EXPERIMENTAL STUDIES IN THE GENUS *Salicornia* L. (CHENOPODIACEAE)

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in the Faculty of Science in the University of London and for the Diploma of Imperial College

by

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ABSTRACT

The main study has involved experimental work on phenotypic variation in the annual species of *Salicornia*, employing a sand culture with subirrigation technique.

Biometrical studies of the progeny grown in culture showed that descendents of different parent plants remained significantly distinct, while anther length, pollen grain diameter and certain morphological characters (associated with the degree of compression of the fertile segments) showed a correlation with chromosome number (diploid v. tetraploid).

Chromatography of the phenolic glycosides in plants of known chromosome number, grown in culture, showed two groups when subjected to Principal Components Analysis with one being diploid (the *S. europaea* group), the other tetraploid (the *S. procumbens* group). The only separate recognisable chromatographically, *S. pusilla*, fell as might be expected in the diploid group. Analysis of field populations showed a good separation into upper and lower marsh groups, presumably because of the preference of diploids for the former level and tetraploids for the latter.

Cultivation at different nitrogen levels produced interesting changes in the balance between dominance by the apical characters (low nitrogen levels) and by the lateral branches (higher nitrogen levels). Low nitrogen levels also favoured increase in seed size and caused an advancement of flowering time. Variation in phosphorus levels produced much less marked effects, but elevated sodium chloride

levels induced stunting of growth. Doubling the daylight ambient light intensity caused a significant increase in branch numbers per plant. Analysis of variance also revealed that samples of differing parentage had differing responses to variation in nutrient levels. In addition, attention is drawn to certain characters (such as fertile segment number and angle of branching) which are little or not at all affected by the nutrient treatments.

Analysis of soils from sites of *Salicornia* populations showed gradients with maximum nitrogen and sodium chloride levels in the upper marsh, and also showed the nitrogen level to be low overall in comparison with normal agricultural soils. Taken in conjunction with the culture experiments, these results indicate that *Salicornia* has adapted to low nitrogen levels, but not to low phosphorus (presumably because phosphorus is adequate for the plant need).

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CHAPTER I

INTRODUCTION

1.1 General

The genus *Salicornia* belongs to the family Chenopodiaceae and like many other genera in the family it is a halophyte. It has been considered as a halophyte since the word "halophyte" was introduced by Pallas for Schrader in Gottigen in 1809, who stated that *Salicornia*, *Salsola* L. and related plants be put "Unten einem Wieer glaubt, pass and er Namen Von Halophyte Vereinigt". Like *Salsola* and *Suaeda* Forsk. ex Scup. it can be considered as an indicator of saline habitats. Since halophytic plants are themselves, as well as their natural habitat, so distinctive, it is not surprising that they attracted the attention of many writers on plants in past centuries. For example Lobelius in his Stirpium adversaria nova of 1570, says about *Salicornia* "multo frequentissima ad quaslibet maritimus oras tum Oceani, tum Mediterranei Maris----". Since *Salicornia* spp. show a remarkable adaptation to survive in highly saline habitats, many authors consider it to be obligately halophytic i.e. that saline conditions are necessary for its optimum growth (e.g. Chapman 1936a, 1942, 1960, 1966; Ranwell 1972, Waisel 1972). However, the plant seems capable of growing in ordinary garden soil with no salt added, when freed from the competition of other plants (Halket 1915; Hilton 1975).

1.1.1. The morphological characters:-

The *Salicornia* plant has a normal root system usually of considerable extent. The aerial parts are built of succulent assimilating internodes constricted at their base, thus giving the plant an articulated appearance (Figure 1.1). The leaves are highly reduced so the

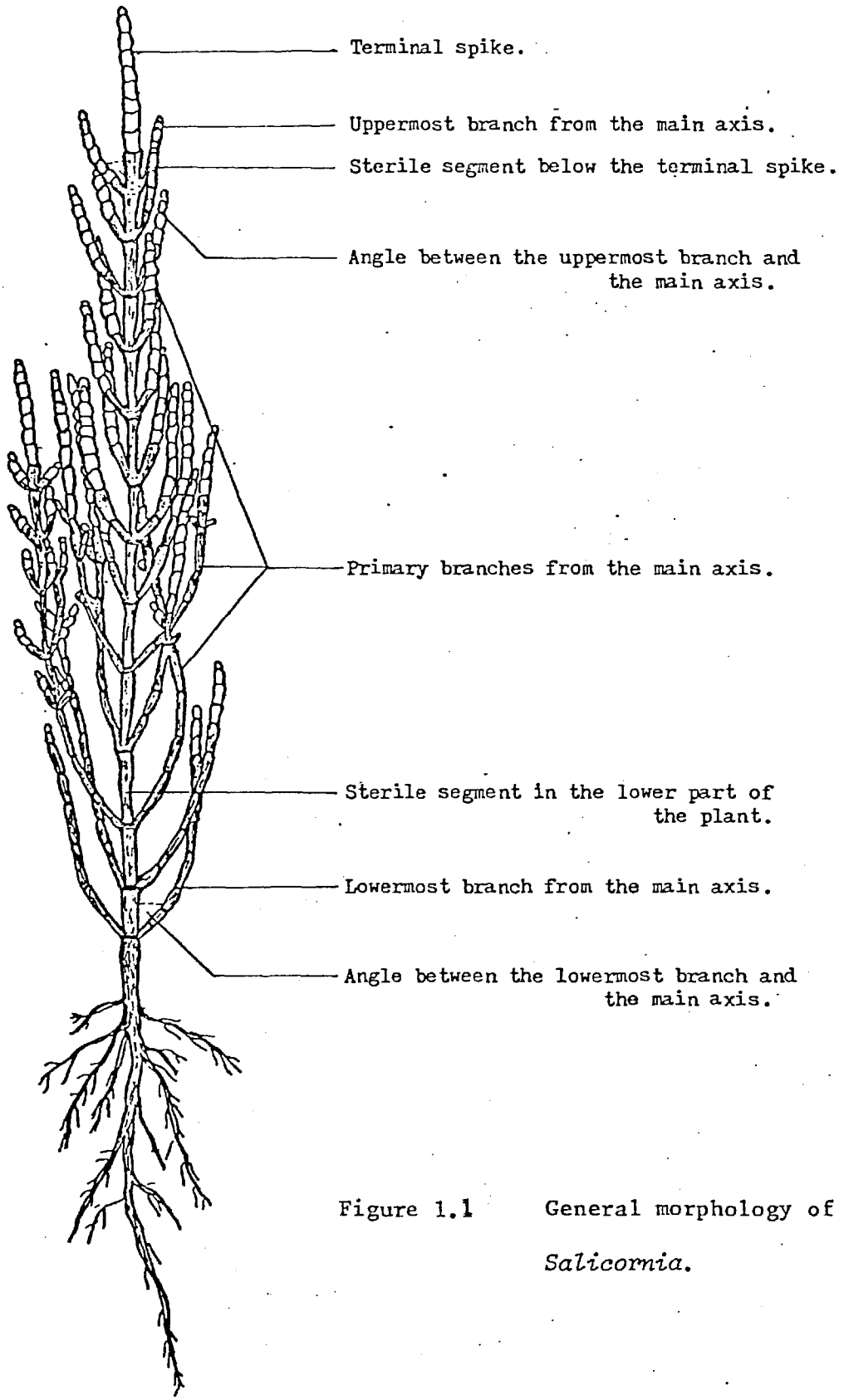


Figure 1.1 General morphology of annual *Salicornia*.

plants look apparently leafless. Authors such as Bentham (1858), Hooker (1884), Babington (1904), and Sehischkin (1936) described such forms as being aphyllous. Cross (1909) indeed said "leaves are entirely absent". DeFrain (1912) explained "the leaves as opposite, fleshy and arising as small, pointed structures with a broad base of insertion, the leaf bases of a pair of leaves nearly surrounding the stem at the node. Subsequently lateral fusion takes place between the adjacent margins of each pair of leaves, producing a connate leaf-base and the meristematic activity in this region finally results in the production of a tubular leaf sheath, which is crowned with the two free leaf tips. As the internodes of the stem elongate, the connate bases of the pair of leaves elongate also, so that each internode is clothed with the basically developed leaf sheath of the pair of leaves of the node immediately above." The single stem bears opposite and decussate pairs of primary branches, which may branch similarly to produce secondary branches and they in turn to produce tertiaries. This arises from the regular structure by which each is formed from a series of succulent internodes often called "sterile segments". Elongation of the young internodes is a result of the activity of an intercalary meristem present at the base of each internode (Abraham Fahn and Tova Arezee 1959). Those segments which are formed later at the terminal end of the main stem and the branches are often called "fertile segments". Fertile segments are usually much shorter than the sterile segments. Their basal parts form a pair of partial inflorescences, each being a reduced dichasial cyme bearing three sessile flowers, (one in *S. pusilla* Wood, 5-10 in *S. australis*), which remain embedded in the fleshy tissue of the segment. This part of the plant, which occupies the distal part of the stem and the branches is known as the "terminal spike". The number of

fertile segments in the terminal spikes varies from one to thirty or more. Flowers are hermaphrodite (polygamous stated in *S. australis*). Each flower has a fleshy, lobed perianth which is approximately pyramidal in form, its base lying flush with the segment surface. The three flowered perianths fit together with their apices against the central vascular strand. Usually the central flower perianth is larger than the lateral ones.

The stamens are perigynous with one or two, though field observations on the member of this genus in India and New Zealand show that the genus possess five, stamens, but only one anther matures at a time (McCann 1952). In the young flower the filament is short, but it later elongates so that the anther hangs out of the pore. The anther lobes are attached to the filament for about half their length. Each lobe consists of two loculi,dehiscence is by longtudinal slits coinciding with the partition between the two pollen sacs. The pollen grains are spherical with numberous evenly-spaced circular pores in the outer exine. The ovary is superior, of one carpel, and is ovoid, containing one basal anatropous ovule. The style tapers to a point, and terminates in a tufted stigma that is very shortly branched, with branches often unequal in length, bifid or trifid, and often persistent.

1.1.2. The life history

The life history of *Salicornia* is very similar to that of many other annuals of the Chenopodiaceae. The few published data of the time at which *Salicornia* taxa germinate show differences, but generally the active germination period can be considered to be between March and May. However, a number of germinated seeds of *S. dolichostachya* were observed in January on a south Devon salt marsh, (Hilton 1975). Chapman (1976) relates the germination time for many species on a

salt marsh with a period of minimum surface salinity. Purer (1942) reported that, in a southern California salt marsh, the annual species of *Salicornia* germinate most abundantly after the first heavy rain of winter, and he related this phenomenon to the reduction in surface salinity. Experimentally, different annual forms of *Salicornia* were shown to germinate very well in distilled water and tap water, with a reduction in the germination rate as the sodium chloride percentage increased in the germination medium, (Keller 1925, Chapman 1960, 1964). Other than salinity one factor which seems to promote germination in *Salicornia* is illumination. Waisel (1972) reported a positive correlation between the germination of *S. herbacea* and illumination. Chapman (1966) also suggests the likelihood of a light requirement among halophytes. The association between soil aeration and occurence of *Salicornia* has been noted by several authors like Chapman (1941), Purer (1942), Brereton (1971), and Ranwell (1972). However, some have suggested that this may arise in part from a high oxygen requirement for germination, presumably the germinated seeds usually are those living on the soil surface.

After the seeds have germinated the process of their establishment must play an important role in life history of *Salicornia*. Wiehe (1935) showed the density of *Salicornia* seedlings on a low marsh to be related to frequency of flooding tides. His data showed a sharp rise in disappearance of the seedlings at the level where there is a daily flooding, due to the mechanical removal of the seedling. Chapman (1942) and Ranwell (1972) both concluded that the zonation on the salt marsh is mainly controlled by the process of seedling establishment rather than any other factor such as duration of tidal submergence or salinity. Ball and Brown (1970) found that the radicle

of *S. dolichostachya* grows more rapidly than that of *S. europaea*, and related this to the greater ability of the former to establish itself on completely open ground in the low marsh to the advantage which this would give in resisting the mechanical tidal disturbance. In general, the process of establishment of the annual forms of *Salicornia* can be defined as Hilton (1975) pointed out "once the seedling is rooted in soil and one or more stem segments have grown".

After the plant is well established, the vegetative growth usually continues till July. Flowers usually first become visible in the second half of July. The flower production peak commonly takes place in August, though flower production may continue into October. The first flower may open on any branch of an individual plant, but all fertile spikes on one plant normally begin to flower within a few days of each other. The central flower is usually, but not always, the first to open. Consequently, all combinations of stigma and anther emergences may be found between the terminal and lateral flowers of a single cyme. There is some evidence in the literature for differences in flowering time between *Salicornia* spp, thus Ball and Tutin (1959), Ball and Brown (1970) note that *S. dolichostachya* flowers slightly earlier than *S. europaea.*

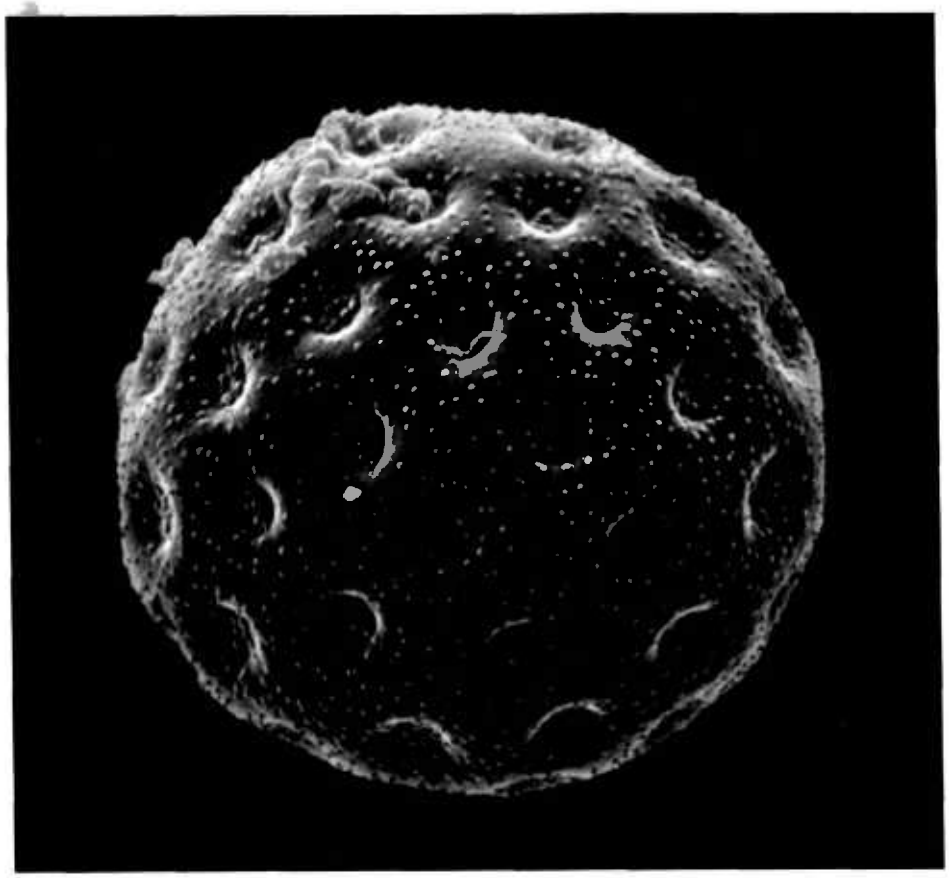
The seeds reach maturity from about mid September onwards, when the vegetative tissues begin to die. As the seeds ripen, the fleshy perianth persists, the cell wall contents disappear, and the cell wall becomes thickened by regular bands which run in different directions in different cells surrounded by its perianth, and the cells are filled with air. Cook (1911) described this as an adaptation process for dispersal of seeds by water, since, due to this persistent perianth, the

seeds float on the top of the water for a long time. The ability of *Salicornia* seeds to be carried by the sea water has been known for some time, (Guppy 1917 and Ridley 1930). Chapman (1936b) related the colonization of the low marsh by *Salicornia* to the ability of the seeds to be distributed by the tide. But this widespread dispersal by tidal current does not seem to apply to all the groups of *Salicornia* spp., especially the diploid form in the high marsh, where the seeds remain with the parent plants; Ball and Brown (1970) pointed out "It is not unusual to find that the seeds have not been shed and have germinated in situ the following spring, by which time the parent has fallen over and been buried". Dalby (1963) also showed that the seeds in *S. pusilla* do not fall, but the whole fruiting head will float in sea water for up to three months before being stranded on or near high water level.

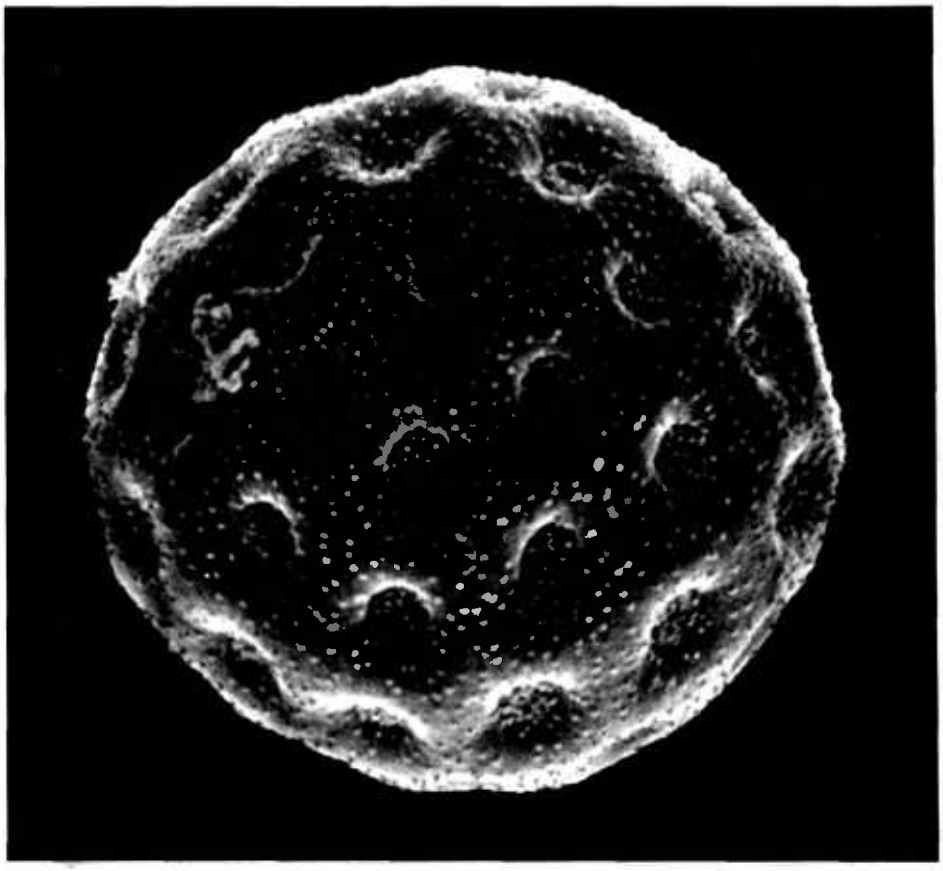
1.1.3. Pollination

Many authors regarded *Salicornia* spp. as being anemophilous, Oliver 1907, Cook 1911, Moss 1912, Purer 1942, Dalby 1962, Ranwell 1972). Supporting this view, *Salicornia* spp. pollen grains are spherical with numerous evenly-spaced circular pores in the outer exine (photograph 1.1). Also *Salicornia* pollen can be carried by the wind in quantity potentially capable of effecting cross pollination, (Dalby 1962, Hilton 1975). However, there are considerations which raise doubts about the effectiveness of wind-pollination in this genus. As knuth (1909) quotes Schulz by saying that the flowers of *Salicornia* spp. are feebly protogynous, but possess a persistant stigma. So that in consequence of the proximity of the anthers automatic self-pollination is easily possible. Dalby (1962) considered that *Salicornia* is usually weakly protogynous and sometimes it may be markedly so. However, he added "often the stigma

Photograph 1.1 : Scanning electron micrographs of *Salicornia europaea* (A), x3812 and *S. dolichostachya* (B), x4104 pollen grains.



-A-



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and anthers appear simultaneously and even when protogynous pollen from earlier flowers on one part of a plant may be transferred to a stigma on later flowers on another part of the same plant. Ferguson (1964) agrees with Dalby (1962) in concluding that annual forms of this genus are weakly protogynous. He bases this conclusion on his observations in the field and in cultivation that the stigma protrudes just before the undehisced anthers are exerted, or the anther and stigma emerge simultaneously. However, Dalby (1955a) observed that many plants (as at Blackeney) are definitely protogynous, every flower having stigmas, but no externally visible anther. Other plants (as on Hayling Island) have their anthers and stigmas maturing simultaneously and in natural contact with each other. He added that in plants such as the latter self pollination is very likely to occur and experimental evidence suggests that *Salicornia* is frequently autogamous. Indeed Ball and Tutin (1959) described the new species *S. obscura* with usually cleistogamous flowers. Generally we can say that these plants are self-compatible, and no hybrids have yet been recorded Dalby (1962) and most of the authors agree the possibility of self-fertilization is very high, though they did not exclude the possibility of wind pollination (Dalby 1962, Hilton 1975.).

1.1.4. Geographical distribution of *Salicornia*.

Good (1974) describes the Chenopodiaceae as being one of the families which are found practically all over the world within their ecological limits and as one of the two families (i.e. with Plumbaginaceae) which are most plentiful in salt desert or coastal areas. Also he pointed out, more than once, that the same qualifications apply to *Salicornia* spp. which he includes among "sub-cosmopolitan genera" because, although credited with an almost world-wide distribution, their edaphic requirements

limit them either entirely or largely to coastal areas or to where inland salt deposits so that the actual size of the area they occupy is relatively small. Other genera of the Chenopodiaceae which are closely related to *Salicornia*, especially *Halocnemum* M. Bieb. and *Arthrocnemum* (Moq.), often occur in similar habitats. *Salicornia* species occupy a pioneer stage in the development of salt marsh vegetation (e.g. Halket 1928, Rikli 1943, Chapman 1960, Brereton 1971, Chapman 1976). Also many inland areas, often far removed from the coast, support an extensive halophytic vegetation. In these *Salicornia* spp. also form the pioneer community. Though in most cases the inland *Salicornia* spp. were given similar names to the coastal species, one does not know whether they are the same species. For example, I have seen species of this genus in the saline depression of Bahr-al-Najaf, south west of Najaf town in Iraq, which are known as *Salicornia europaea* L.

