.4	163.2	87.0	86.2	25.2	283.4	196.6	15.8	569.0
22	10.2	143.8	138.8	54.08	60.16	635.4	220.8	74.4	96.6	38.2	510.0	422.8	17.6	575.8
23	8.2	122.8	122.0	32.16	63.00	586.8	218.2	111.6	133.6	30.0	471.6	394.6	19.8	407.6
25	6.6	128.2	125.2	47.28	69.36	611.6	218.0	71.6	105.4	30.8	501.8	407.2	19.4	664.0

Spec. No.	A ₁	A	B	C	D	E	F	G	H	I	J	K	L	M
26A	8.2	152.0	161.0	71.0	82.0	607.2	200.0	84.4	88.2	70.8	574.4	480.8	16.4	542.4
26	7.8	130.0	124.4	71.5	85.7	637.6	242.0	93.6	113.6	44.8	572.4	479.2	18.4	579.4
27	9.6	127.6	136.0	69.2	33.4	557.0	220.4	52.4	82.0	49.4	543.6	436.6	15.8	472.8
28	7.5	147.4	145.8	60.9	63.1	603.0	196.0	57.6	83.4	36.4	507.0	409.6	19.2	554.6
29	5.6	124.8	121.0	55.0	65.4	553.0	213.2	74.6	92.2	34.8	493.6	409.2	19.4	468.8
30	3.8	121.8	119.0	40.5	55.4	507.2	205.6	77.0	95.0	25.0	474.9	392.4	16.2	533.6
31	8.4	125.8	131.8	42.9	52.6	603.6	218.4	62.6	77.4	30.8	543.2	444.0	19.0	624.2
32	6.8	143.0	139.6	50.2	61.8	658.8	229.8	81.0	108.8	46.4	569.0	462.6	19.6	568.0
33	9.4	134.6	130.6	47.8	58.8	555.6	214.2	62.0	72.0	56.4	410.2	329.0	19.0	587.0
34	12.4	148.4	143.4	54.3	70.6	600.4	211.4	62.0	86.2	33.4	512.4	426.6	19.0	599.2
35	8.2	130.6	126.4	49.8	54.4	504.8	198.2	60.8	83.8	32.6	552.4	357.6	16.4	446.8
36	6.4	121.6	125.6	40.4	62.4	569.8	225.4	64.8	86.8	32.2	516.2	447.2	20.0	454.2
38	7.2	106.2	111.0	16.7	53.5	455.4	165.2	62.2	85.4	30.4	327.5	241.0	18.4	369.8
C/1	7.2	153.0	172.8	36.8	49.2	590.4	207.0	65.0	85.0	18.4	526.5	426.6	20.0	639.2
C/2	6.8	155.0	159.8	38.2	55.6	604.4	234.0	75.6	97.4	26.0	549.4	438.8	21.0	654.4
C/3	6.4	157.4	155.2	60.2	70.8	578.0	209.0	86.8	78.2	24.4	464.4	370.4	20.0	751.6
C/4	5.9	118.8	119.6	24.0	61.2	507.4	217.6	49.8	75.2	32.0	439.8	352.4	17.4	600.0
C/5	6.0	115.8	111.8	25.8	63.0	558.4	214.4	66.4	83.4	27.0	430.8	342.8	16.4	624.8
C/6	5.8	126.8	134.6	60.4	68.0	560.0	210.6	66.6	85.6	21.0	480.4	381.2	19.2	590.8
C/7	8.0	127.2	132.8	51.2	65.0	517.2	218.4	73.2	93.8	22.8	491.6	391.2	15.6	535.6
C/8	6.6	120.6	126.8	33.0	86.4	536.6	237.0	77.4	98.8	28.2	350.0	276.6	22.6	536.2
C/9	6.2	136.8	149.2	44.2	58.0	613.6	243.2	91.2	107.0	32.4	499.0	408.6	19.4	668.6
C/10	6.8	152.8	154.2	66.2	75.2	579.2	233.6	67.6	82.2	24.4	549.6	466.8	18.2	622.6
C/11	5.8	142.2	151.8	52.8	63.6	529.6	224.0	70.8	85.2	26.2	531.6	445.4	19.4	627.8
C/12	6.0	139.4	145.4	59.6	71.2	610.4	226.6	67.0	82.8	29.8	502.8	412.6	20.0	634.0

Spec. No.	A ₁	A	B	C	D	E	F	G	H	I	J	K	L	M