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1.1.5. Economic uses of *Salicornia* spp.

Economically the plant is of minor importance, though ecologically it has a valuable place in the colonisation and reclamation of salt marshes. *Salicornia* spp. had been used previously in glass making, due to its richness in soda, and this is why it is known as "glasswort". The plant itself is edible because of its salty test, usually being pickled after initial boiling.

1.2. The species problem in *Salicornia*.

The genus *Salicornia* has always presented taxonomists with considerable problems which, despite the renewed interest in recent years and the extensive investigation in a number of European countries, are by no means solved, as there is no general agreement as to the

number of species in existence (mainly in Europe and Britain). It is interesting to note that most, if not all, of those workers who have studied the plants in the field agree that there is more than one species (e.g. Wood 1851, Duval-Jouve 1865, Dumortier 1868, Townsend 1904, Moss 1911, Willmott 1939, Dalby 1956, Ball and Tutin 1959).

Linnaeus in his first edition of "Species Plantarum" (1753), recognized only one species in north-west Europe (*Salicornia europaea* L.). Subsequently the outlook has become more and more critical and the number of supposed species has risen sharply. Indeed, Willmot (Willmot unpublished) mentioned over 50 species in the British Isles alone. This is indicative of the magnitude of the problem. This difficulty had been recognised even by the earliest botanists of the last century, as Hooker (1830) pointed out for the first time that there was confusion between the perennial species. Baxter (1839) also said "Botanists of the highest authorities differ in opinion respecting the specific distinction of British *Salicorniae*". Dalby (1955a)relates this variable treatment of the group as a result of the fact that the various characters used in species discrimination show very few correlated discontinuities; in general variation is continuous, between extremes.

The classification of *Salicornia* followed is based on that proposed by Clapham et al.(1962). At present their nine species have generally been accepted as distinct species of this genus in Britain. These species are:- *Salicornia perennis* Mill., *S. ramosissima* Woods., *S. europaea* L., *S. obscura* P.W. Ball and Tutin, *S. pusilla* Woods, *S. nitens* P.W. Ball and Tutin, *S. fragilis* P.W. Ball and Tutin, *S. dolichostachya* Moss, and *Salicornia leutescens* P.W. Ball and Tutin.

Salicornia perennis is a very distinct species and the only perennial one in the British Isles.

At present a primary division according to the chromosome number is established. One diploid 2N = 18 and the other tetraploid 2N = 36, with no triploids recorded as crosses between diploid and tetraploid. However, there is a continuum for most other characters (Hambler 1954, Ball and Tutin 1959, Dalby 1962).

The diploid species are:- *Salicornia ramosissima* Woods., *S. europaea* L., *S. obscura* Ball and Tutin, and *S. pusilla* Woods. The tetraploid species are:- *S. nitens* Ball and Tutin, *S. fragilis* Ball and Tutin, *S. dolichostachya* Moss, and *S. lutescens* Ball and Tutin. However, there is considerable agreement on chromosome numbers for each of the above taxa, apart from *Salicornia ramosissima* and *S. europaea* both of which appear to contain diploid and tetraploid forms, Dalby (1962). Identification of a single specimen in the field of the annual forms (apart from *S. pusilla*) in the traditional way is still difficult, and at times impossible, and it may even be difficult to tell if the specimen belongs to the diploid or tetraploid group without actually counting the chromosomes.

The question which arises is why *Salicornia* should be taxonomically difficult? The most obvious point is the remarkable morphology of the plant which is represented by the extreme reduction in both the floral and leaf structure and the consequent lack of orthodox characters. The remaining morphological characters, mainly the plant habit and the branching, have recently been proved to be of little taxonomic value as these characters are greatly affected by the environmental conditions

under which the plant grows. Dalby (1955a)reported that the progeny of two prostrate parents were completely erect, or with a slightly bent or shortly decumbent portion below the bottom node. Though the progeny of a third prostrate parent were mostly prostrate. On the other hand, some forms of *Salicornia* (referred to by Hambler (1954) as *S. Smithiana* Moss) possess prostrate and erect forms. Also seeds from a considerable number of prostrate plants have been grown in cultivation and only one collection of *S. pusilla* gave prostrate progeny (Ball and Tutin 1959). It seems the habit forms (prostrate/erect) possess a genetical basis, but quite often erect forms may be trampled or are decumbent, particularly in the early stages of growth, or prostrate forms may become semi-erect (Ball and Tutin 1959, Dalby 1962). Thus, the intermediate forms usually lead to confusion concerning the branching habit, even the potentially most richly branched plant can, under the influence of competition, water stress or nutrient deficiency, become nearly or quite unbranched (Dalby 1955b, Pigott, 1969). For instance, *S. ramosissima*, though typically much-branched and bushy is often quite unbranched when growing in crowded pure stands or in competition with other plants (Clapham et al. 1962). Other morphological characters, such as the degree of branching and the length of the branches, also proved to be affected by different factors such as injuring of the terminal spikes and the plant falling over and being phenotypically prostate (Ball and Tutin 1959). Even the supposedly more reliable characters, such as the morphology of the spikes, morphology and outline of the fertile segments, show some considerable phenotypic variation. Microscopical characters, such as pollen grain size, anther size, stomatal guard cell and seed size, also show a considerable overlap, even in relation to chromosome number (Ball and Tutin 1959; Dalby 1962, Ball and Brown 1970). However, they consider

the pollen size to be more closely related with the chromosome number than the other characters, but this relationship is not sufficiently precise to be used alone as a reliable indication of the chromosome number. For instance Ball and Tutin (1959) regarded pollen diameter of about 29.5μm as marking the change from diploid to tetraploid, whereas Dalby (1962) would put it at 27.0μm.

De Frain (1912) suggested that the occurrence and distribution of "spiral cells" and "stereids" were of taxonomic significance. The thorough examination of the occurrence, development and connection between these peculiar types of cells and their possible correlation with environmental factors, such as sub-stratum drainage, and amount of submergence, would be very desirable (Ball and Tutin 1959).

Due to the plant succulence, most of the characters observed in the fresh plant will be lost when it is dried in the normal manner and frequently identification becomes impossible. Even for plants preserved in recommended preservatives, such as 70% alcohol or with a mixture of one part glycerine/one part 90% alcohol (Ball 1960a), it is recommended that this be accompanied with photographs, and notes on colour and texture. These factors make revision of the genus under the present circumstances difficult, if not fruitless if this is to involve correlation with earlier worker's studies and would result in yet more confusion.

There is clear evidence that much of the variation encountered is caused by environmental conditions. The wide range of habitats in the salt marsh ecosystem plays an important role in the morphological variation of this difficult genus. The physiographic complexity of salt marshes, as well as the predictable temporal fluctuations in

edaphic conditions, result in considerable environmental heterogeneity. Genetic differentiation within salt marsh species in response to environmental heterogeneity is well established (Gregor 1930, 1946, Chapman 1960, Aston and Bradshaw 1966, Sharrosk 1967, Hannon and Bradshaw 1968, Waisel 1972, Gray 1974). The tide represents the major factor influencing the vegetational zonation and succession (Chapman 1938, Jensen 1974). The salt marsh is subjected to periodic inundation by sea water, the lower the marsh the more frequent the inundation. When the flooding tide leaves the marsh and is followed by a heavy downpour there is a rapid change in the salinity of the soil water close to the surface. In addition, there is also a purely mechanical effect exerted by the tide. It seems this factor is in part responsible for colonization of different forms of *Salicornia* throughout the salt marsh. The lowest part of the marsh, which is subjected to the highest mechanical effect of the tide, is characterized by the presence of the decumbent, green, long-spiked plants of *S. dolichostachya*, while the edges of the channels and creeks at a higher level, but still in free connection with the sea, are characterized by the erect, green, medium spiked plants of *S. stricta*, and finally on reaching the upper marsh the dominant form is *S. ramosissima*. This kind of zonation was observed by Dalby (1955b)on a salt marsh at Shingle Street, Suffolk. The presence of *S. dolichostachya* in the habitats where there is frequent disturbance by the sea is related to the germination rate and the initial rate of growth of their seedlings establishment (Wieh 1935, Ball and Brown 1970). However, Pigott (1969) related this ability of the seedling to the availability of nitrogen.

A number of studies have been made to correlate the various environmental factors such as salinity and tidal height to standing crops and marsh production (Adams 1963, Stalter and Batson 1969, Good 1972). However, the results have often been inconclusive and, due to the nature of the

correlational approach, failed to directly identify the causes of the large differences in primary production. Pigott (1969) and Valiela and Teal (1974) have claimed that nutrients were the most likely factors determining the amount of plant growth on a salt marsh. Since coastal salt marshes are repeatedly washed by sea water, it is likely that micronutrients are not limiting factors to plant growth (Valiela and Teal, 1974). Also it seems very likely that iron, potassium, magnesium, and calcium are available in abundance throughout the year in marsh sediments (Adams 1963, Goldberg 1963, Mooring et al. 1971, Tyler 1971a, Ranwell 1972). Most authors working on the nutrient aspects of the salt marsh agree that nitrogen, in particular, and phosphorus are the most likely macroelements limiting growth in the salt marsh plants. Pigott (1969) showed that nitrogen deficiency is mainly responsible for the stunted growth of *Salicornia* in the upper marshes. His analysis of nitrogen and phosphorous concentrations in large and stunted plants of *Salicornia dolichostachya* showed consistently lower concentrations in the latter, which suggests deficiency restricting growth. Similarly populations of *S. europaea* agg. from the upper levels of a salt marsh at Stiffkey have slower growth rates than corresponding populations from a low marsh at the same locality (Jefferies 1977). But he suggested that the slower growth response to nitrogen of plants, from the upper marsh away from drainage channels, is the result of selection for plants with relatively low growth rates which are able to survive the periods of stress during the summer months when the soil is hypersaline.

During periods of exposure salt marshes are affected both by evaporation and rain. The upper marsh is exposed at all times, except for relatively short periods of high water spring tides, but the lower marsh is only ever exposed for no longer than a few hours at neap tides and even then the water-table remains high. Dalby (1955b) noticed that the

soil water content is responsible for much of the variation in size of *S. ramosissima*; for instance, those along the side of small pools in Shingle Street salt marshes are much larger than those found away from the pool side. Observations in the Lincoln, Nebraska marshes in 1968, indicated that the pre-growing season precipitation and soil moisture content are respectively indirectly and directly responsible for the distribution of *Salicornia* (Unger et al. 1969). Dalby (1955a)has pointed out that the reduced size in *Salicornia* can be induced by intense physical competition in the one instance, and by water shortage during the growing season in the other. As an example he referred to *S. gracillima* types which are small and simple and usually markedly red when in fruit and with few fertile segments.

The pattern of variation in water content of the soil produces gradients in aeration and salinity. Chapman (1938), Brereton (1971), and Chapman (1976) pointed out that the presence of an aerated layer just below the soil surface may be of the utmost importance in understanding how plants can live on salt marshes. This aerated layer has a composition quite different from that of the atmosphere in that it contains more carbon dioxide than oxygen and its composition varies considerably over a single marsh, from marsh to marsh, and probably seasonally as well (Chapman 1976). Brereton (1971) has shown that the shoot and root growth of *Salicornia* was stimulated at the higher oxygen level. Similarly he found the development of increasingly dense stands of *Salicornia* was associated with the improved drainage conditions. Dalby (1956) used the technique of alternating layers of silt and sand, with a glass tube penetrating through the substratum, to provide a good aeration for culturing *Salicornia*. Tyler (1971a) in analysing the problem of differentiation in the Baltic sea-shore meadows pointed out that "within the vegetation complex, however, it is chiefly the

drainage conditions which decides the vertical range of the enduring species and the zonal differentiation of the plant cover.

Variation in salinity of the salt marsh soil arises from the same interplay of tidal flooding, evaporation, rainfall, proximity to creeks, and mechanical composition of the soil (Morss 1927, Pigott 1969, Chapman 1976). So, as far as salinity values are concerned the upper marsh is a much more varied habitat for plant growth than the lower marsh. During summer, due to evaporation, the upper marsh may become hypersaline. Observations in Nebraska indicate that with high evaporation rates during the summer salinity stress continues to increase and *Salicornia* cannot establish itself on the salt ponds (Unger 1970).

It seems that the exceptional plasticity of this genus to environmental factors is the main reason for continuous variation between the extremes, which blur the boundaries between the taxa (Dalby 1955a). Heslop-Harrison (1955) used salt marsh species of *Salicornia* as an example to show that plastic modifications of the phenotypes may permit a species to occupy an extreme habitat until genetically better adapted forms have evolved, when they will oust the originals, so that ecotype replaces ecad. Then he added "If this is so then variations in *Salicornia* may be genotypic in some cases and phenotypic in others". Waddington (1957) expressed this phenomenon by saying "there is a close integration between the two, the environment can modify the channel which the form of the organism can take", while Bradshaw (1965) considers that the wide variation in characters due to the environmental factor, could be due to the lack of adaptation to these environmental factors, and the genotype concerned consequently being inadequately buffered against the environment.

The majority of *Salicornia* flowers as mentioned earlier are self pollinated. On the other hand, observations in the field show that although there is some overlap in flowering time between populations, between the upper and lower marsh, there is a difference in flowering time for example between *S. ramosissima* and *S. stricta*, the latter flowers perhaps a fortnight earlier than the former (Dalby 1955a). Differences in flowering time between the populations may reduce the effect of gene flow on the genetic composition of the population (Jefferies 1977). So one can expect more or less a pure breeding line which can be considered as microspecies or local races to be produced (Stebbins 1950). In addition Dalby (1962) suggested that segregates from occasional crosses between different lines could then act as the source of new lines.

1.3. Taxonomic treatment of *Salicornia* in North-West Europe.

The first use of the name *Salicornia* appears to be in Cruÿdt Boek of Dodoens (1554), which gave it to one of the plants included under "Kali".

Linnaeus in his first edition of the "Species Plantarum" (1753) describes one species of *Salicornia* as *S. europaea* L. under this name he recognised two varieties as:- *herbacea* and *fruticosa*. While in his second edition of "Species Plantarum" (1763) these were raised to specific rank, as an annual *S. herbacea* and a perennial *S. fruticosa*, and the specific epithet of *S. europaea* was abandoned.

With regard to English forms of *Salicornia* we will begin with "Ray Synopsis" edited by Dillenius (1724). Ray described two species only. Hudson (1762) grouped all Ray's species annual and perennial

under one species, *S. europaea* L., but with a number of varieties based on Dillenius (1724). However, Ray's species were gradually ressurected, first as varieties (Withering 1776, Smith 1800), and then as full species (Gray 1821, Smith 1828).

The next work, in which any change in British *Salicornia* was made, was that of Smith (1797 and 1813). He recognised four species, two of them perennial. The precise identities of these species is uncertain.

The first critical study of *Salicornia* in Britain was carried out by Woods (1851). He recognised five annual species in the area he had studied (Sussex and Hampshire). The identity of four of these species has now been definitely ascertained, whilst the fifth species, *S. intermedia*, is seen to be a mixture of the plants not placed in the other four species. He was the first one who introduced the name of *S. pusilla* and *S. ramosissima*, though he failed to notice the most important diagnostic character of *S. pusilla*, the one-flowered cyme.

In Belgium and on the French Coast Dumortier and Duval-Jouve followed Wood's steps in examination and description of their native forms of *Salicornia*. Dumortier (1868) described four species of *Salicornia* as *S. stricta*, *S. procumbens*, *S. prostrata* and *S. appressa*. His classification was mainly based on habit and branching. Nevertheless, he expressed his doubts that many species could be hidden under the name *S. herbacea* L. Duval-Jouve (1865), who was obviously much impressed by the vegetative plasticity of the genus, classified his species in dichotomous series as to duration, habit, floral envelopes, seeds, epidermis and tissues respectively. His two annual species were *S. patula*, as representing the diffuse forms, and *S. emerici* (including

S. procumbens Sm.) as representing the erect forms. Of the perennial forms he recognised *S. fruticosa* L., and *S. sarmentosa* Duv-Jouve.

Townsend (1904), who revised Wood's material, also failed to observe the most diagnostic character of *S. pusilla*: the one-flowered cyme, which led him to consider a small form of *Salicornia* with 3-flowered cymes as a variety of *S. pusilla* (Var. *gracillima*, M.S.). The most important features of Townsend's work was the recognition of six annuals and two perennials. The annual forms are:- *S. stricta* Dum., *S. procumbens* Sm., *S. ramosissima* Woods, *S. pusilla* Woods, *S. appressa* Dumort, and *S. intermedia* Woods. The perennial forms are *S. radicans* Sm. and *S. lignosa* Woods.

The most important work of this period was that of Moss (1911, 1912) and Moss and Salisbury (1914). Moss (1911) initiated a fresh attack on the problem presented by the annual species of this genus found on English coasts and on the neighbouring French coast. He succeeded in clearing up a number of errors in the account of Woods (1851) and Townsend (1904) and recognised two of the more distinct species of this genus; *S. dolichostachya* and *S. disarticulata* (= *S. pusilla*).

Wilmott, shortly after the war of 1914-1918, began an extensive study of this genus in Britain, but unfortunately he died before he had produced an account of the genus in a form suitable for publication. It seems his trained eye enabled him to distinguish many different forms and certainly more than described in his contribution to the "Flora of Hampshire" in Martin and Fraser (1939). He referred in his notes to over 50 species.

Butcher and Strudwick in 1930 produced an account based on that

of Moss (1911) and Moss and Salisbury (1914), but with some improved illustrations.

Apart from investigation by British workers two Scandinavians have examined *Salicornia* in North West Europe. Gram (in Raunkier 1922, 1934) considerably revised the Danish plants. He recognised five species, two of them new. These five species are:- *S. dolichostachya*, *S. strictissima* Gram, *S. europaea* L., *S. ramosissima* Wood, and *S. leiosperma* Gram. The identity of the fifth species is uncertain. It seems to be identified as having glabrous seeds, but Nannfelatt (1955) has indicated that this character is of little significance, since an examination for seeds of this species showed that they possess a hairy surface.

Attempts have been made to correlate the chromosome number with the morphology. The first attempts to do so was by König (1939). He worked on plants from the German Baltic coast and found two sets of chromosome numbers: diploid plants, 2n = 18, and tetraploid plants, 2n = 36. He published a series of photographs of the plant he had examined. The cytotaxonomic work of Hambler (1954, 1955) was restricted almost entirely to the determination of the chromosome number. He showed that *S. disarticulata* Moss (= *S. pusilla* Wood) has 2n = 16.

Dalby's cytological work (1956) confirmed the presence of two sets of chromosome numbers, diploid (2n = 18) and tetraploid (2n = 36), with no triploid plant as a cross between the diploid and the tetraploid. His results showed that *S. pusilla* is definitely diploid (2n = 18), *S. dolichostachya* is definitely tetraploid (2n = 36), and both *S. ramosissima* and *S. europaea* appear to contain diploid and tetraploid forms. The other main part of Dalby's investigation was concerned with

the variation in branching and habit characters in *Salicornia*. By cultivation he demonstrated that the degree of branching attended by any one individual is environmental rather than genetical. Also he pointed out that in many cases prostrate and erect forms were identical apart from their habit. Excluding *S. pusilla*, he recognised three groups on gross morphological character. These groups were referred to as *S. ramosissima* (including *S. gracillima* group), *S. stricta*, and *S. dolichostachya*.

Ball and Tutin (1959) attempted to assess the value of the characters used in defining species of *Salicornia* depending on evidence from both culture experiments and field observations, and tried to correlate these characters with the chromosome number of the plant. They grouped the annual species into eight species: four of them were new. The species are:- *S. ramosissima* Woods (2n = 18), *S. europaea* L. (2n = 18),*S. obscura* P.W. Ball and Tutin, *S. pusilla* Woods, *S. nitens* Ball P.W. and Tutin (2n = 36), *S. fragilis* Ball P.W. and Tutin (2n = 36), *S. dolichostachya* Moss (2n = 36), and *S. lutescens* Ball P.W. and Tutin (2n = 36).

They suggested that the name *S. prostrata* Pallas was not applicable to plants from the British Isles, that *S. appressa* and *S. smithiana* were phenotypes of *S. ramosissima* Woods, and that *S. gracillima* could not be maintained as a species distinct from *S. ramosissima*.

CHAPTER II

CULTURING OF *SALICORNIA*:-

There have been many attempts to grow *Salicornia* even as early as 1876 by Batalin. Halket (1915) cultured them in garden soil and watered them with Tidman's sea salt, whilst Baumgartel(1917) cultured *Salicornia* for anatomical purposes. Others such as Van Eijk (1939), Dalby (1956), Ball (1960b), Baumeister and Schmidt (1962) Langlois (1967), have also grown *Salicornia* for different purposes. In general, *Salicornia* has been grown successfully in culture to maturity, either from seedlings transplanted from the marsh (Halket 1928 and Van Eijk 1939), or from seeds (Dalby 1956). However, difficulties have been reported in many of the culturing attempts, as Moss and Salisbury (1914), Van Eijk (1939) and Baumeister and Schmidt (1962) reported that their plants tended to fall over. Ball (1960b)also pointed out that the serious difficulty which was not overcome in most of the species, particularly the tetraploids as *S. dolichostachya*, was that their fertile segments became flaccid before the seeds were mature.

From the field observations and the previous experiments it seems that the main requirements for normal growth of *Salicornia* are:- 1) Very humid conditions particularly during the early stages of growth, 2) A high light intensity, 3) The presence of sodium chloride, though it was found that this was not essential to start germination, and 4) A firm support for the roots, so that the plants will not fall over, provided the roots are well aerated, (Dalby 1956; Brereton 1971). Covering the plant with the sea water is not essential to achieve optimum growth, since *Salicornia* spp. have been reported in inland salt marshes which are completely away from any tidal influence.

2.1. Choice of the culture technique:-

One of the primary objectives of the present study is to deal with the phenotypic variability of the genus in relation to the factors causing it, and the range of this variation in terms of the morphological characters, it is inevitable that attention should be given to ensuring uniform growth conditions.

An automatic subirregation sand culture technique was preferred because it:- 1) Affords, in conjunction with the nutrient solutions an environment similar in some respect, to soil, and provides the necessary physical support, which is important for a plant as succulent as *Salicornia*, 2) Permits a complete control of the level of the nutrient solutions, and 3) Ensures a liberal aeration for the root when the solution drains, without the need of a special device to do so.

This apparatus has proved to be quite successful for growing *Salicornia* and relatively trouble-free in operation. The system in general incorporates the same principles as that of Arnon and Grossenbacher (1947) with some modifications which will be discussed in describing the apparatus.

2.2 Description of the apparatus:-

The apparatus may best be described by referring to the illustration (Figure 2.1) which shows the general layout of the apparatus.

Compressed air was firstly passed through two glass cylinders (B_1 and B_2) each of 36cm length. Their necks (25cm. length and 6.0cm in diameter) were packed with glass wool to free the compressed air flow from any trace of oil from the pump. An adjustable escape screw

Illustration of Figure 2.1 :-

A = air pump compressor (power 20 pounds/square inch, supplied by Edward High Vacuum Ltd., Manor Royal, Crawley, Sussex).

B_1 and B_2 = two glass cylinder which their necks packed with glass wool.

C = adjustable escape screw clip.

D = normally closed solenoid valve (2/2-way valve, supplied by Herion - Werke KG. Regel-Und Stertechnik. 7012 Fellbach).

E = compressed air inlet.

F = hard walled compressed air distributor bottle of polythene.

G = P.V.C. tube in which the air pressure flows from the air distributor bottle to the nutrient solution reservoir.

H = normally open solenoid valve (description similar to the above one).

I = nutrient solution reservoir of 20 litres capacity.

J = nutrient solution delivery tube from the solution reservoir to the culture tank.

K = the rubber bunge, number 18.

L = glass tube.

M = copper tube.

N = glass tube connected with nylon tube (nylon connector.)

O = nylon fitting, (supplied by Simplifix).

P = brass fitting (N 125/24, supplied by Simplifix).

Q = sand filter.

R = sand culture tank (Osma glass, supplied by Osma Plastics Ltd., Hayes, Middlesex. U.K.).

S = sand surface.

T = adjustable screw which can be used to isolate any culture unit from the system.

U = the culture bed.

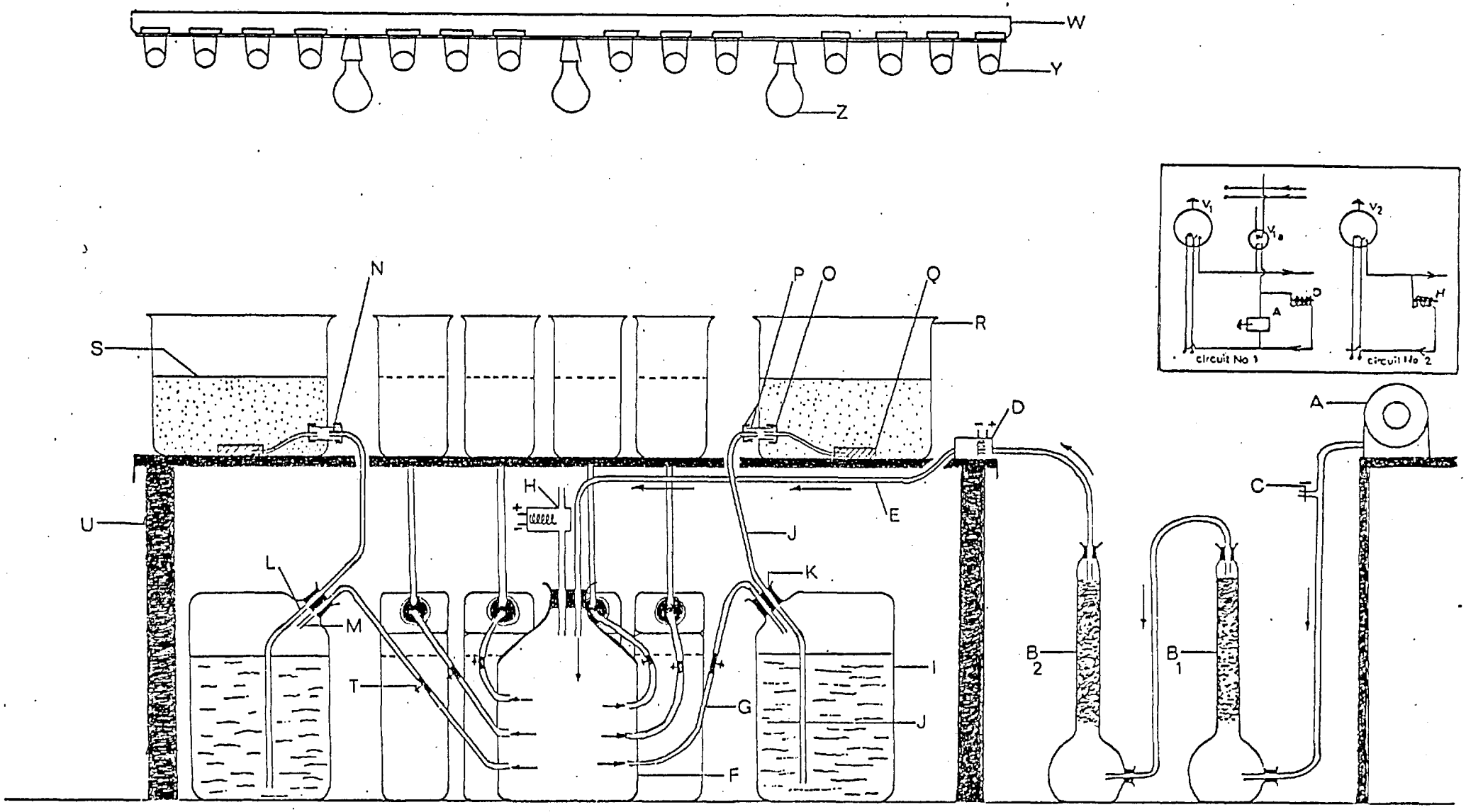


Figure 2.1 General sketch of the automatic subirrigation system which had been used for culturing *Salicornia* plants. (For illustration see the opposite page).

Illustration of Figure 2.1 (Continued):-

W = light banke which consists from 30 cool flourscet tube (Y) and eight tungsten bulbs (Z).

V = shows the electrical circuits for main and subsidiary time clock switches, pumps and solenoid valves which are used to operate the system.

V_1 = 24 hour clock.

V_{1a} = 1-hour subsidiary clock.

D = normally closed solenoid valve.

A = air pump compressor.

V_2 = 24 hour clock.

H = normally open solenoid valve.

clip (C) was used to provide a slight leak to prevent a build up of pressure in the system; especially when the nutrient reservoirs were full with the solution. This clip was also used to adjust the time needed for the solution to be raised to the level required in the culture tanks (R). The compressed air line (E) was fed into a hard-walled 15 litre polythene bottle (F), referred to as the central distributor bottle, via a solenoid valve (H). This solenoid valve was normally kept closed. This central distributor bottle (F) was fitted with 16 flexible p.v.c. tube side outlets (G). Each outlet was connected with one nutrient solution reservoir (I). Passing the compressed air initially to the central bottle and then to each reservoir ensured that the air pressure was distributed uniformly to each reservoir (I) and so each culture tank (R) received an equal amount of nutrient solution. Solenoid valve (D), normally closed, opened when the compressor was 'on', to allow the air to pass, and closed when the compressor was 'off', to stop leaking from the system through the inlet tube (E). A solenoid valve (H), normally open, was fitted at the top of the central distributor bottle (F), and was closed when the compressor was 'on', to build up the required pressure inside the system and open when the pressure needed to be released. Through this valve, the level of the solution inside the culture tanks (R) could be adjusted.

Each solution reservoir was fitted with a rubber bung (K), through which passed two tubes; one glass (L) and the other copper (M). The bottom of the glass tube (L) was connected with a flexible p.v.c. tube (J) which reached to within one inch of the bottom of the solution reservoir (I), and its top was also fitted with a flexible p.v.c. tube connected with the culture tank through a brass fitting (P).

The copper tube (M) protruded about 3.0cm. from the both sides

(above and below) of the rubber bung. The outer diameter of the copper tube was 0.9cm and its inner diameter 0.8cm. The upper part of the copper tube (M) was connected with one of the air pressure outlets, made of p.v.c. tubing, (G) from the central distributor bottle (F).

Each of the 16 culture tanks (R) was supplied with a hole of 1.7cm. in diameter, placed about 6.5cm from the bottom of the tank. This hole was fitted with a brass fitting (R) which protruded about 3.5cm. from outside and 3.0cm. from inside the tank. The outer part of this brass fitting (P) was connected with a short piece of glass tubing (N) through a nylon connector. This glass tubing was inserted in the solution delivery p.v.c. tubing (J). The nylon connector was connected with the brass fitting via an olive to prevent leaking of the solution. The inside part of the brass fitting was connected with flexible p.v.c. tubing of 22.0cm. length via a black nylon fitting (O). The other end of this p.v.c. tube was inserted in the body of a hard nylon cylinder (Q) opened from the both sides (6.0cm. in length, 4.0cm. in diameter, and 0.2cm. thickness). This nylon cylinder (P) was positioned in the centre of the culture tank (R), and placed horizontally, so that the two openings faced sideways. Then it was packed with a glass wool and its two openings were wrapped with a nylon mesh clothing. This cylinder served as a filter to retain the small particles of sand from passing into the solution delivery tubes (J). The culture tanks (R) used in the experiment were Osmaglass (C.10) expansion cisterns, sold as water tanks with a minimum capacity of 27.2 litres (6.0 gallons) to the water line, with dimensions 49.0 x 36.0 x 34.0cm. Each tank was supplied with 30 kilograms of sand to cover to a depth of 15cm. The 16 culture tanks were positioned rectangularly in a row of four above the culture bed (photograph 2.1), almost in the middle of the green house, so that each tank received an equal amount of natural light.

Photograph 2.1 : Shows the layout of the culture tanks and the tanks number in the greenhouse.

The culture bed had a length of three metres and a width of two metres, and 60cm. above ground level. The nutrient solution reservoirs (I), each of 20 litres capacity, were placed below the culture bed in the same sequence as the culture tanks, so that each container was positioned directly below its tank (photograph 2.2). The culture bed was covered completely with a black polythene sheet to exclude the light from the nutrient reservoirs and the solution delivery tubes. The exposed parts of the solution delivery tubes, above the culture bed were painted black. All the brass fittings and the copper tubes in contact with the solution were painted with a physiologically inert black paint.

This system was designed so that each culture tank has its own nutrient solution reservoir, each with its own delivery tubes, thus giving the advantage of being able to have different kinds of nutrient treatment at the same time.

2.3 Operation of the apparatus:-

The operation of the apparatus was as follows:-

1. The system was arranged to operate twice daily with 12 hour intervals. The air compressor (A) and the solenoid valve (D) were both connected to one circuit (circuit No. 1. Figure 2.1) controlled by one 24 - hour, and one 1 - hour subsidary time switch. The solenoid valve (H) was connected to a separate circuit (circuit No. 2, Figure 2.1) controlled only by one 24 - hour time switch. The two 24 - hour time switches have been synchronised to read exactly the same time.

2. At the beginning of each irrigation cycle the nutrient solutions were in the containers. Then the circuit connecting the valve (H) was switched 'on' 30 minutes before the circuit connecting the air

Photograph 2.2 : Shows the layout of the nutrient reservoirs under the culture bed in the greenhouse.

compressor (A) and the solenoid valve (D).

3. At a predetermined time, the time switch connecting the air compressor and the valve (D) opened, and the compressed air fed into the system. The adjustable escape screw clip (C) was adjusted so that the solution reached the sand surface within two and a half minutes, also at this rate any air lock in the delivery tubes due to the air bubbles would be dislodged.

4. When the solution was raised in the culture tanks to the level required, the circuit connecting the valve (H) remained 'on'. This allowed the pressure to be maintained in the system, but there was no further rise of the solution in the culture tanks.

5. At the end of the 12 hour interval the circuit connecting the valve (H) closed causing the valve to open, and the pressure in the system to fall to atmospheric, and as the pressure falls the tanks drain and the solution flows back into the reservoirs.

6. As the solution drained out of the culture tanks at the end of each cycle air was drawn down into the sand by its retreat, ensuring aeration of the roots.

2.4 Selection of the culture solution:-

To select a suitable solution for culture is very important. The solution must contain all the macro-and micro-nutrients in a balanced proportion and at the same time the pH must also be suitable for the growth of the plant. In selecting the solution frequent references were made to Hewitt (1966).

The solution finally selected in this study was that of Arnon (1938), and sometimes cited as Arnon's or Hoagland's Solution and the same as solution No. 2 of Hoagland and Arnon (1938). However, in this study the solution is referred to as Hoagland and Arnon (1938). The Table (2.1) shows the composition, molarity and the weights used in preparing each of the 10 salts. This solution has been shown to be of use in growing a wide range of species including halophytic plants. Since the solution does not have any source of sodium or chloride, this will simplify the process of increasing the salinity in the solution to the required level simply by addition the appropriate weight of sodium chloride to the prepared solution. The concentrations of sodium chloride adopted throughout the present study will be shown later in each of the forthcoming experiments.

All the chemicals used were 'Analar' grade reagents so as to minimise the effect of impurities. Reagents of the same made and grade were used throughout, for the sake of uniformity.

In preparing a solution, the proper weight of the reagent (Table 2.1) was dissolved in glass distilled water. For each salt a stock of 1,000 litres was prepared and stored in dark bottles. Iron (as Ferrous sulphate + tartric acid) was mixed in immediately before use, and added to the nutrient solution twice or three times weekly. In all weighings accuracy was maintained upto the three decimal places. The machine used for this purpose was a Mettler balance, Model B6.

In preparing the full strength solution a polythene aspirator of 25 litres was used. The proper volume from each stock was added (Table 2.1), usually the solution of calcium nitrate and ammonium dihydrogen orthophosphate was added at the end to avoid the risk of

Table 2.1 The composition of the complete nutrient solution used in the present study, according to Hoagland and Arnon (1938) formula.

Salt	Molarity	Weight	g./1000 l.	Molcular weight	ml. in a litre of nutrient solution
		(g./l.)			
1. KNO_3	0.006	0.656	656.00	101.10	2
2. $Ca(NO_3)_2$	0.004	0.656	656.00	164.10	2
(or $Ca(NO_3)_2 4H_2O$	0.004	0.945	945.00	236.15	2
3. $NH_4H_4PO_4$	0.001	0.115	115.00	115.08	2
4. $MgSO_4 7 H_2O$	0.002	0.49	490.00	246.49	2
5. Ferrous sulphate (0.6p.p.m.Fe)					
$FeSO_4 7 H_2O$		5.0		278.03	)
+					) 0.6
Tartric acid		4.0		168.10	)
		(mg./l.)			
6. H_3BO_3		2.86	2.860	61.84	1
7. $MnCl_2 4 H_2O$		1.81	1.810	197.91	1
8. $ZnSO_4 7H_2O$		0.22	0.220	287.55	1
9. $CuSO_4 5H_2O$		0.08	0.080	249.71	1
10. H_2MoO_4		0.09	0.090	161.97	1

precipitation. Then the prepared solution was mixed thoroughly by shaking the aspirator very vigorously. This solution from here onwards will be known as the normal or complete culture solution. Then the proper weight of sodium chloride was added and again the solution was mixed until the sodium chloride had dissolved completely. The reaction of the complete culture solution was about pH6. These values were read on an Electronic Instrument Ltd pH meter Model 7060. The addition of sodium chloride did not bring about any significant changes in the pH of the solution.

The new complete solution was prepared on the same day as the previous solution needed to be changed. During the process of changing the solution, the previous solution was drained out completely, meanwhile the sand surface in the culture tank was flushed with distilled water. Since the growth season was during the summer, the actual process of changing the solution was done after sunset, to avoid any effect of the sun light on the composition of the prepared complete culture solution. Before adding the new culture solution to the nutrient reservoirs the reservoirs were rinsed many times in glass distilled water, after they had been washed with hot water and detergent.

2.5 Source and treatment of the sand before use:-

The sand used in all the growth experiments was obtained from Leighton Buzzard, Bedfordshire, with a particle size of about 12 mesh.

The sand was initially washed with an ample amount of running tap water using sieve size 16 mesh to remove the smaller particles as far as possible. This process used to be repeated at least three times. Then the sand was soaked with cold 3% hydrochloric acid in a big polythene bin of 25 gallons capacity for a week. Then the acid treated

sand was leached with running tap water several times during the day, this process being repeated for three to four days. The sand was then soaked with the appropriate culture solution. The solution was changed every day until the leached of 24 hours showed no change in the pH. The sand was then ready for use. The pH indicator used for this purpose was Brom-Cresol green which has the pH range 3.8 - 5.4. Usually this process of leaching took about three weeks.

For each growth experiment a new sand sample was used, and each time the sand was treated exactly the same.

2.6 Cleaning of the glassware and the culture equipment used in the growth experiments:-

All the glassware and reagent bottles, which were used in preparation and storing of the stock solutions, and the polythene aspirator, which was used for the preparation of the complete nutrient solution, were initially washed with hot water and detergent, and then with hot hydrochloric acid : water 1:1 by volume, and then washed with an ample amount of tap water and later rinsed thoroughly in glass distilled water and dried before use for the solution work.

Initially all the culturing equipment, including the tanks, the solution reservoirs, the solution delivery tubes (p.v.c.), the glass tube connections and all the material which was in contact with the nutrient solution, were washed in the same way as above.

Before each growth experiment, all the solution delivery p.v.c. tubes, and the cotton wool of the sand filters, were changed completely. While the culture tanks and the solution reservoirs were cleaned before re-use in the same way as mentioned above, particularly in the nutrient-

deficiency experiments.

CHAPTER III

MORPHOLOGICAL BEHAVIOUR OF DIFFERENT TYPES OF *SALICORNIA* UNDER UNIFORM GROWTH CONDITIONS.

In experimental taxonomy the first step is to study the behaviour of different forms (of the same taxonomic category) of the plant in question under controlled environmental conditions and to see how these different forms behave under uniform growth conditions. This permits comparison of the behaviour of plants of unlike heredity in a uniform environment, thereby distinguishing between genotypic variation and environmental modification. Also the comparison between the progeny of similar types collected from different salt marshes, as well as between individuals which belong to the same population, may throw light on how environmental variation, due to the salt marsh habitat, results in genetic differentiation in *Salicornia*. In addition, this study also attempts to relate the morphology of the plant to the ploidy level of the types of *Salicornia* grown.

3.1 Experimental procedures:-

3.1.1 Plant collection:-

An attempt was made to grow plants belonging to the following types of *Salicornia; S. ramosissima, S. europaea,* and *S. dolichostachya.* Ten to fifteen plants were collected from well developed populations during the summer months (August - September 1973). These collections were made from Milford Haven, Hayling Island, and the Norfolk salt marshes on the English coast. The plant types collected and their respective locations can be seen in Table 3.1. The plants, after provisional identification, were exposed to the air in the greenhouse, under natural environmental conditions, until they became brown in

Table 3.1 Shows the origin of *Salicornia* types cultivated in 1974 growth experiment.

Salicornia type	Tank No.	Origin of the parent seeds.
I - *Salicornia dolichostachya*	3A	Bentlass, Pembroke river, Milford Haven : 923032.
(parent plants collected	4A	" "
from one population)	7A	" "
	12A	" "
	15A	" "
II - *S. dolichostachya*		
(parent plants collected	10B	Warham saltmarsh, Wells - next to the sea, - Norfolk: 934447
from different localities)	11B	Northney, Hayling Island Hampshire. 728042
	12B	Warham saltmarsh, Wells - next to the sea, - Norfolk. 934448
	13B	" "
	14A	Norton and Overy saltmarsh Burnham Norton, - Norfolk: TF8344
III - *Salicornia europaea*		
(parent plants collected	1B	Norton and Overy saltmarsh Brunham Norton, - Norfolk: "
from one population)	2A	" "
	5B	" "
	7B	" "
	11A	" "
	15B	" "
IV - *S. europaea*		
(parent plants collected	2B	Near Yacht Haven, Hayling Island, Hampshire: SU7201
different localities)	4B	Titchwell saltmarsh, Brancaster - Norfolk: TF7544

Table 3.1 (Continued)

Salicornia type	Tank No.	Origin of the parent seeds.
IV - *S. europaea* (Cont.)		
	6B	Northney, Hayling Island, Hampshire. 728042
	8A	Warham saltmarsh, Wells - next to the sea, - Norfolk: TF9444
	9B	Near Yacht Haven, Hayling Island, Hampshire: SU7201
	16B	Titchwell saltmarsh, Brancaster - Norfolk: TF7544
V - *Salicornia ramosissima*		
(parent plant collected	9A	Titchwell saltmarsh, Brancaster - Norfolk: TF7544
from different localities)	10A	Bentlass, Pembroke river, Milford Haven 923032
	16A	Titchwell saltmarsh, Brancaster - Norfolk: TF7544

colour and the seeds ripened. Extra caution was taken so that no mixing of seeds could take place. Each plant was then placed in a paper bag and stored in the cold room (± 5°C) throughout the winter season.

3.1.2. The growth conditions:-

In this experiment, each culture tank was partitioned into two equal sections, referred to as A and B. Each section was sown with the seeds of one parent plant. The experiment had been planned so that six tanks (sections) would be sown with the seeds of six plants belonging to *S. dolichostachya*, all collected from one population, and six tanks sown with the seed of six other plants (*S. dolichostachya*), but collected from different localities. A similar pattern was used for *S. europaea*. In addition, three tanks were sown with seeds of *S. ramosissima*. The tank numbers for each of the cultured plant groups can be seen in Table 3.1.

When sowing the seeds, caution was taken not to push them too deep into the sand. The seeds were usually sown in the tank after the nutrient solution had risen to the sand surface, which was just enough to keep it in a moist or wet condition. This conditions was maintained for the first six weeks of the cultivation period, to avoid any physical disturbance during seedling establishment. This stage of the growth period is very critical for *Salicornia* and so the plants were kept under continuous observation, particularly during the summer mid-day, to avoid the sand surface becoming too dry through evaporation. The pressure inside the culturing system was increased once the nutrient level fell. In addition each culture tank was covered with a thin transparent polythene sheet to increase the atmospheric humidity inside the culture tank and the sand surface regularly sprayed with distilled

water to dissolve any crystallized salt, particularly around the lower part of the plant.

Each culture tank was supplied with 17 litres of complete nutrient solution (Hoagland and Arnon 1938). Once germination had commenced 15 gm of Sodium chloride was added to each litre of nutrient solution bringing the total salinity up to 1.5 percent. The nutrient solution was changed each fortnight after the first six weeks. Besides the greenhouse being naturally illuminated, a light bank of 30 cool white fluorescent tubes and eight 60 - watt tungsten bulbs were added. The light bank was positioned at 80 cms. distance from the sand surface in the culture tank. This provided a light intensity of 2500 Lux at the surface.