C/13	7.8	153.6	160.8	47.2	60.8	393.6	151.4	56.8	78.6	22.4	411.8	339.0	17.4	492.6
C/14	8.3	129.0	127.6	57.6	65.2	632.6	235.2	35.0	90.8	20.6	539.0	439.0	17.2	657.8
C/15	7.8	143.2	135.2	59.0	67.6	659.6	280.8	62.2	132.2	22.2	488.4	378.8	19.0	662.2
C/16	5.8	128.2	137.0	59.4	61.2	494.8	207.2	62.4	88.0	27.2	423.6	333.2	18.2	628.4
C/17	8.4	133.8	141.4	57.8	45.0	561.6	248.0	75.8	96.2	37.4	461.2	349.8	20.4	604.8
C/18	8.4	151.0	160.2	43.0	56.4	618.2	266.2	82.2	95.0	28.4	522.0	445.8	20.6	663.0
C/19	6.8	118.0	115.2	48.2	61.4	587.2	228.0	64.0	83.8	25.6	490.0	414.0	19.8	647.2
C/20	7.2	139.0	148.0	54.0	79.0	540.0	213.0	71.8	88.0	31.0	468.8	376.0	19.4	585.2
C/21	6.8	150.2	162.4	66.6	64.6	599.6	226.2	68.8	88.2	43.2	513.6	442.4	19.4	665.2
C/22	8.4	148.2	152.2	57.0	57.0	505.4	216.8	59.4	88.2	57.6	459.2	373.6	17.4	551.6
C/23	6.9	150.8	159.2	67.2	74.0	538.2	234.4	59.2	76.8	29.8	512.2	413.2	19.2	660.0
C/24	9.7	162.4	174.8	62.2	80.0	569.0	223.6	82.4	104.2	41.4	466.6	380.0	20.2	745.0
C/25	6.0	159.2	165.6	61.0	79.0	558.8	225.8	69.4	78.2	32.2	426.4	347.0	17.2	632.4
C/26	6.4	127.8	131.0	61.2	69.0	628.6	235.4	75.0	91.6	52.6	609.4	503.6	16.6	717.6
C/27	5.9	123.2	131.0	28.2	71.8	512.6	191.6	53.8	73.8	22.8	377.6	207.6	16.8	654.8
C/28	5.6	114.0	112.6	18.4	57.8	613.2	225.6	77.0	105.0	34.0	465.4	382.4	19.4	656.0
C/29	7.2	150.6	152.8	60.2	83.2	590.0	251.0	65.6	86.0	24.6	495.6	406.0	16.0	658.8
C/30	7.5	172.4	172.4	60.2	92.4	629.2	238.8	81.2	109.6	31.0	532.4	451.6	19.4	703.4
C/31	8.2	130.0	135.6	54.2	68.2	576.0	217.4	68.8	83.2	54.8	495.2	415.2	20.0	676.2
C/32	6.0	131.6	130.6	46.0	61.8	558.4	235.8	67.4	103.6	62.4	525.8	438.4	17.4	674.0
C/33	7.0	139.6	144.6	48.4	69.6	618.0	244.0	64.8	95.6	25.2	571.0	478.0	20.2	636.8
C/34	5.6	126.0	122.0	22.4	64.6	525.2	225.0	65.6	80.8	24.4	314.6	244.4	17.2	559.6
C/35	5.8	130.2	138.2	34.0	53.0	542.4	231.4	61.6	74.8	26.2	464.6	377.2	19.2	645.4
C/36	7.6	157.6	162.8	53.2	73.2	623.0	254.0	74.2	97.0	27.4	534.8	448.4	20.0	715.8
C/37	7.6	129.6	127.0	45.6	64.6	585.0	238.8	70.8	88.6	30.6	490.8	398.2	20.6	664.4
C/38	8.0	148.0	153.2	41.2	56.8	569.4	259.8	62.0	84.0	28.4	545.2	452.8	20.6	630.0
C/39	9.4	148.0	161.0	52.2	66.2	605.6	236.4	57.6	70.0	35.0	502.4	420.2	20.2	668.0
C/40	6.5	143.8	145.0	61.4	61.2	606.4	222.2	76.0	101.0	30.8	546.0	454.4	19.0	669.2

Spec. No.	A ₁	A	B	C	D	E	F	G	H	I	J	K	L	M