Cultivation started with the sowing of seeds on 29th April,1974. The daily relative humidity and temperature (C^{o}) of the greenhouse throughout the 25 weeksgrowth period can be seen in the following Table (3.2). They were measured with a CASELLA Thermohygrograph.

3.1.3. Cytological technique:-

The following technique was adopted in this study for counting the chromosome number of selected specimens of *Salicornia*. It proved to give satisfactory results:-

3.1.3.1. Seed germination:-

The seeds were germinated in sterilised petridishes with three Whatman filter papers soaked with distilled water. The petridishes were then kept in an incubation room at $25^{o}C$. Germination usually started within 3-5 days, but it was found root tips of 7-10 days old gave better results.

Table 3.2 The means and range of the maximum and minimum daily temperature and relative humidity in the greenhouse

Temperature (C^{o})			Relative Humidity (%)		
	Mean	Range		Mean	Range
Maximum	29.00	20 - 33	Maximum	97.03	85 - 99
Minimum	13.26	10 - 16	Minimum	43.37	25 - 66

3.1.3.2. Staining technique and the preparation of permanent slides from root tips:-

Chromosome counts were made, from fresh material, during the metaphase stage of mitotic division. Since *Salicornia* chromosomes are small - 0.6mm - 1.8mm in length - and frequently show a tendency to aggregate (Dalby 1956), it was found necessary to pretreat the root tip to disperse the chromosomes. A saturated aqueus solution of Para dichlorobenzene (P.D.B.) was found convenient for this purpose. The germinated root tips (7-10 days old), were placed in a test tube with a few mls of saturated P.D.B. and placed in an incubator, in the dark, at 10° - 14°C (Sherma and Sherma 1972) for 2½-3 hours. This pretreatment usually gave a good separation of the chromosomes, since less than two hours achieved poor separation and more than 3 hours often caused their fragmentation. After the pre-treatment the root tips were rinsed quickly in distilled water and fixed for 12-24 hrs. in freshly prepared 1:3 glacial acetic acid: absolute ethanol (Carnoy's fluid 1886). The root tips were then placed in 70% ethanol for about one hour in which they can also be stored at a low temperature for a longer time, if required. However, in this study no slides were made from stored material. The root tips were then rinsed several times in distilled water and placed in test tubes containing 1N Hcl at 60°C in a water bath for hydrolysis. A thermometer was used to observe any change in the temperature. Hydrolysis time was between 16-18 minutes, and usually gave a good result. Hydrolysis was stopped by dipping the root tip carefully in distilled water, followed by 2-3 quick rinses. The stain used was Feulgen's Stain (Schiff reagent, supplied by Gurr, High Wycombe, Bucks, England). The root tip was usually placed in a few mls. of fresh Feulgen and kept in the dark, until the ultimate tip of the root tip appeared deep purple (about 1½ - 2 hours). Permanent slides were then made according to Schedule 2., Feulgen staining

of plant tissue (Shaw 1973).

3.2 General observation on *Salicornia* in culture:-

In general the growth techniques used proved to be very satisfactory for the growth of *Salicornia* spp. All the selected types were grown well from seeds producing well developed branches, flowers and seeds, though it seems the adopted nutrient solution (Hoagland and Arnon, 1938, Table 3.3) was comparatively rich in its nitrogen content in relation to the requirements of *Salicornia*. All the cultivated plants developed very rich vegetative growth, in comparison with those well grown plants in the field, (photograph 3.1). In addition ,the plants showed a high tendency for branching, and in many cases this resulted in some growth abnormality, such as stimulating the production of lateral branches from the normal terminal spikes, (photograph 3.3. page 91).

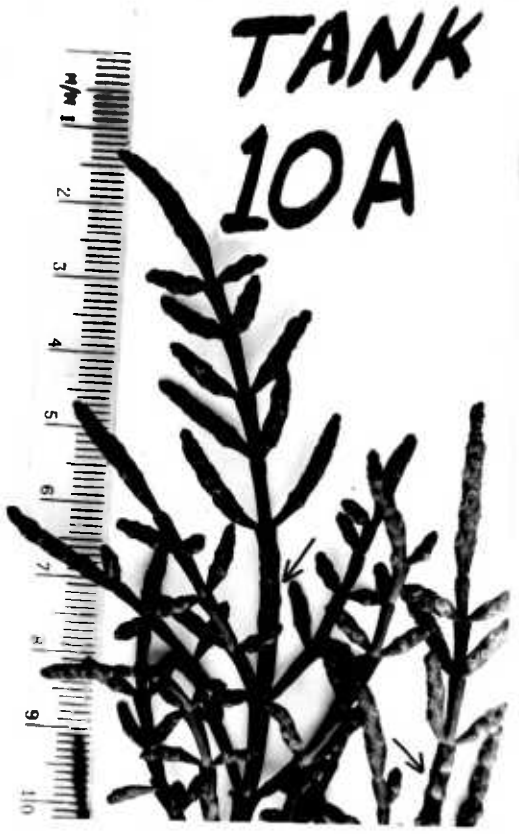
In the 3rd - 4th weeks of cultivation almost all the plants grown began to form fertile segments (terminal spike). Prior to this the plants had received a 16 hour daylight period. However, when the light period was reduced to 14 hours/day the plants returned to producing sterile segments (vegetative growth). This phenomenon is referred to here as "pre-flowering attempts". It seems that this light treatment (16 hour/day) resulted in some disturbance in the physiology of the plant, as in some plants 3 - 4 pre-flowering attempts were noticed, though the majority of the plants only showed one pre-flowering attempt, (photograph 3.2). However, this treatment did not produce any other morphological abnormality as the plant continued their normal life cycle in producing the terminal spikes and seeds.

The selected types of *Salicornia* showed differences in their

Table 3.3 Shows the concentrations as milligram equivalents per litre, and as parts per million, which are supplied to the plants grown in complete nutrient solution of Hoagland and Arnon (1938).

Elements	Mg. equiv/l	p.p.m.
Ca ++	8	160.
Mg ++	4	48
K +	6	234
N as NH_4^+	1	14
N as NO_3^-	14	196
P as PO4 ---	3	31
S as SO4 --	4	64
Mn	0.5	
Cu	0.02	
Zn	0.05	
B	0.5	
Mo	0.01	

Photograph 3.1 : Shows the enormous vegetative growth which attained by the two plants of *Salicornia; S. europaea* (11A) and *S. dolichostachya* (13B).



Photograph 3.2 : Shows *S. ramosissima* plant, with the pre-flowering phenomenon as a result of 16 hours daylight period in the early stages of growth.

flowering time, but in general the plants which belonged to *S. dolichostachya* flowered earlier than those of *S. europaea* and *S. ramosissima* by 10 days and in some cases more than two weeks. No differences were noticed between these types concerning their germination date.

Concerning the plant's colour, all the types grown were green to dark green and none of them developed the red colouration (betacyanin), which is usually developed in the field at the end of the growth season. Even the progeny of completely red plants (*S. europaea*, tank 9B), did not show the red colouration, but a few individuals developed pink spots in the perianth. All the cultured plants at the end of their flowering stage became yellowish-green or pale-green.

It was noticed that any abnormality in the terminal spike, e.g. if the terminal spike ceased to complete its normal growth, resulted in the elongation of the two upper branches. In some cases each branch behaved like the main axis in forming sterile segments and secondary branches followed by the terminal spike. In other cases, it was found that the death of the terminal spike resulted in the increase of the number of the terminal spikes originating beneath the sterile segment.

It was observed that the length of the side branches (particularly the lower ones) were affected by the degree of crowding of the plants, as the branch closest to another plant ceased to grow, while the branch of the opposite side grew much longer if no plant was close to it.

3.3. The statistical analysis of the morphological characters:-

The characters selected in the present investigation can be grouped as follows:-

1. - Vegetative morphological characters.
2. - Microscopical characters.
3. - Fertile segment ratio characters.

3.3.1. Vegetative morphological characters:-

The vegetative characters considered in this study can be seen from Table 3.4. For each type of *Salicornia* cultured, the vegetative characters were measured from 10 - 15 mature plants with the aid of a small-divisioned ruler. The mean, $\pm$ 2 standard deviations and the variance were calculated, in the appendix (Tables A.3.1 - A.3.5.). Also the significance level for each of the selected vegetative characters between the means of selected plant groups were tested using both 'F' and 't' tests. For example for each vegetative character between any two *Salicornia* types are considered significantly similar when both 'F' and 't' tests values are not significant, or if they possessed a probability of greater than 0.05. On the other hand if the value of any one of them or both ('F' and 't') showed a probability of less than 0.05, then these two means are considered significantly different.

The probability levels for each of the vegetative characters are presented separately in the form of a half similarity matrix (Figure 3.1). The presentation of the probability levels in this form enabled the calculation of similarity indices for each of the vegetative characters between the selected plant groups. The plants selected for this comparison included plants belonging to *Salicornia dolichostachya*

and *S. europaea* types, and employed individuals which originally belonged to one population, as well as individuals whose parents were collected from different localities. The similarity index was calculated as follows:-

$$\% \text{ similarity} = \frac{\text{number of significantly similar means}}{\text{number of significantly similar means} + \text{number of significantly different means}} \times 100$$

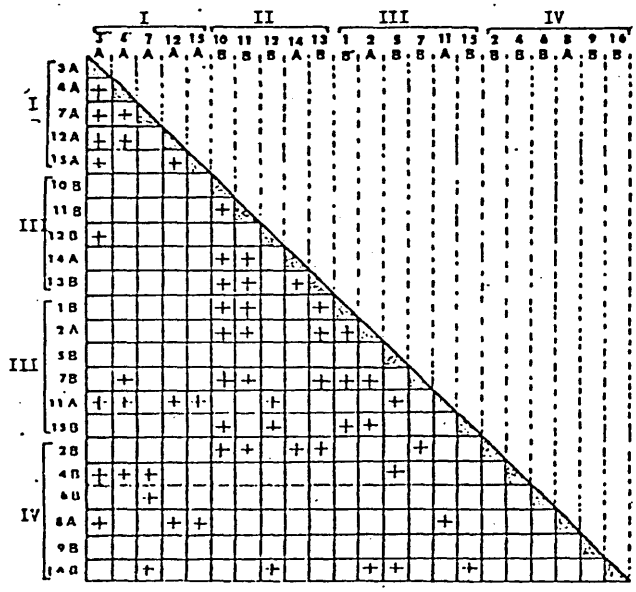
From the significance triangle (Figure 3.1) and the similarity index (Table 3.4), it can be noticed that almost all the vegetative characters of both plant types of *Salicornia (dolichostachya* and *europaea)* showed higher similarity between the types which belonged to one population than between types which originated from different localities. Table 3.4, also shows that the differences in the similarity index, between the types from one population and those from different localities, are much higher between *S. europaea* types than between *S. dolichostachya* types. In general, the vegetative characters showed higher similarity between individuals of *S. dolichostachya* than between individuals of *S. europaea*, such variation can also be noticed from figures 3.2-3.12, and photographs 3.3-3.5.

An attempt was made to relate the vegetative characters of the 25 cultivated types of *Salicornia* to the ploidy level. Simply the mean values with $\pm$ 2 standard deviation were plotted for each character in the 25 plant types (Figures 3.2-3.12). The results of this present investigation reveal that none of these vegetative characters showed a positive correlation with the ploidy level. Even such a distinctive character, in the field, as terminal spike length showed overlapping between the diploid and the tetraploid forms of *Salicornia*. For example, from Figure 3.5, it can be seen that some forms of diploid *S. europaea* showed a longer terminal spike than some tetraploid forms

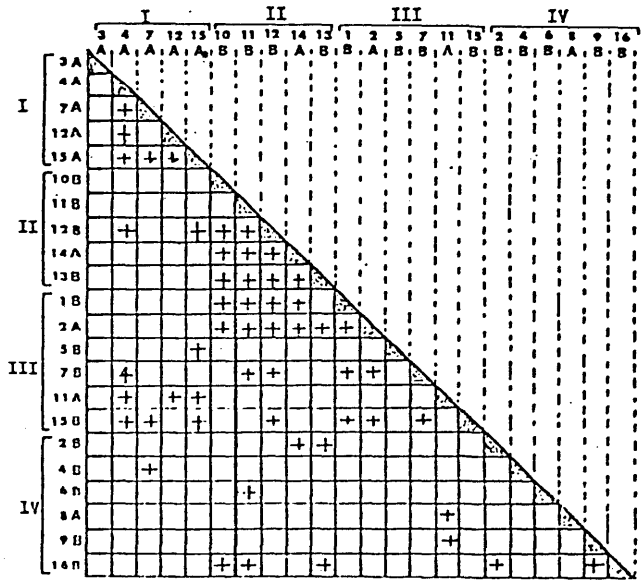
Figure 3.1 Shows the level of significance for the vegetative characters measured, between the cultured *Salicornia* groups.

⊞ Significantly similar - The values of both 'F' and 't' test are not significant, or if they possessed a probability greater than 0.05.

☐ Significantly different = The value of one or both 'F' and 't' test show a probability of less than 0.05.



1. Shoot length.



2. Total number of primary branches from the main axis.

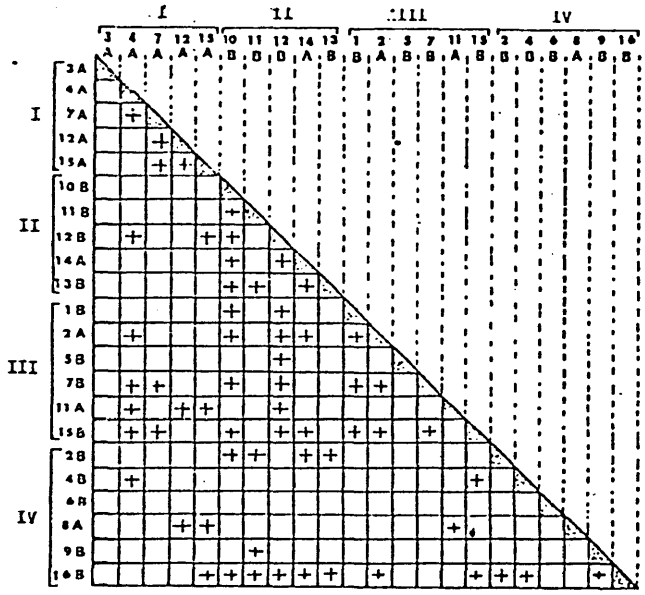
I - *Salicornia dolichostachya* (parent plants from one population)

II - *S. dolichostachya* (parent plants from different localities)

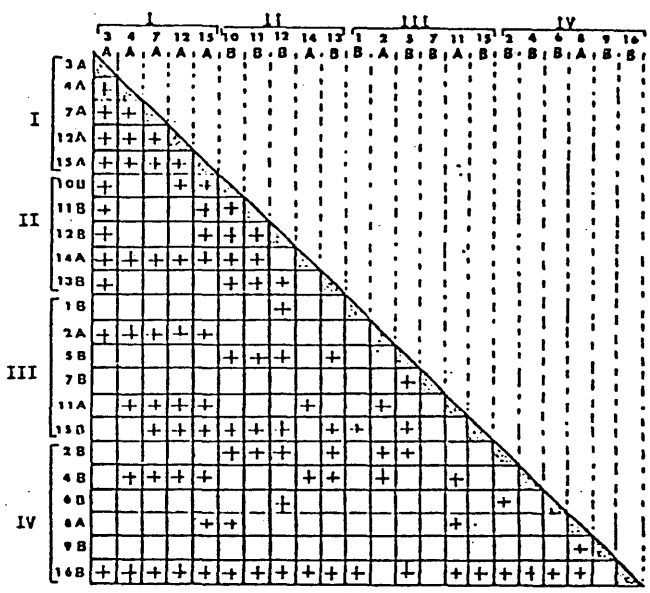
III - *Salicornia europaea* (parent plants from one population)

IV - *S. europaea* (parent plants from different localities)

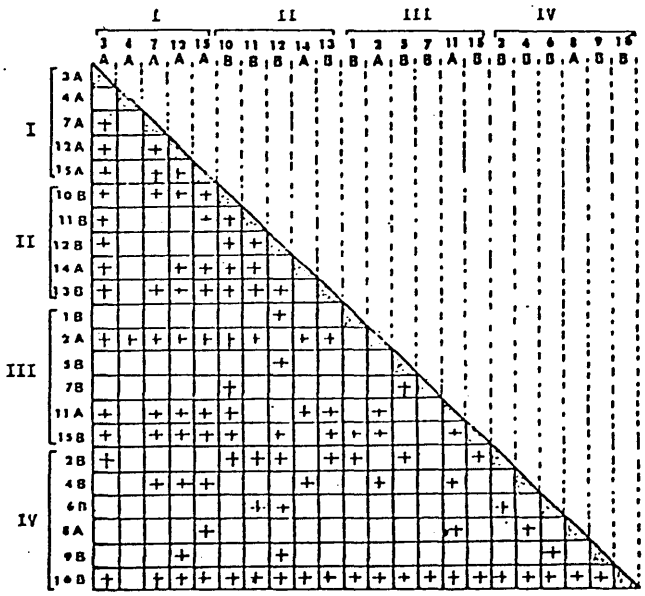
Figure 3.1 (Continued)



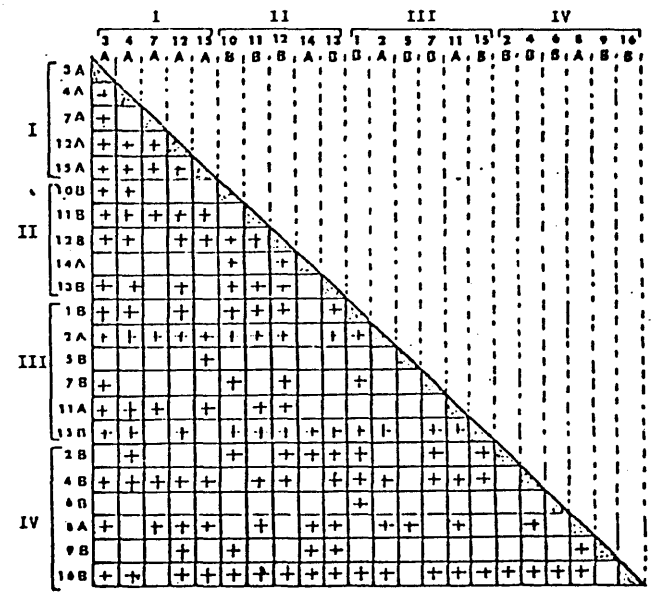
3. Number of sterile segments in the main axis.



4. Terminal spike length.

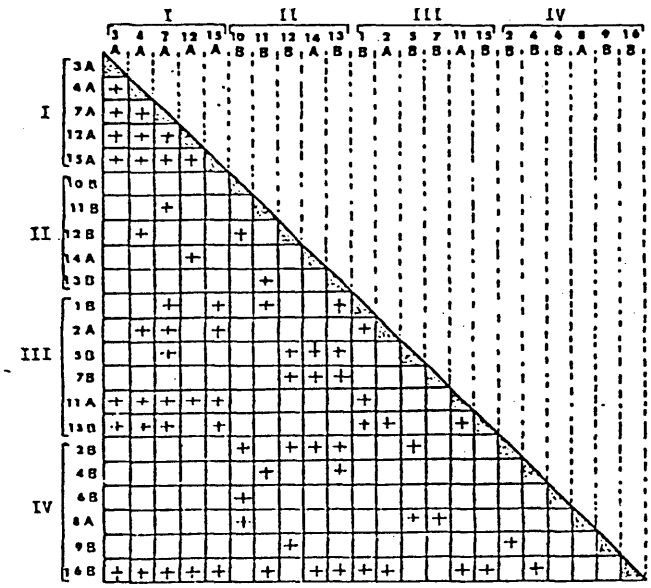


5. Number of fertile segments in the main axis.

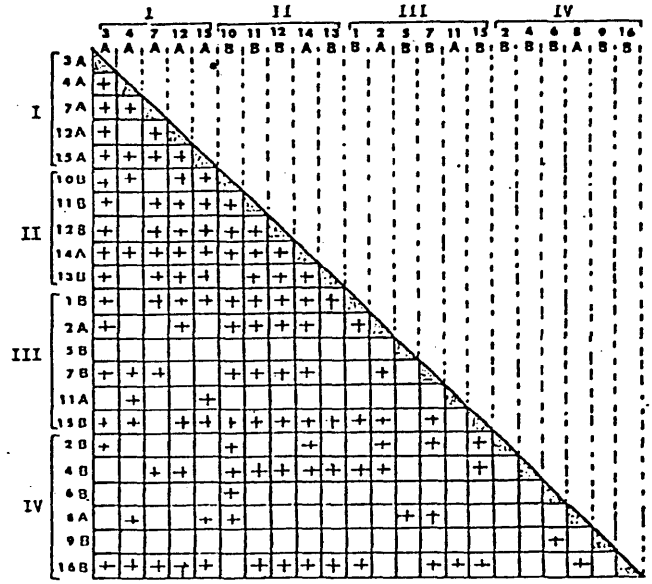


6. Length of the lowermost branch from the main axis.

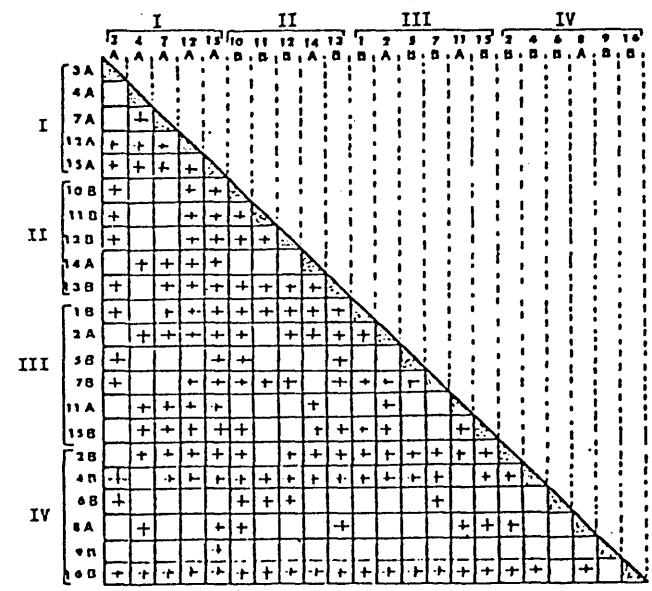
Figure 3.1 (Continued)



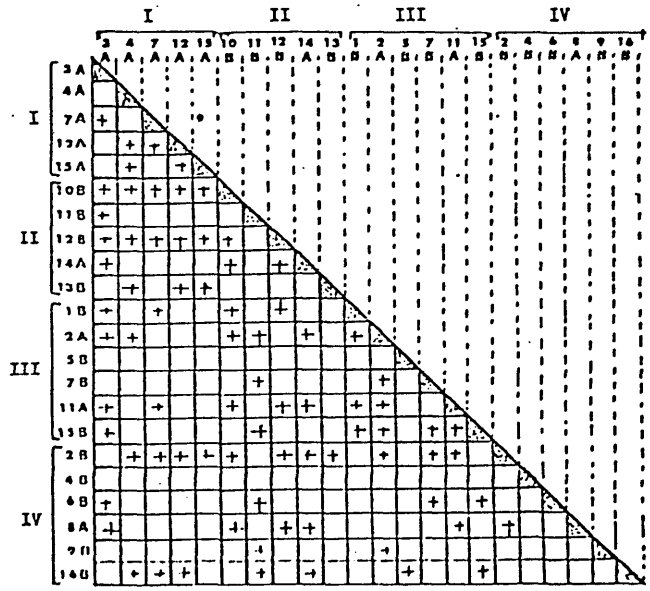
7. Angle of the uppermost branch with the main axis.



8. Angle of the lowermost branch with the main axis.



9. Length of the sterile segment below the terminal spike.



10. Length of the sterile segment in the lower part of the main axis.

Table 3.4 Shows the similarity index (in percentages) between the plants of each of the cultured *Salicornia* groups, in terms of the vegetative characters measured.

Salicornia groups / Vegetative characters	*S. dolichostachya* (plants from one population)	*S. dolichostachya* (plants from different localities)	*S. europaea* (plants from one population)	*S. europaea* (plants from different localities)
1. Shoot length	70.0	60.0	33.33	0.0
2. Total number of primary branches from the main axis.	83.33	100.0	40.00	14.0
3. Number of sterile segments in the main axis.	66.67	70.0	40.0	20.0
4. Terminal spike length	100.0	80.0	20.0	40.0
5. Number of fertile segments in the terminal spike	60.0	80.0	33.33	53.0
6. Length of the lowermost branch from the main axis.	90.0	70.0	53.33	40.0
7. Angle of the uppermost branch with the main axis.	100.0	20.0	40.0	20.0
8. Angle of the lowermost branch with the main axis.	90.0	90.0	40.0	90.0
9. Length of the sterile segment below the terminal spike.	80.0	70.0	53.33	33.33
10. Length of the sterile segment in the lower part of the main axis.	50.0	30.0	53.33	14.00

Figures 3.2-3.12 – Comparison the mean values of shoot length, total number of primary branches from the main axis, total number of sterile segments in the main axis, terminal spike length, number of fertile segments in the terminal spike, length of the uppermost branch from the main axis, length of the lowermost branch from the main axis, length of sterile segment in the lower part of the plant, length of the sterile segment below the terminal spike, angle of the uppermost branch with the main axis, and angle of the lowermost branch with the main axis respectively for the 25 cultured types of *Salicornia* of known chromosome number (2 x = diploid, 4 x = tetraploid), with ± 2 standard deviation as an estimate of the range. The 25 cultured types of *Salicornia* were grouped as follows:-

○ *Salicornia dolichostachy* (Parent plants from one population).

● *S. dolichostachya* (Parent plants from different localities).

◇ *S. europaea* (Parent plants from one population).

◆ *S. europaea* (Parent plants from different localities).

△ *S. ramosissima* (Parent plants from different localities).

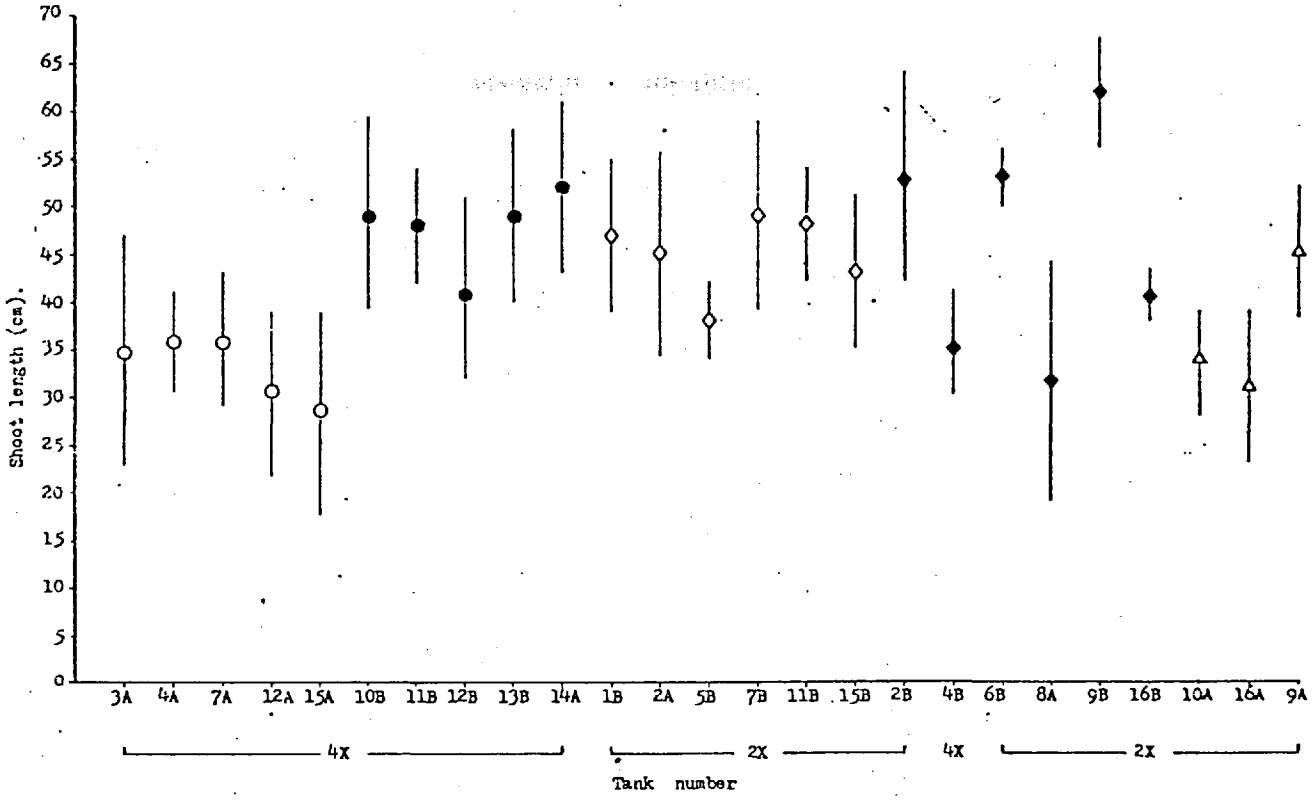


Figure 3.2.

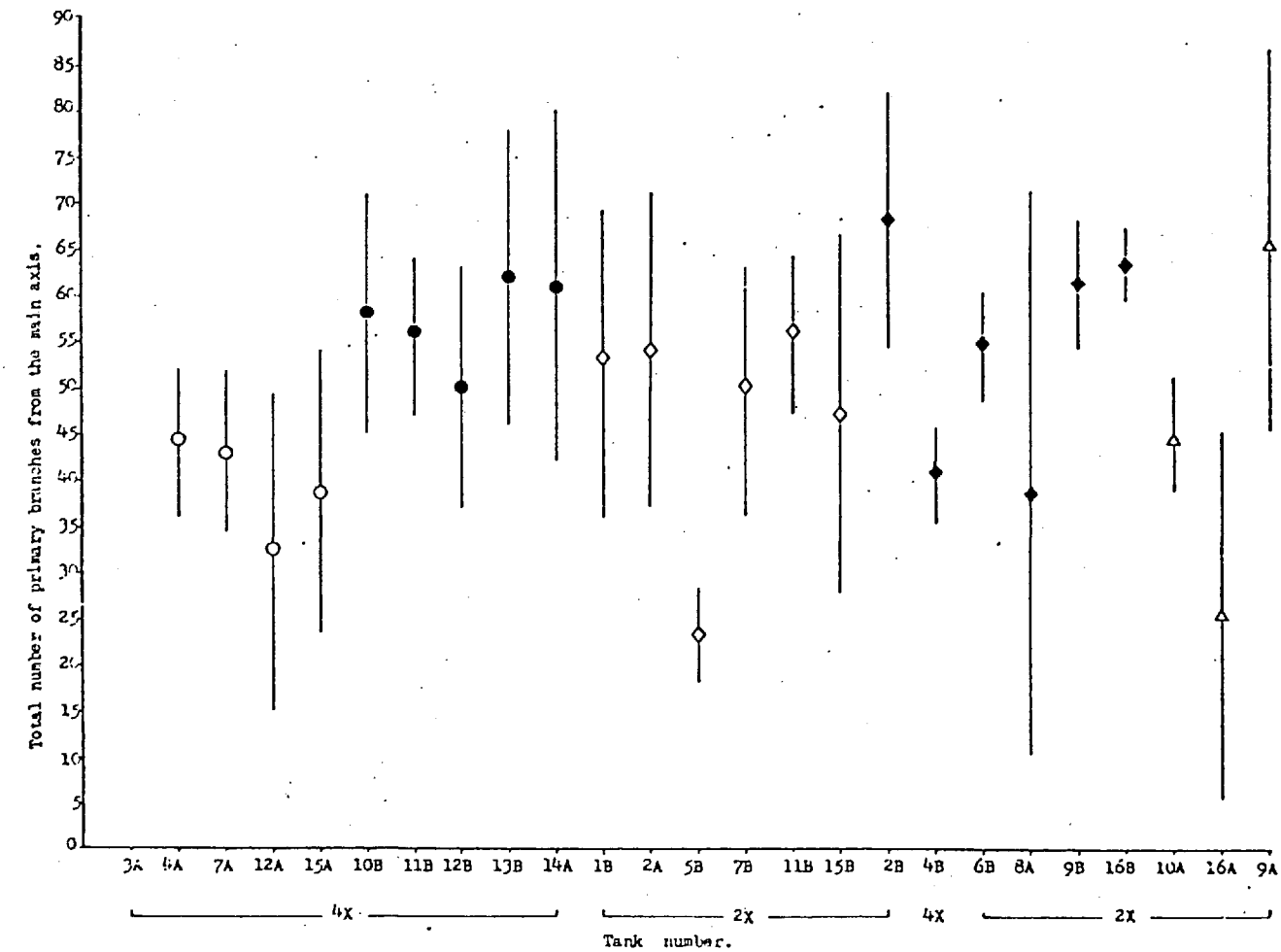


Figure 3.3

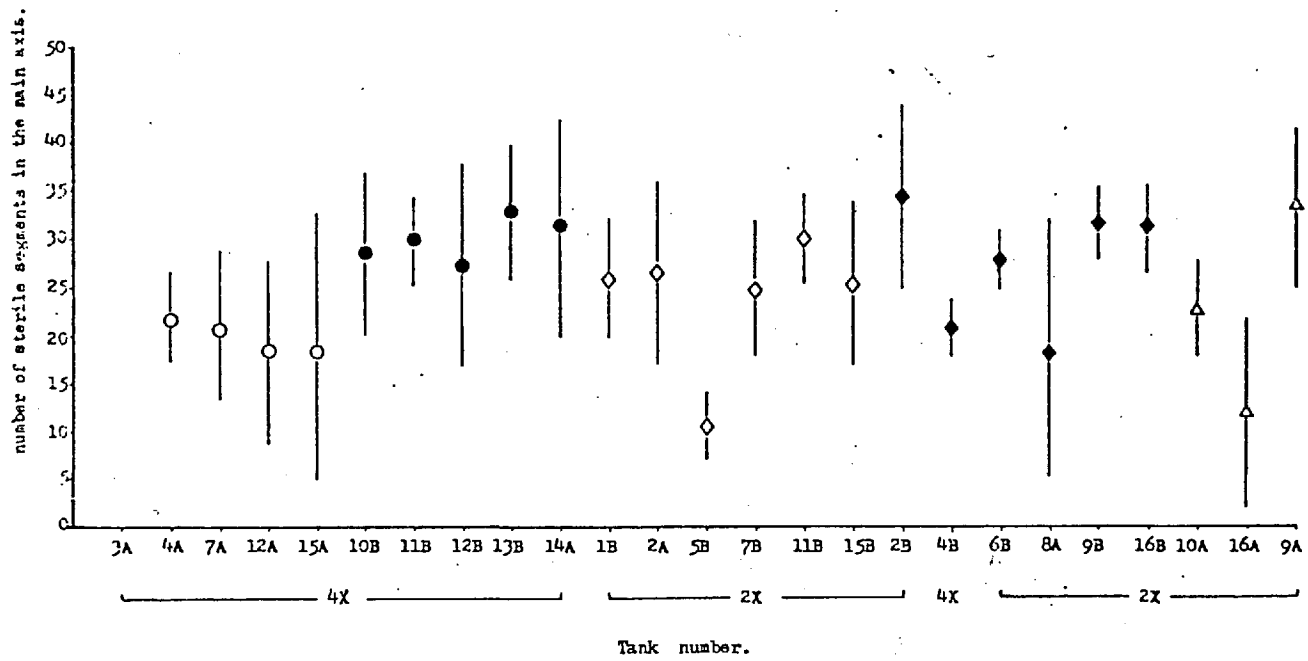


Figure 3.4

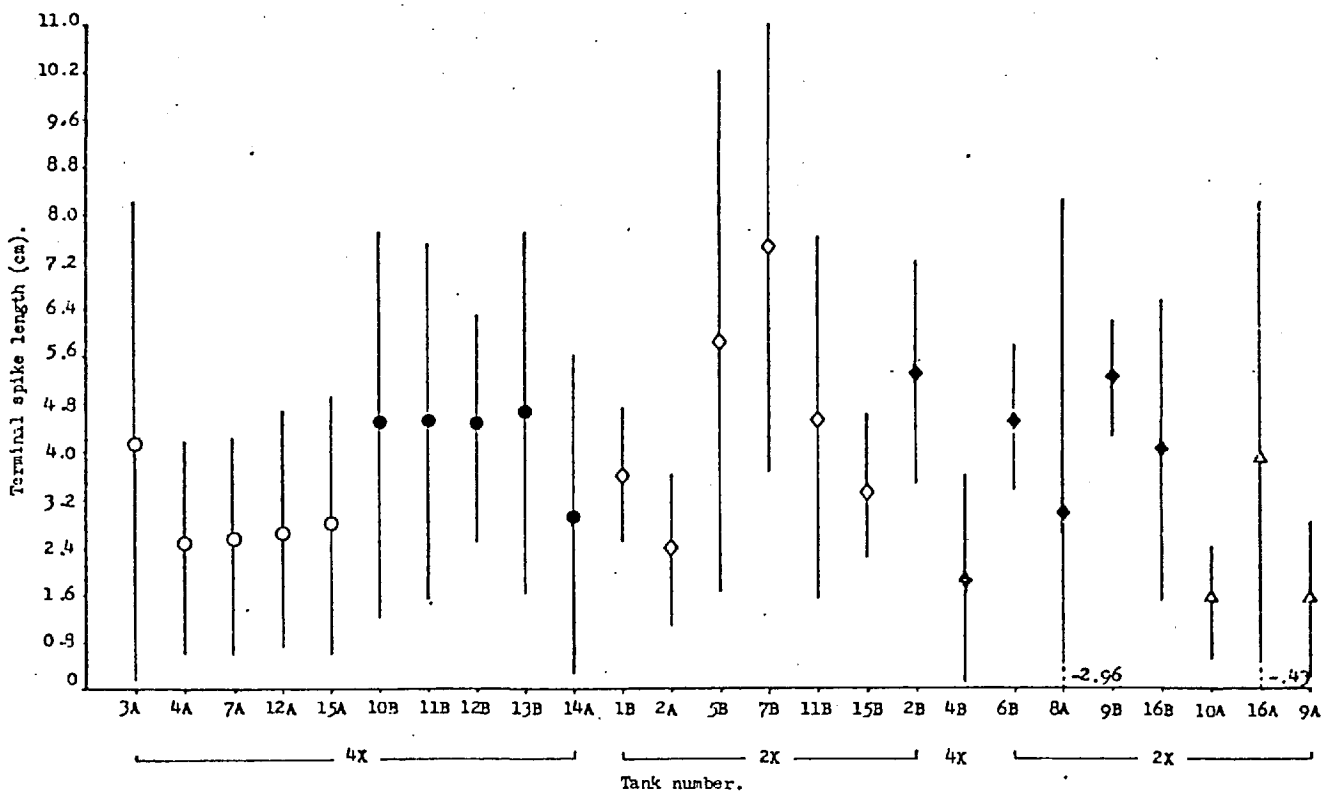


Figure 3.5

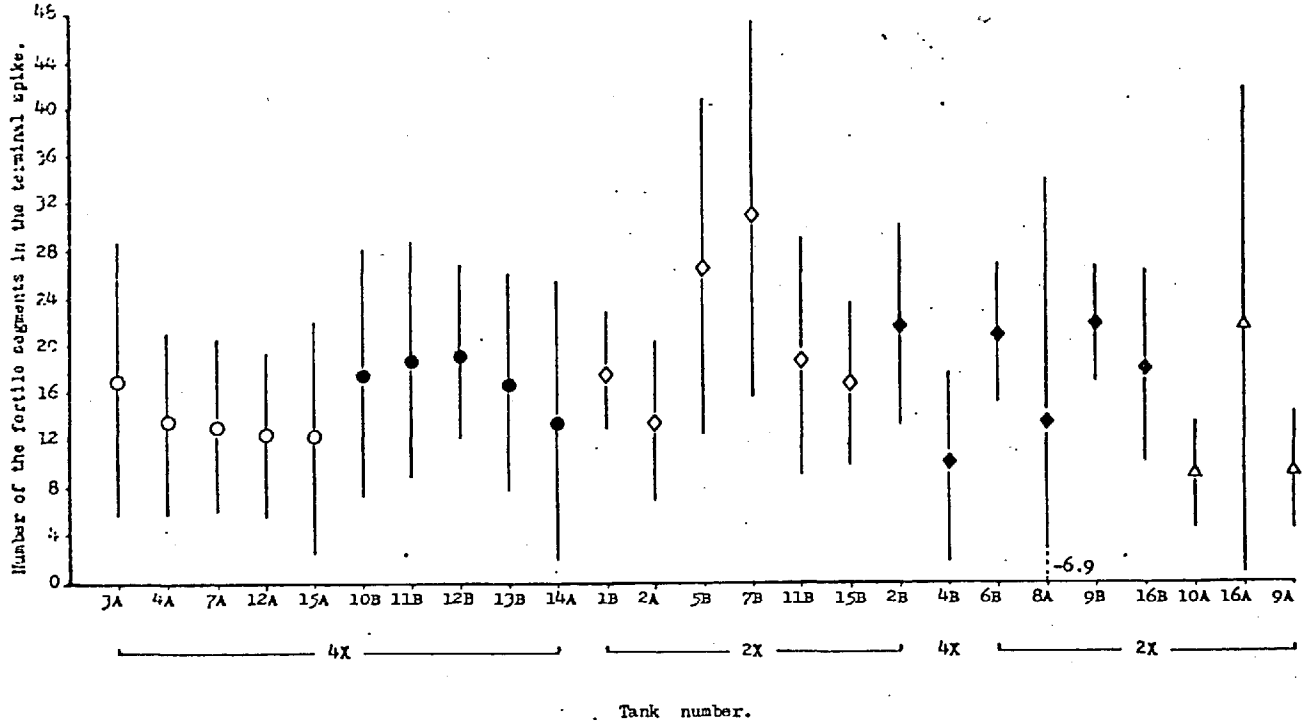


Figure 3.6

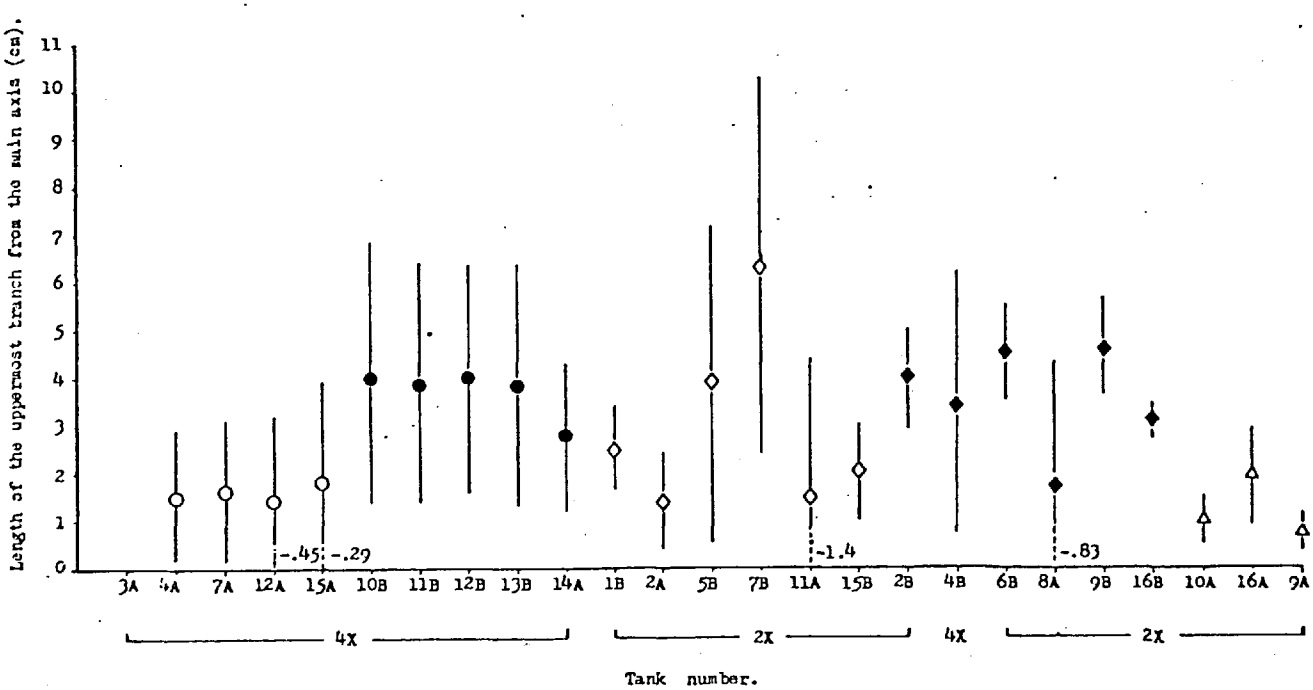


Figure 3.7

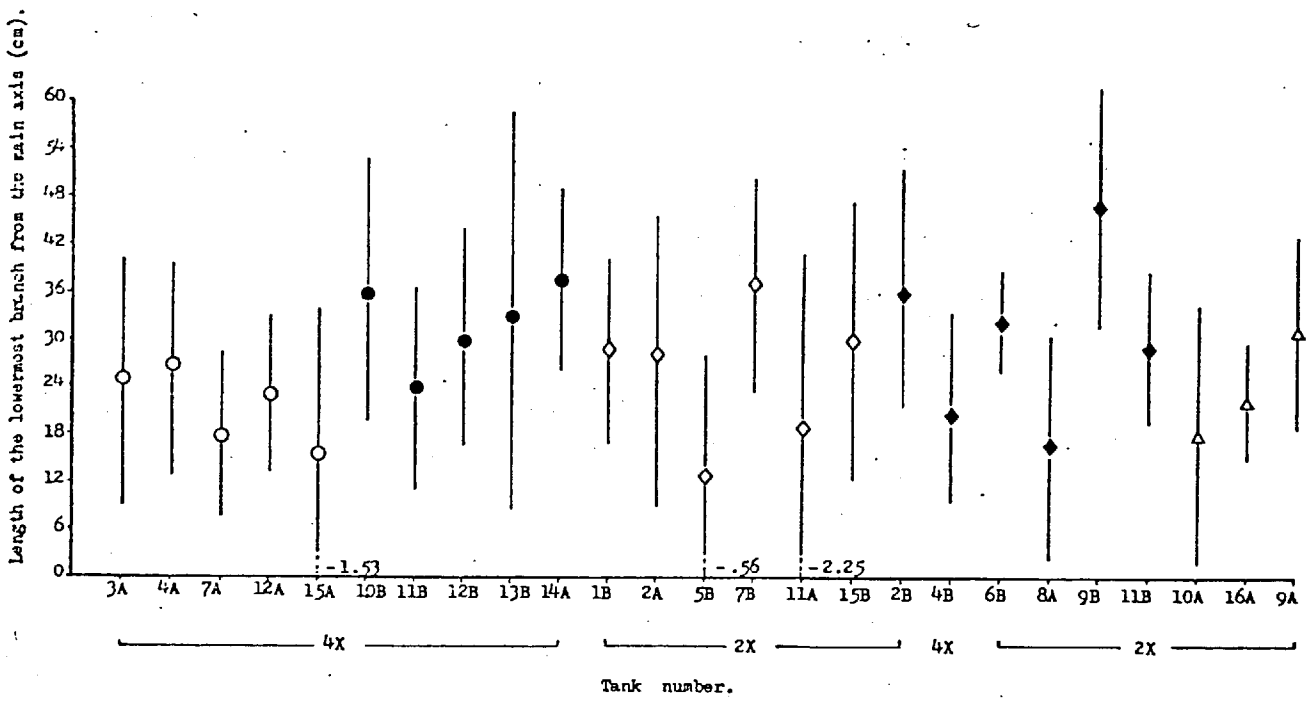


Figure 3.8.