C/41	6.5	130.2	134.6	53.6	79.6	572.0	224.0	68.8	85.2	35.2	491.4	407.6	19.4	659.4
C/42	6.8	164.0	167.6	57.4	71.8	637.2	246.8	82.8	101.4	33.6	547.2	451.2	20.2	730.0
C/43	7.0	147.2	152.8	48.8	67.4	614.0	232.4	67.2	84.4	36.4	503.6	420.4	18.8	624.2
C/44	5.8	130.0	137.8	64.8	58.4	589.6	226.8	55.2	74.6	32.6	507.4	429.8	20.4	647.2
C/45	8.0	141.6	144.4	52.6	70.4	571.8	221.2	63.0	81.6	31.2	466.4	377.6	18.2	590.4
C/46	5.8	137.0	132.2	53.0	72.4	609.0	244.4	68.0	85.8	30.2	496.4	418.2	20.0	561.6
C/47	7.4	132.0	137.4	36.2	51.4	599.2	220.2	60.0	78.8	32.8	515.4	428.6	18.8	642.4
C/48	8.0	126.0	131.0	27.2	66.4	527.0	232.4	64.0	78.6	32.6	360.4	210.6	17.8	557.8
C/49	8.0	147.6	156.0	57.4	78.0	578.8	254.4	46.6	78.2	24.4	557.6	476.8	18.2	720.0
C/50	8.8	154.8	149.8	91.6	77.4	601.8	252.8	63.2	78.8	32.6	530.8	449.2	20.2	700.2
C/51	8.4	140.4	145.2	76.2	62.2	553.4	253.0	50.8	65.2	29.4	511.6	423.0	20.2	601.0
C/52	6.8	143.8	147.6	55.2	59.6	600.2	243.0	52.8	68.8	32.2	491.4	407.0	20.4	607.4
C/53	7.2	143.6	146.8	52.8	58.8	560.0	226.0	37.6	58.4	26.2	483.0	409.2	19.0	598.8
C/54	8.5	157.6	156.4	77.4	76.2	610.8	242.2	68.0	89.0	30.8	530.8	433.8	20.0	717.8
C/55	4.8	121.0	123.6	24.4	43.0	565.8	229.2	66.2	86.0	32.8	494.2	414.2	19.4	615.4
C/56	7.2	129.6	128.8	26.8	66.0	534.8	212.8	71.2	82.2	15.6	424.0	345.6	18.4	584.2
C/57	6.4	120.2	129.2	42.8	61.6	573.0	235.6	61.4	71.2	29.0	479.2	384.2	19.4	617.0
C/58	5.8	128.0	128.6	32.2	42.6	608.6	227.6	45.4	60.8	19.4	508.6	429.0	20.6	644.0
C/59	6.7	135.2	139.8	60.8	72.8	601.0	248.8	46.6	58.6	19.6	485.2	387.6	19.6	626.2
C/60	7.6	148.0	152.6	63.2	88.0	627.2	230.2	55.4	70.2	34.0	529.4	438.8	18.8	675.6
C/61	6.4	153.0	157.4	58.6	72.6	643.8	245.2	63.8	85.6	26.4	521.6	434.0	17.6	711.1
C/62	7.0	145.8	149.2	48.0	67.6	653.6	233.8	68.4	87.8	31.0	419.8	431.2	19.6	651.8
C/63	6.8	148.8	155.2	50.8	69.4	547.0	224.8	67.4	85.2	26.6	511.2	427.2	17.2	659.2
C/64	7.6	142.0	145.2	39.0	61.6	572.0	238.0	59.6	73.2	25.0	499.4	413.8	17.8	621.8
C/65	8.0	144.8	146.2	48.6	63.8	595.6	249.4	64.0	78.8	31.6	521.6	446.4	18.8	648.8
C/66	10.0	150.8	159.4	60.8	80.2	620.0	241.2	58.8	52.6	27.2	565.4	468.8	19.2	683.4
C/67	6.0	141.2	144.2	48.8	64.0	597.4	221.6	54.0	58.4	23.2	499.6	420.0	19.6	695.2
C/68	6.4	144.4	144.2	59.1	70.8	618.6	230.4	45.0	51.6	34.2	498.4	486.0	18.4	647.2
C/69	8.8	144.6	141.8	60.0	66.8	591.6	230.8	67.4	39.6	29.4	509.4	434.0	19.6	663.0

Total number of specimens examined = 108.