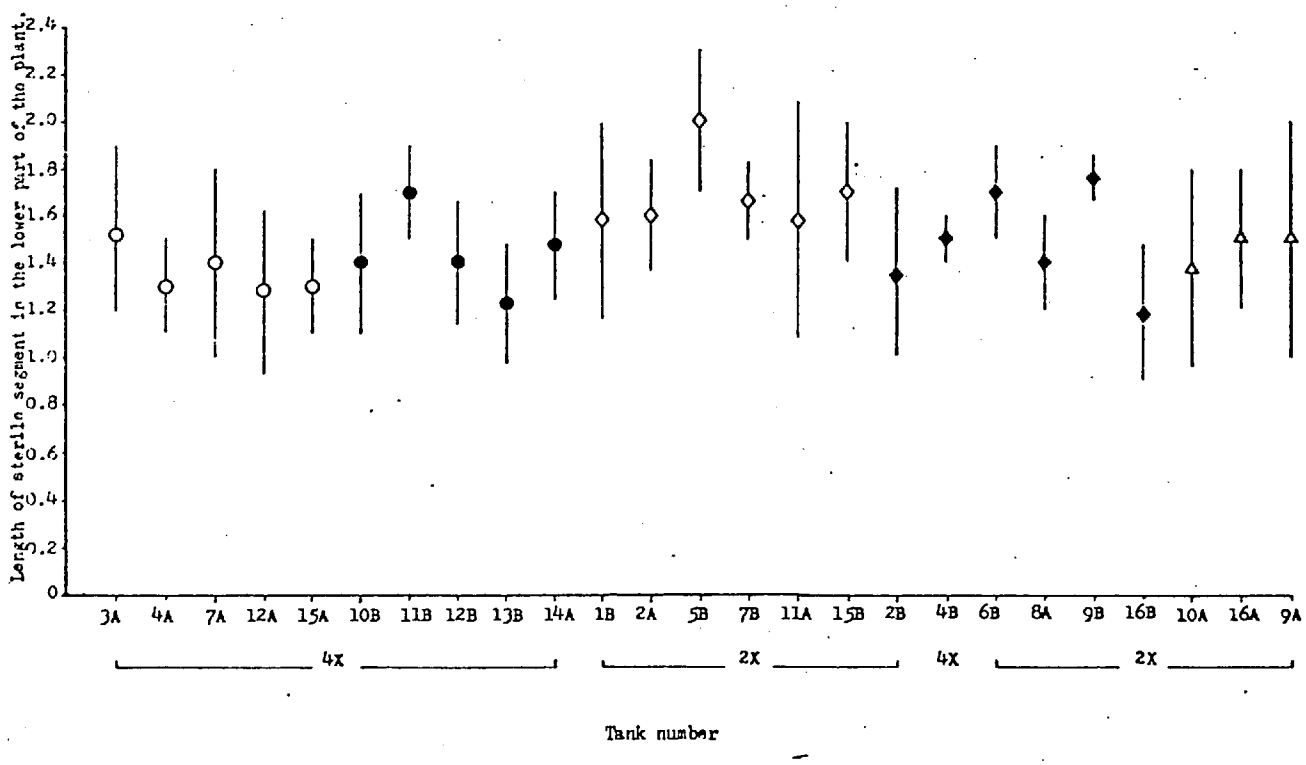


Figure 3.9

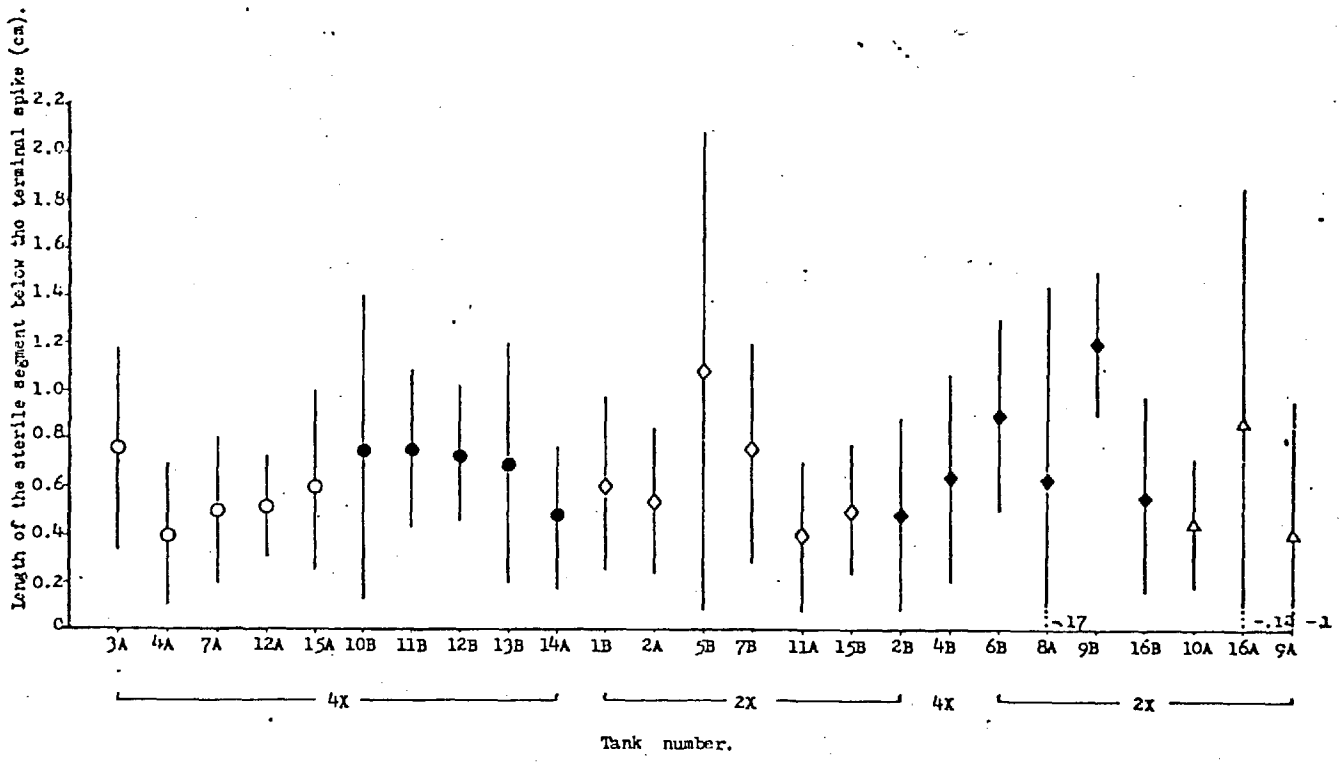


Figure 3.10

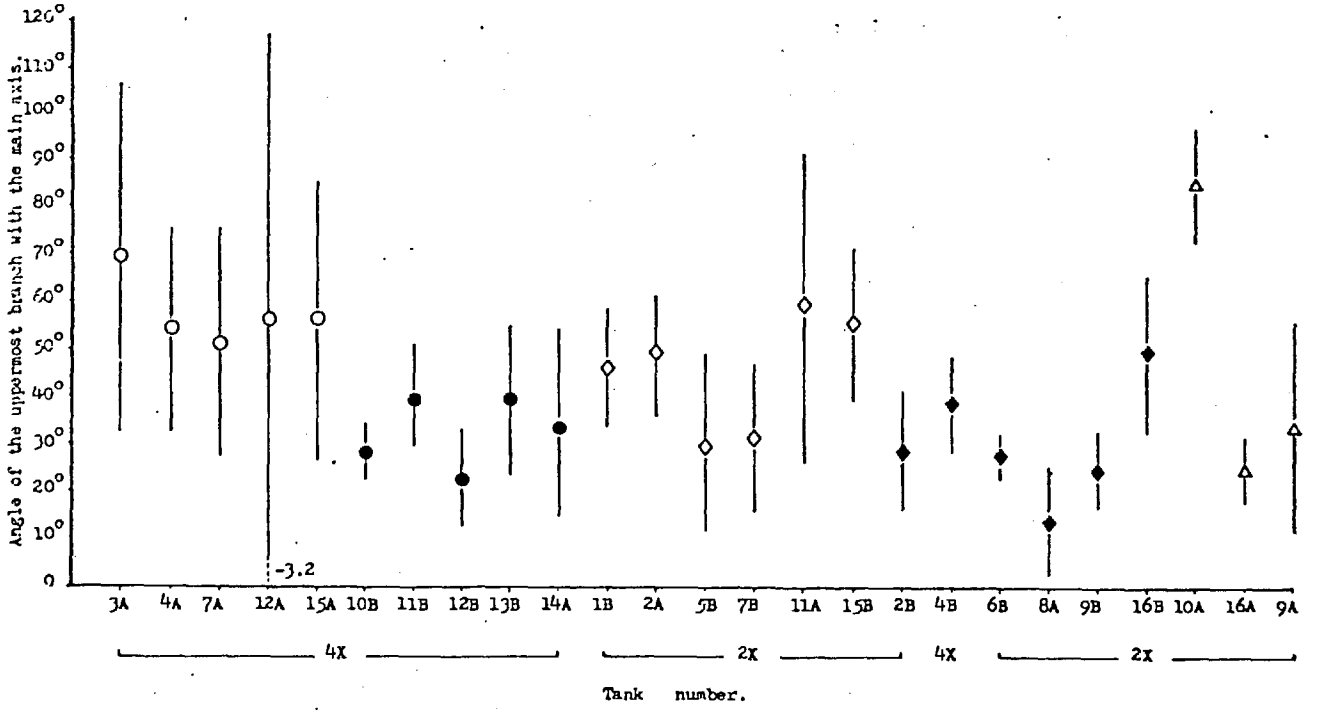


Figure 3.11

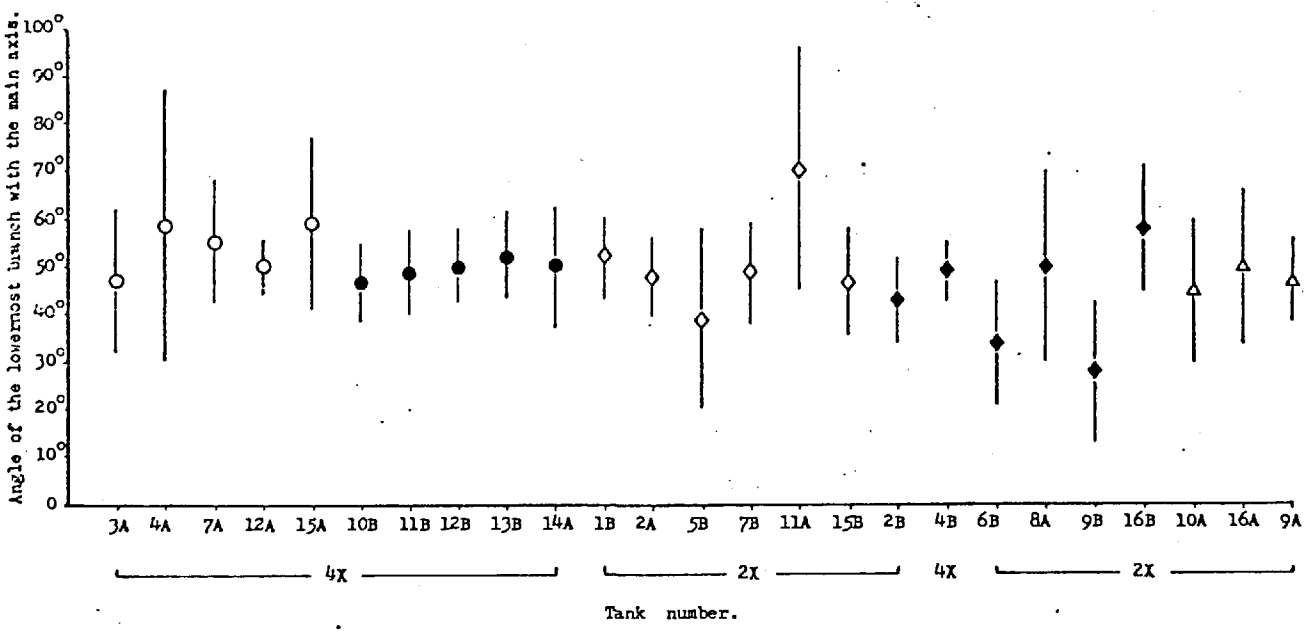
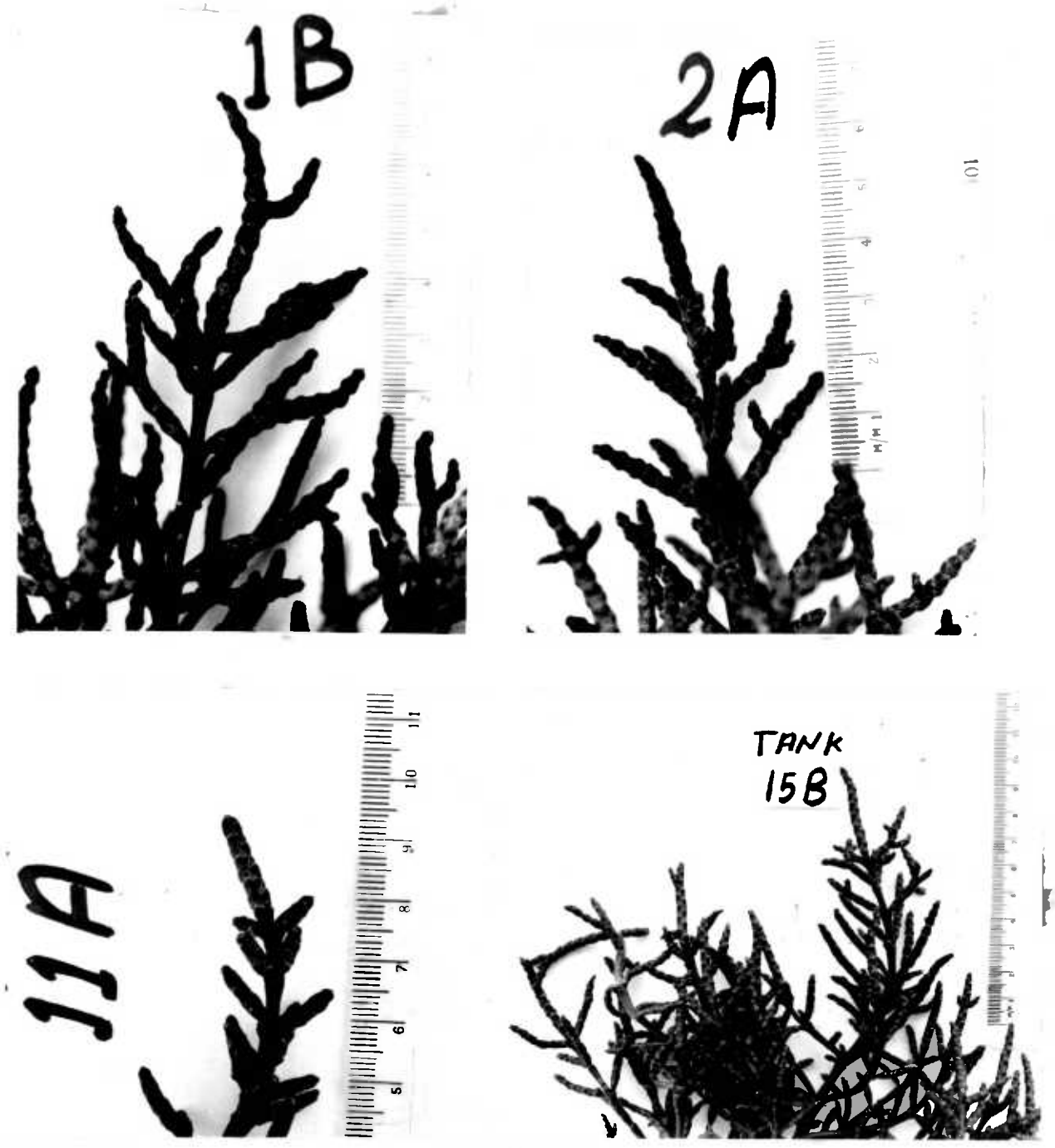
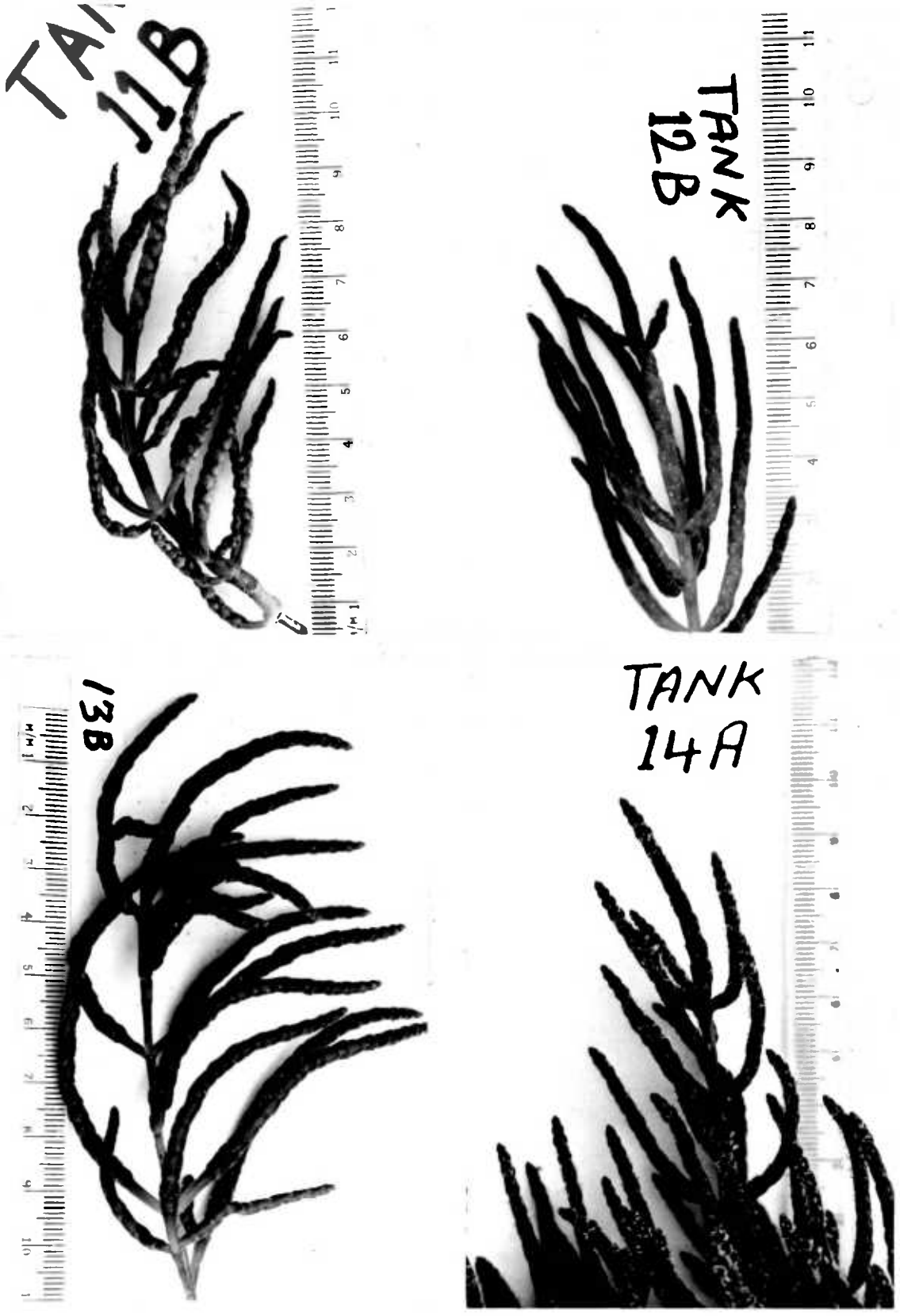

Angle of the lowermost branch with the main axis.
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0
3A 4A 7A 12A 15A 10B 11B 12B 13B 14A 1B 2A 5B 7B 11A 15B 2B 4B 6B 8A 9B 16B 10A 16A 9A
4X
2X
4X
2X
Tank number.

Figure 3.12



Photograph 3.3 : Shows four plants of *Salicornia europaea* whose parents were collected from one population. Also notice the phenomenon of producing lateral terminal spikes, may be as a result of high dosage of nitrogen, which often happened in *S. europaea* types.



Photograph 3.4 : Shows four types of *Salicornia dolichostachya* group whose parents were collected from different localities.

Photograph 3.5 : Shows four plants of *Salicornia dolichostachya* group whose parents were collected from one population.

of *S. dolichostachya*.

3.3.2. Microscopical characters:-

The microscopical characters selected in this study were the anther size, pollen grain diameter, and the stomatal length. The length of fully mature anthers was measured with the aid of an eye-piece micrometer. For each of the cultivated *Salicornia* types 50 anthers were measured, usually 5 anthers being measured from each individual plant. The fully matured anther was crushed on a slide usually in a drop of aceto-orcein to stain the pollen grains. The stomata were measured in the epidermal layer, which was stripped off the sterile segment below the terminal spike from the already fixed mature plants (fixative used was 50% ethanol). The stomatal length and the pollen grain diameter were both measured with the aid of an eye-piece micrometer, and in each case one hundred measurements were taken for each of the cultured 25 *Salicornia* types, 10 measurements being made from each individual plant. The measurements for the three characters are presented in μm, and their mean values with the ± standard error of the mean were plotted for the 25 *Salicornia* types in Figure 3.13 .

From these figures it can be seen that the anther length and the pollen grain diameter are larger in the tetraploid forms than in the diploid ones. The cultured plant types can be placed in two groups on the basis of anther length and pollen grain size. However, the pollen diameter shows more overlap between the tetraploid and the diploid. Figure 3.19 illustrates a strong relation between the pollen grain. diameter and the anther size (Page 103).

On the other hand, the stomatal length did not show positive

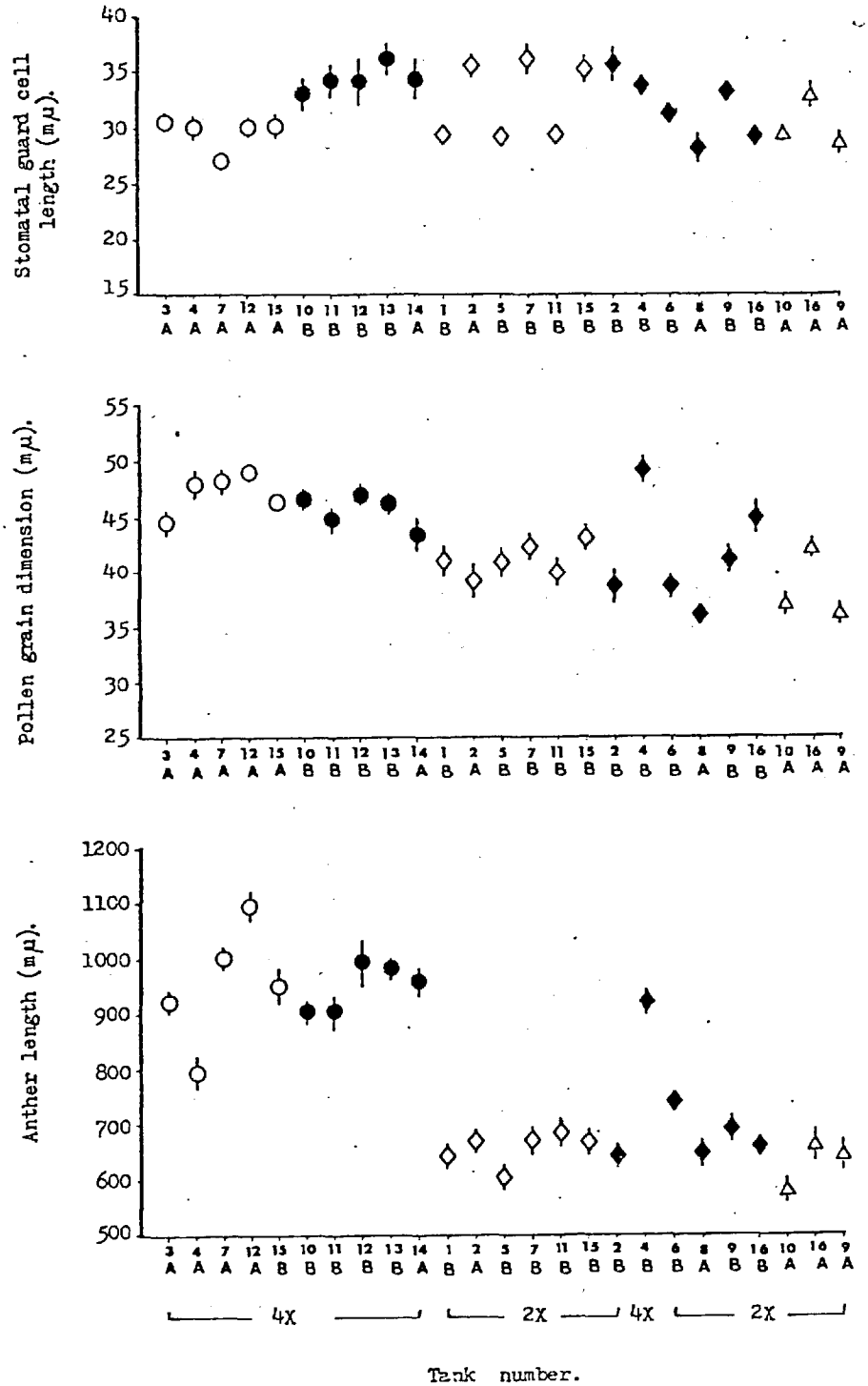


Figure 3.13 Stomatal guard cell length, pollen grain dimension and anther length means and standard error of the mean of the 25 cultured types of *Salicornia* (see page 84 for explanation of the groups).

correlation with the ploidy level of the plant types grown under controlled conditions (Figure 3.13).

3.3.3 Fertile segment ratios:-

In the present comparison 11 fertile segment ratios were cal culated (See Figure 3.14 and Page 97). The mean values of each ratio (presented as an index) are plotted for the 25 cultured *Salicornia* types in figures 3.15 - 3.19.

From the figures the ratios $\frac{D}{B}$ and $\frac{C+D}{2B}$ show the strongest correlation with the chromosome number of the plant. Both ratios for *S. dolichostachya* types showed higher values than those for *S. europaea* and *S. ramosissima* types. However, an overlap between the diploid and tetraploid form can be observed, in particular, in ratio $\frac{D}{B}$. The ratios $\frac{C}{B}$, $\frac{E}{D}$, $\frac{F}{D}$, $\frac{E-F}{E+D-F}$ and $\frac{A+B}{2C}$ also showed a positive correlation with the ploidy levels of the plant, but not as strongly as the ratios $\frac{C+D}{2B}$ and $\frac{D}{B}$. Figures also show that the diploid ratios, in general, have more variation than those of the tetraploid ratios.

On the other hand with the ratios $\frac{G}{F}$, $\frac{G}{D}$, $\frac{D-F}{E+D-F}$ and $\frac{E}{E-F}$ almost no positive relationship was observed with the ploidy level, though in the ratio $\frac{E}{E-F}$, most of the tetraploid ratios showed higher values than those of the diploid form but there was considerable overlapping, (Figure 3.17).

It will be seen from figure 3.19 that the two ratios $\frac{C+D}{2B}$ and $\frac{D}{B}$ are strongly correlated with the anther size, as in both diagrams the tetraploid ratios and the diploid ratios are well separated into two groups. Nevertheless, the former ratio $\frac{C+D}{2B}$ keeps the members of

Fertile segment ratios calculated in the present study.

1. The minimum width of the segment/maximum width of the segment: $\frac{C}{B}$

2. Length of the segment/maximum width of the segment: $\frac{D}{B}$

3. Observed length of the lateral flower/Observed length of the central flower: $\frac{G}{F}$

4. Total length of the central flower/Length of the segment: $\frac{E}{D}$

5. Observed length of the lateral flower/Length of the segment: $\frac{G}{D}$

6. Observed length of the central flower/Length of the segment: $\frac{F}{D}$

7. Distance between the apex of the central flower and the segment top/total length of the central flower + distance between the apex of the central flower and the segment top: $\frac{D-F}{E+D-F}$

8. Covered part of the central flower/total length of the central flower + distance between the apex of the central flower and the segment top: $\left(\frac{E-F}{E+D-F}\right)$

9. Minimum width of the segment + length of the segment/ 2 x maximum width of the segment: $\frac{(C+D)}{2B}$

10. Maximum width of the 2nd segment from the base + maximum width of the 4th segment from the base/ 2 x minimum width of the 3rd segment from the base: $\frac{A+B}{2C}$

11. Total length of the central flower/total length of the central flower - distance between the apex of the central flower and the segment top: $\frac{E}{E-F}$

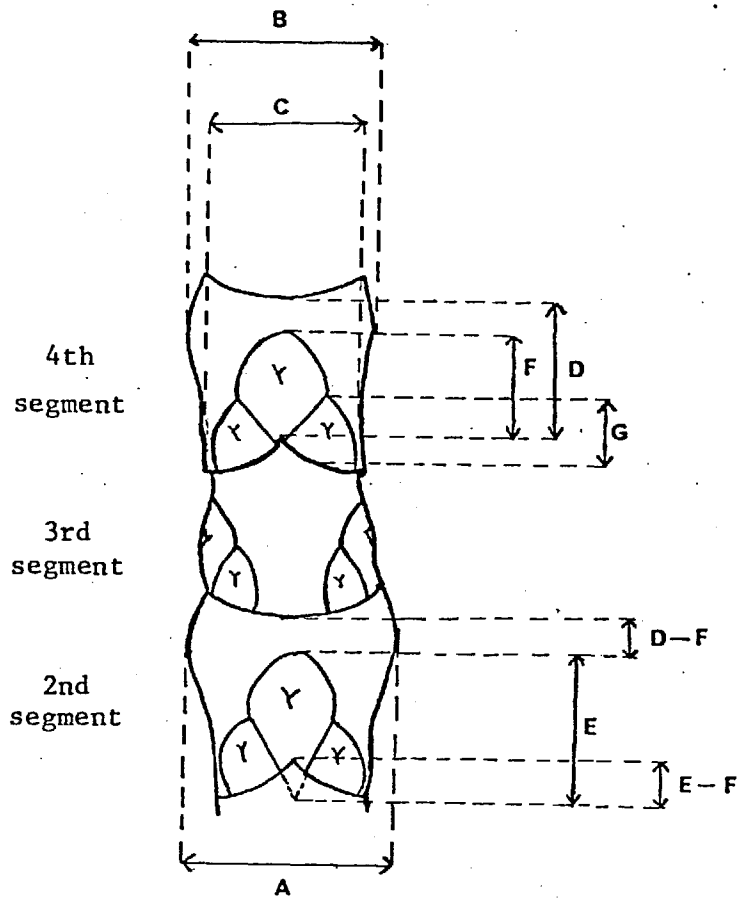


Figure 3.14 Fertile segment components which are measured in the present investigation.

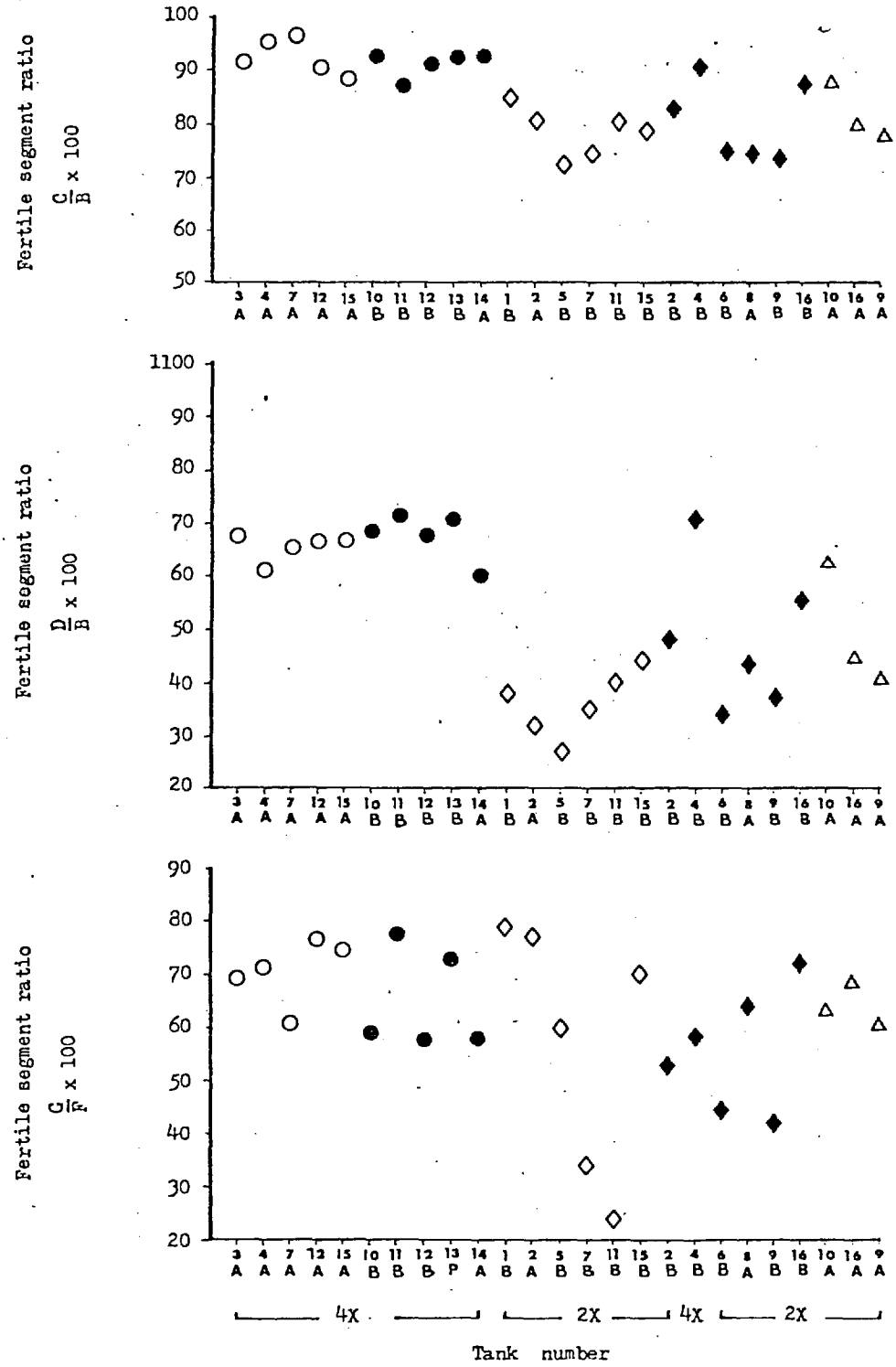


Figure 3.15 Mean values of the fertile segment ratios; $\frac{C}{B}$, $\frac{D}{B}$ and $\frac{G}{F}$ for the 25 cultured types of *Salicornia*. (See page 84' for explanation of the groups).

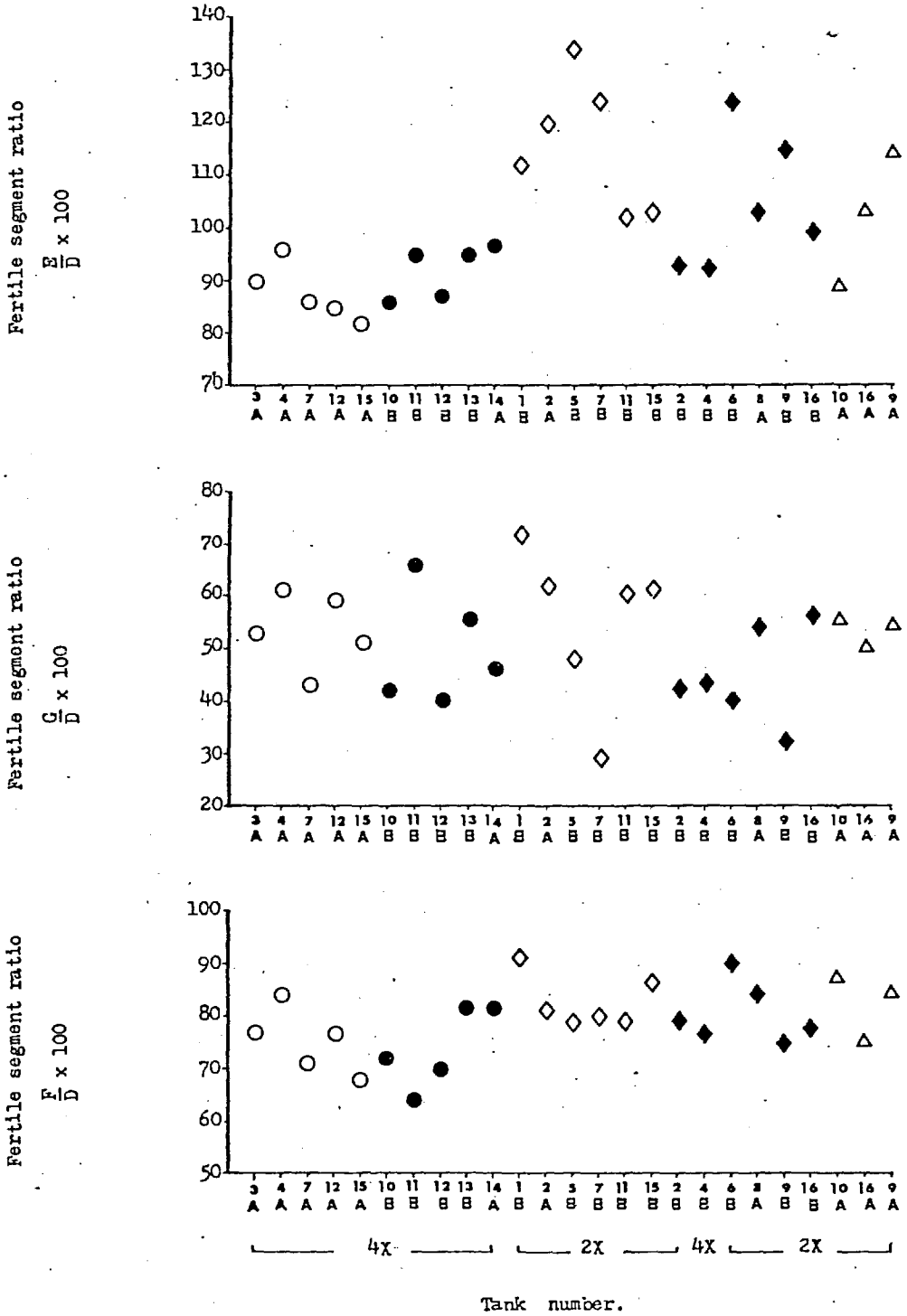


Figure 3.16 Mean values of the fertile segment ratios; $\frac{E}{D}$, $\frac{G}{D}$ and $\frac{F}{D}$ for the 25 cultured types of *Salicornia*. (See page 84 for explanation of the groups).

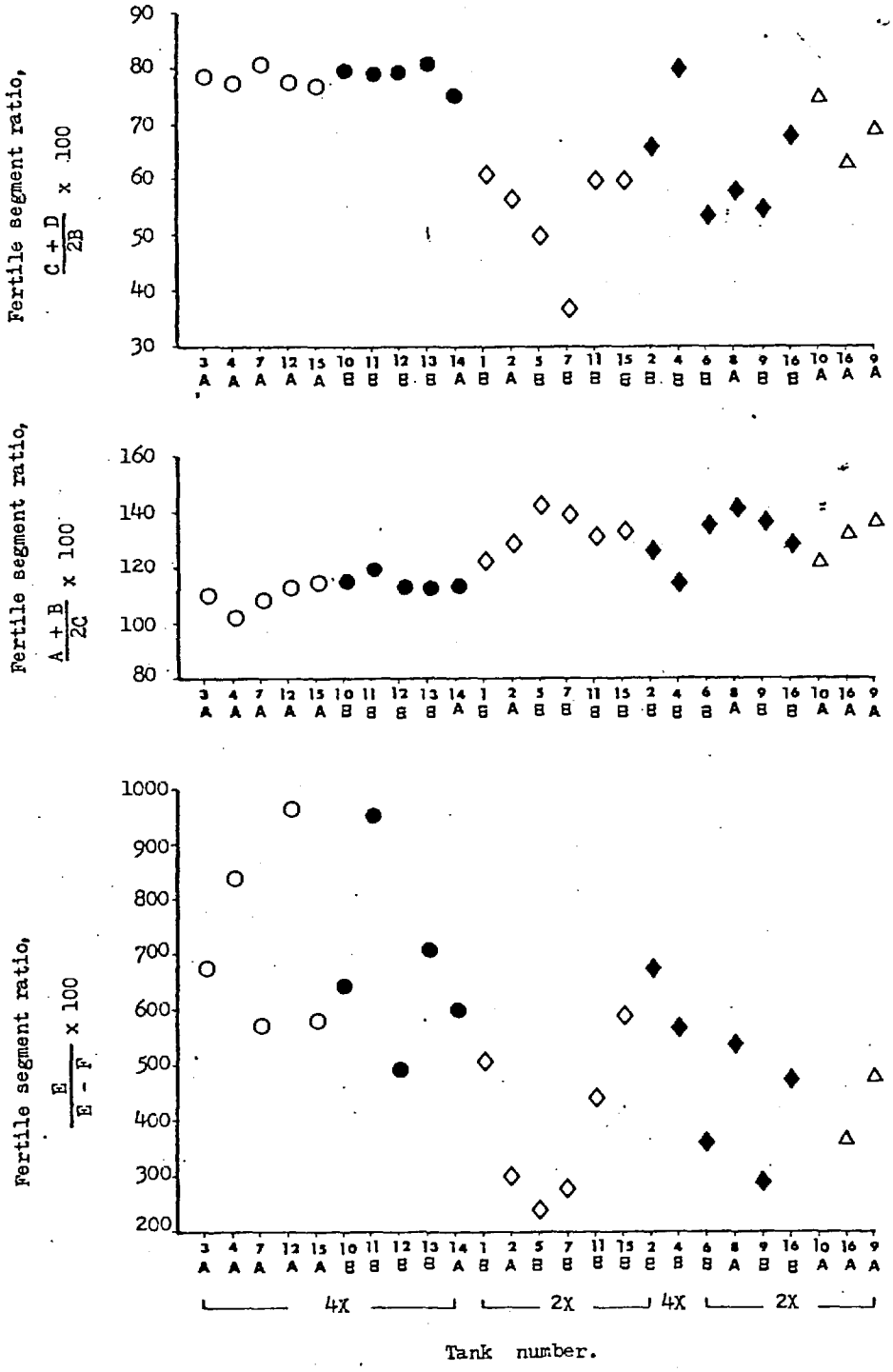


Figure 3.17 Mean values of the fertile segment ratios; $\frac{C + D}{2B}$, $\frac{A + B}{2C}$ and $\frac{E}{E - F}$ for the 25 cultured types of *Salicornia*.
(See page 84 for explanation of the groups).

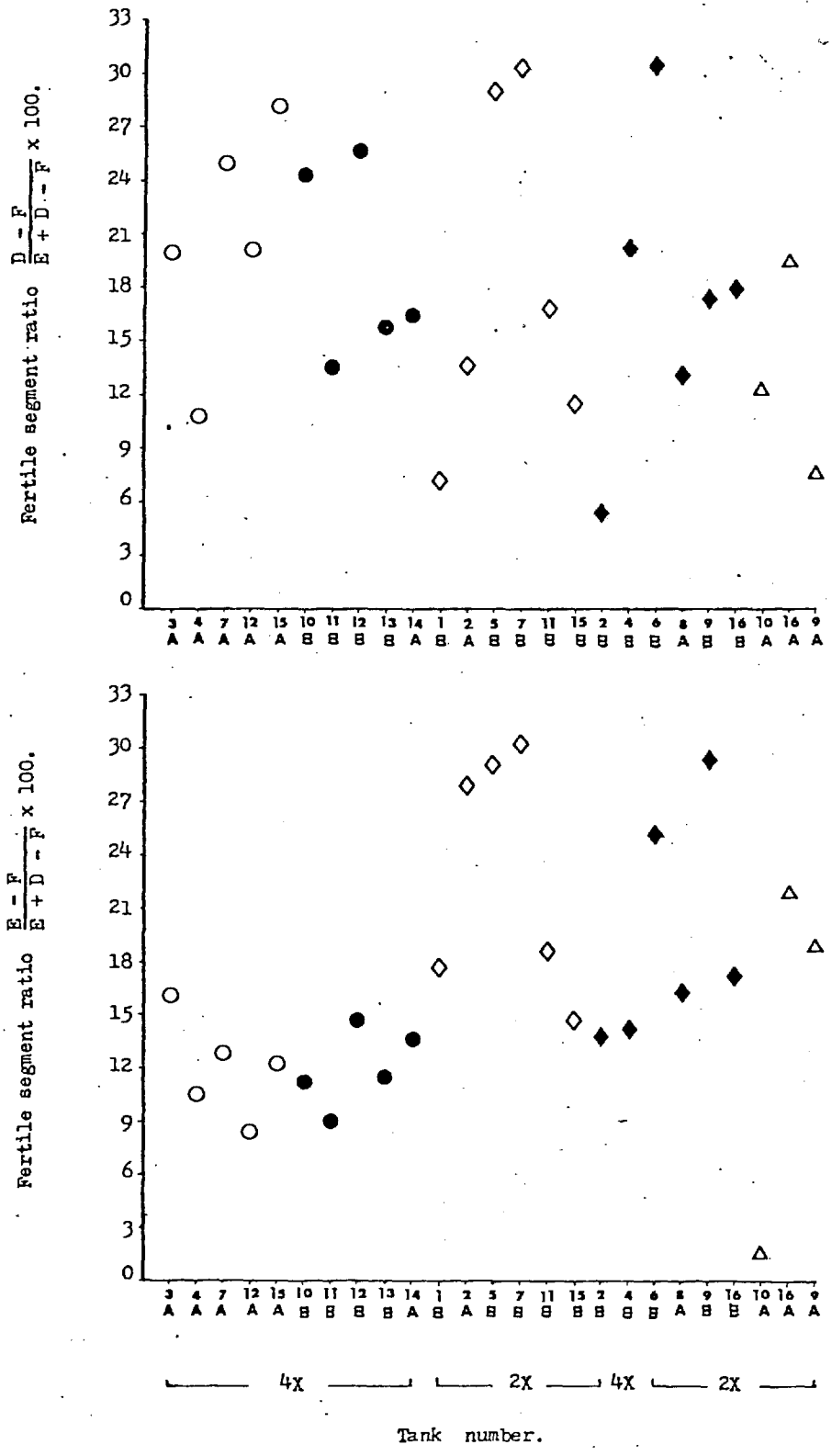


Figure 3.18. Mean values of the fertile segment ratios; $\frac{D-F}{E+(D-F)}$ and $\frac{E-F}{E+(D-F)}$ for the 25 cultured types of *Salicornia* (See page 84 for explanation of the groups).

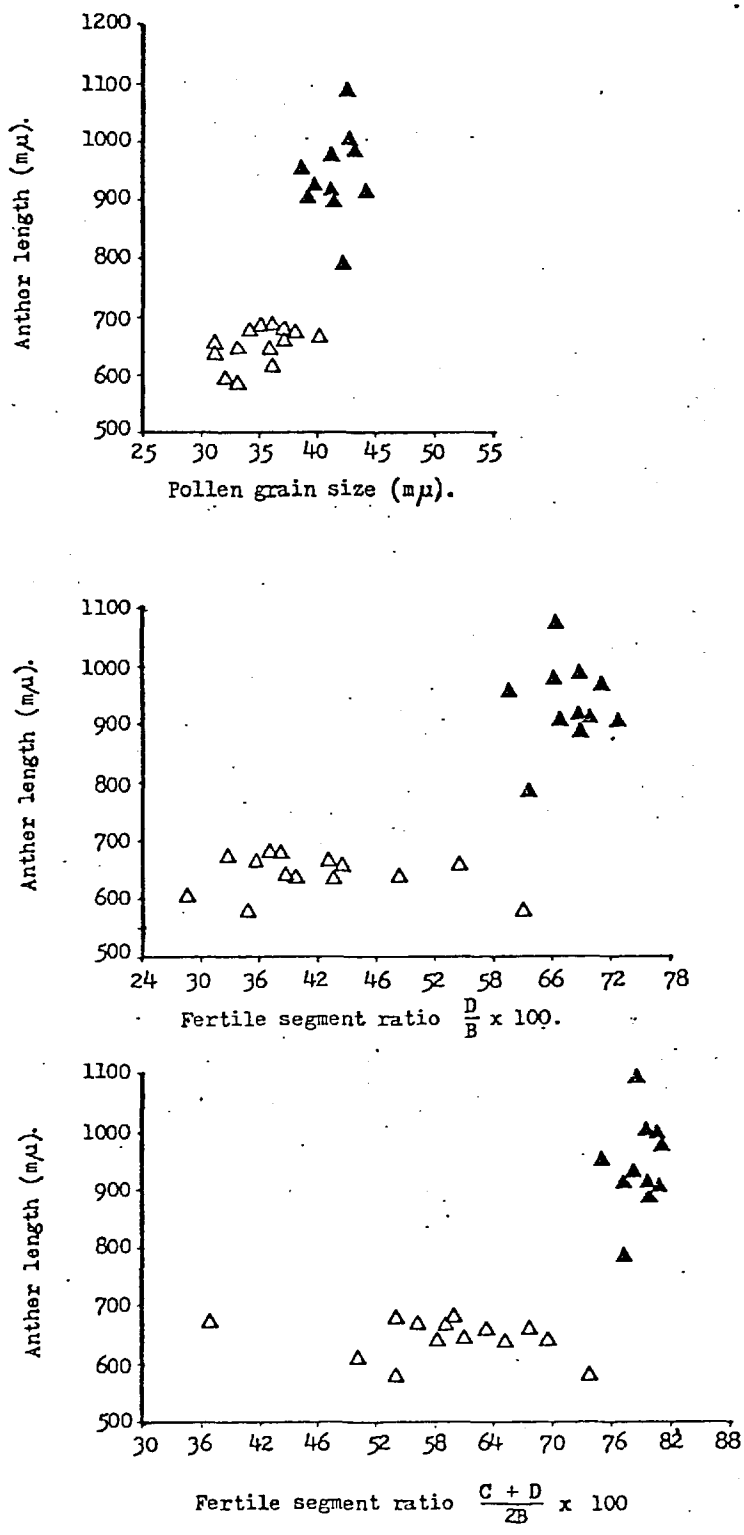


Figure 3.19 Scatter diagrams of pollen grain size and fertile segment ratios $\frac{D}{B}$ and $\frac{C + D}{2B}$ with the anther length for the 25 cultured types of *Salicornia* (Δ diploid, ▲ tetraploid).

each group (tetraploid/diploid) closer to each other, or in other words it is more strongly correlated with the anther length.

3.4 General conclusion:-

The present comparative study reveals that the different *Salicornia* types showed a significant variation in most of their vegetative characters, and thus most of the cultivated types remain distinct from each other. This was particularly so in those which belonged to *S. europaea*, in spite of the highly uniform growth conditions. The results also illustrate that the similarity index between the cultivated types of *Salicornia* was significantly higher between the progeny of one population. In addition members of *S. dolichostachya* are more similar than those of *S. europaea* in terms of the measured vegetative characters. Such phenomena can be interpreted, in part, in that such morphological variation could have existed between the parent plant populations due to genetic differentiation. Such genetic differentiation could have been caused by environmental factors which vary over the salt marsh habitat, acting differentially on specific genotypes. However, it has been proved that variation over the salt marsh could result in differentiation within salt marsh species (Gregor 1930, 1946; Chapman 1960; Aston and Bradshaw 1966, Sharrosk 1967; Hannon and Bradshaw 1968; Waisel 1972, Gray 1974). This, in part, may explain why members of *S. dolichostachya* showed more similarity in their morphological characters than members of *S. europaea*. It is known that *S. dolichostachya* usually occupies the lower marsh where conditions are considered to be less variable than those of the upper marsh, where *S. europaea* can usually be found. However, results of this kind underline the importance of seeking the limiting environmental factor or factors for the growth of *Salicornia*

in the field, and then the nature and the range of this variation on the general morphology of the plant. There is no need to point out here the importance of such an investigation in a genus in which the main boundaries between its taxa could depend on statistical analyses.

Concerning the investigation of the vegetative morphological characters with the ploidy level of the cultivated types, none of these characters showed a positive correlation with the chromosome number. On the other hand, in the microscopical investigation, (anther size, pollen grain dimension and the stomata length), the anther length showed the strongest correlation with the chromosome number, whilst the pollen size, though positively correlated, did not give as clear a separation as the anther length did. In this study the stomatal length did not show any correlation with the chromosome number. While from the calculated fertile segment ratios, only the ratios $\frac{D}{B}$ and $\frac{C+D}{2B}$ showed strong correlations with the chromosome number. However, these two ratios were also used by Ball and Tutin(1959) and Dalby(1962) respectively, to distiguish the ploidy levels(diploid v. tetraploid).

CHAPTER IV

CHROMATOGRAPHIC STUDY OF THE PHENOLICS OF *SALICORNIA* SPP.:-

Phenotypic characters are usually used in establishing the biological status of taxa at the specific and infraspecific level. However, biochemical studies can often be used as a supplement to the morphological characters in resolving difficult systematic problems, as shown by McClure and Alston (1963) on the Lemnaceae and Alston and Turner (1963) on *Baptisia*. Particularly valuable are the phenolic substances, accumulated as secondary metabolites of essential biological processes such as the biosynthesis of phenylalanine and tyrosine (Grisebach 1961). No physiological function is readily attributed to most phenolics (Alston and Turner 1963). This may indicate that they are subjected to little selective pressure and for this reason are less affected by environmental conditions than are active. Substances such as sugars or amino acids (Erdtman 1958). Brehm and Alston (1964) in their studies on *Baptisia* sound phenolic compounds to be more reliable indicators of species relationships than alkaloids or amino acids. Moreover, they are so chemically stable that they can be detected in herbarium tissues easily and rapidly (Harborne 1973a).

The objective of the current analysis was to determine the extent to which the phenolic patterns shown by the annual types of *Salicornia* could be used as a supplement to the morphological characters already established in *Salicornia*. Such an analysis might throw some light on the breeding relations in the genus, as repeatedly inbred progeny might be expected to be genetically and, hence, chemically uniform.

4.1 Plant source:-

Plants, used in the phenolic analysis were selected from those cultured in the greenhouse under standard growth conditions. The plants were chosen to represent a range of types of *Salicornia*, as well as a selection of different localities (Table 4.1). In addition, some of the parental plants of these plants (grown in the greenhouse) were also included in the study.

4.2 Preparation of the plants for analysis:-

The plants for analysis were harvested at their flowering stage (August - September, 1974). In order to avoid enzymatic activity, during the extraction process, it was preferable to work on over-dried material (Riberea-Gayon 1972). After separating the woody parts from the green parts. the plant material from each individual plant was bulked on the day of collection, and oven dried under standard conditions of 55^{o} - $60^{o}C$, in a well ventilated oven for 48 hours. The dried material was then thoroughly ground in a mortar and transferred to small paper bags and stored within nylon bags in the deep freeze (Zero ^{o}C).

4.3 Experimental procedures:-

In the following analysis, the following solvents were used:-

1. Forstel solvent; acetic acid - hydrochloric acid - water, 30:3:10 V/V (Bate-Smith 1954).
2. BAW; n- Butanol, acetic acid-water, 6:1:2 V/V , one phase, (Nordstrom and Swain 1953).
3. PhoH; phenol saturated with water.
4. 5% acetic acid in water.
5. H_2O - distilled water.
6. 10% acetic acid in chloroform.
7. 45% ethylacetate in benzene.
8. Benzene- acetic acid - water; 6:7:3 V/V.

Table 4.1 Shows plant groups and origin of material used in the chromatographic analysis.

Plant reference and species identification using T.G. Tutin et al, Flora Europaea, Vol. 1, 1964.	Tank number	Site of origin and material, and grid reference.
I - *Salicornia europaea* (parent plants collected from one population)		
Salicornia 3	1B	Salt marsh around Ovary-Norfolk:
"	2A	" 865451.
"	7B	"
"	11A	"
"	15B	"
II - *Salicornia europaea* (parent plant collected from different localities)		
Salicornia europaea	2B	Near yacht haven-Hayling Island:SU7201
" "	3B	Titchwell salt marsh-Norfolk 755442
" "	4B	"
" "	5A	"
" "	6B	Northney, Hayling Island-728041
" "	8A	Warham Saltmarsh-Norfolk-944443
" "	8B	Titchwell Saltmarsh-Norfolk-755442
" "	9A	"
" "	9B	Near yacht haven-Hayling Island-SU7201
Salicornia europaea (*ramosissima* type)	10A	Pembroke - 923032
Salicornia europaea	13A	Titchwell Saltmarsh-Norfolk-755442
" "	14B	"
Salicornia europaea (*ramosissima* type)	16B	Pembroke - 923032
III - *Salicornia procumbens* (parent plants collected from one population)		
Salicornia dolichostachya	3A	Pembroke - 923032
"	4A	"
"	7A	"
"	12A	"

Table 4.1 (Continued)

Plant reference and species identification using T.G. Tutin et al, Flora Europaea, Vol. 1, 1964.	Tank number	Site of origin and material, and grid reference.
Salicornia dolichostachya	15A	Pembroke - 923032
IV - *Salicornia procumbens* (parent plants collected from different sites)		
Salicornia procumbens	10B	Warham Saltmarsh, Norfolk-943447
" "	11B	Northney, Hayling Island - 728042
" "	12B	Warham Saltmarsh-Norfolk-934448
" "	14A	Salt marsh around Overy-Norfolk -865456
Salicornia nitens	17	Near yacht haven-Hayling Island -SU 7201
V *Salicornia pusilla*	1A	Pembroke - 923032

9. 15% acetic acid in water.

4.3.1 One-dimensional chromatographic techniques:-

The methods of Bate Smith (1962) and Harborne (1973b)were adopted in this analysis. About 7ml of 2N Hydrochloric acid was added to 0.3 gm of the powdered dried material in a test tube and the mixture heated for 30 minutes in a water bath (100°C). The cooled extract was then cleared from the plant material by centrifugation, and its colour was observed. The clear extract was transferred to a small narrow test-tube (capacity 3ml), and extracted twice with equal quantities of ethylacetate, shaking the test tube vigorously each time and allowing a separate layer to form. The two combined portions of the ethylacetate were then washed and brought to dryness under a wind current of cold air from a hair drier. The residue was then dissolved in 1-2 droplets of ethanol (95%), and chromatographed one-dimensionally on Whatman No. 1 chromatographic paper (46 x 28.0 cm).

The chromatograms were developed by the descending method in Forstal, BAW, PhoH and H_2O. The aliquot was applied in the form of spots using a Hamilton syringe, and after each application a current of cold air from a hair drier was used for drying. A distance of 5 cms. was kept between each spot. In all instances the chromatograms were developed in the dark room at a constant temperature of 25 $\pm$ °C. In the case of the BAW solvent the papers were equilibrated for 12 hours.

Since the acid hydrolysate solution remain coloured (yellowish brown - deep brown) after the extraction with the ethyl acetate, the aqueous extract was further heated for about one and a half hours in a water bath (100°C) to remove any traces of ethylacetate and re-extracted with a small volume of iso-amylalcohol. This was shaken vigorously and a

separate layer allowed to form. The alcohol layer was then removed with a Hamilton syringe and applied to the chromatographic paper. The chromatograms were developed one-dimensionally in Forstal and BAW solvents. This further extraction was undertaken so as to recover any other compounds which were not soluble in ethyl acetate (e.g. C - glycosides or Glycosylflavones).

4.3.2 Two - dimensional chromatographic techniques:-

1 :- Chromatography of the phenolic glycosides.

2 :- Chromatography of the simple phenols and phenolic acids.

4.3.2.1. Chromatography of the phenolic glycosides:-

0.5 gm of the powdered, dried, green parts were pre-extracted in the cold with petroleum ether (boiling range 40^{o} - 60^{o}C), to remove the non-flavonoid substances; in particular chlorophyll, (Mabry, et al. 1970). Then the ground plant material was dried under a current of cold air to remove the traces of petroleum ether completely. The dry powdered material was extracted with hot methanol (80%) two or three times. The combined aqueous extract with the plant material was allowed to stand in the dark over night at room temperature (about 25^{o}C). The next day, the aqueous extracts were shaken vigorously, several times, and then centrifuged at a speed of 5-6 X1000 R.P.M., for about 20 minutes (as the ground material of *Salicornia* showed a high ability to float on the surface of the aqueous extract). The machine used for this purpose was MSE Superminor.

The volume of the clear aqueous extract was reduced under vacuum to one ml. at 25^{o} - 30^{o}C; by means of Bochi rotatory evaporator. Portions of the concentrated extract were then spotted on the corner of a square sheet of chromatographic paper (45 x 45 cm.). The chromatograms were

developed two-dimensionally in BAW as the first solvent and 5% HOAC as the second solvent. A portion of the concentrated extract was also spotted on thin layer plates of cellulose MN 300 (20 x 20 cm.) supplied by polygram, Macherey - Negel + Co. Germany), and run two - dimensionally in BAW and 5% HOAC.

4.3.2.2. Chromatography of simple phenols and phenolic acids:-

The method of Harborne (1973b) was used for extraction. Portions of the previous concentrated aqueous extract were subjected to acid hydrolysis by adding equal volumes of 2N hydrochloric acid and heating for 30 minutes in a water bath (100°C). The cooled acid hydrolysate was transferred to a small narrow test tube (capacity 3 ml.), and extracted twice with equal portions of ether. The combined portions of ether were washed and brought to dryness under a current of cool air. The residue was redissolved in 2 or 3 drops of ethanol. Half of the ethanol extract was spotted on one corner of Silica gel plates (20 x 20 cm.), and was run two - dimensionally in the solvents; 10% acetic acid in chloroform as the first solvent and 45% ethylacetate in Benzene as the second solvent to detect simple phenols. The other half of the ethanol extract was spotted on one corner of cellulose plates MN300 (20 x 20 cm.) to detect phenolic acids. The plates were run two - dimensionally in the solvent Benzene-acetic acid - water 6:7:3 V/V in the first direction, and in 15% HOAC as the second solvent.

4.4 Results

4.4.1 One - dimensional chromatography of the direct acid hydrolysates:-

The results of the chromatographic analysis of the direct acid hydrolysates, developed in the solvent; Forstal, BAW, PhoH, and H_2O of the studied individuals of *Salicornia*, are presented in Table 4.2, in the form of presence/absence data (+/-). The R_F values and the appear-

Table 4.2 Results of one-dimensional chromatograms of the direct acid hydrolysates extract in the four solvents.

Solvents/ spots number / Plant reference and Plant groups	Forstal			BAW				PhoH				H_2O			
	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4
1A - *Salicornia pusilla*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
16A - *S. ramosissima*	+	+	+	+	+	+	+	+	+	−	+	+	+	−	+
10A *S. ramosissima*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2B *S. europaea*	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+
6B "	+	+	+	−	+	+	+	+	+	−	+	+	−	+	+
8A "	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+
16B "	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+
5A "	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8B "	+	+	+	−	+	+	+	+	+	−	+	+	+	−	+
9A "	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+
13A "	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+
1B "	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+
2A "	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+
5B "	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
7B "	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
11A "	+	+	+	+	+	+	+	+	+	−	+	+	+	−	+
15B "	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3B "	+	+	+	+	+	+	+	+	+	−	+	+	+	−	+
14B "	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+
4B "	+	+	+	−	+	+	+	+	+	−	+	+	+	−	+
3A *S. procumbens*	+	+	+	−	+	+	+	+	+	+	+	+	+	+	+
4A "	+	+	+	−	+	+	+	+	+	+	+	+	+	+	+
7A "	+	+	+	−	+	+	+	+	+	+	+	+	+	+	+
12A "	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+
15A "	+	+	+	−	+	+	+	+	+	−	+	+	+	−	+
10B "	+	+	+	−	+	+	+	+	+	+	+	+	+	+	+
11B "	+	+	+	+	+	+	+	+	+	−	+	+	−	+	+
12B "	+	+	+	+	+	+	+	+	+	−	+	+	+	−	+
14A "	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+

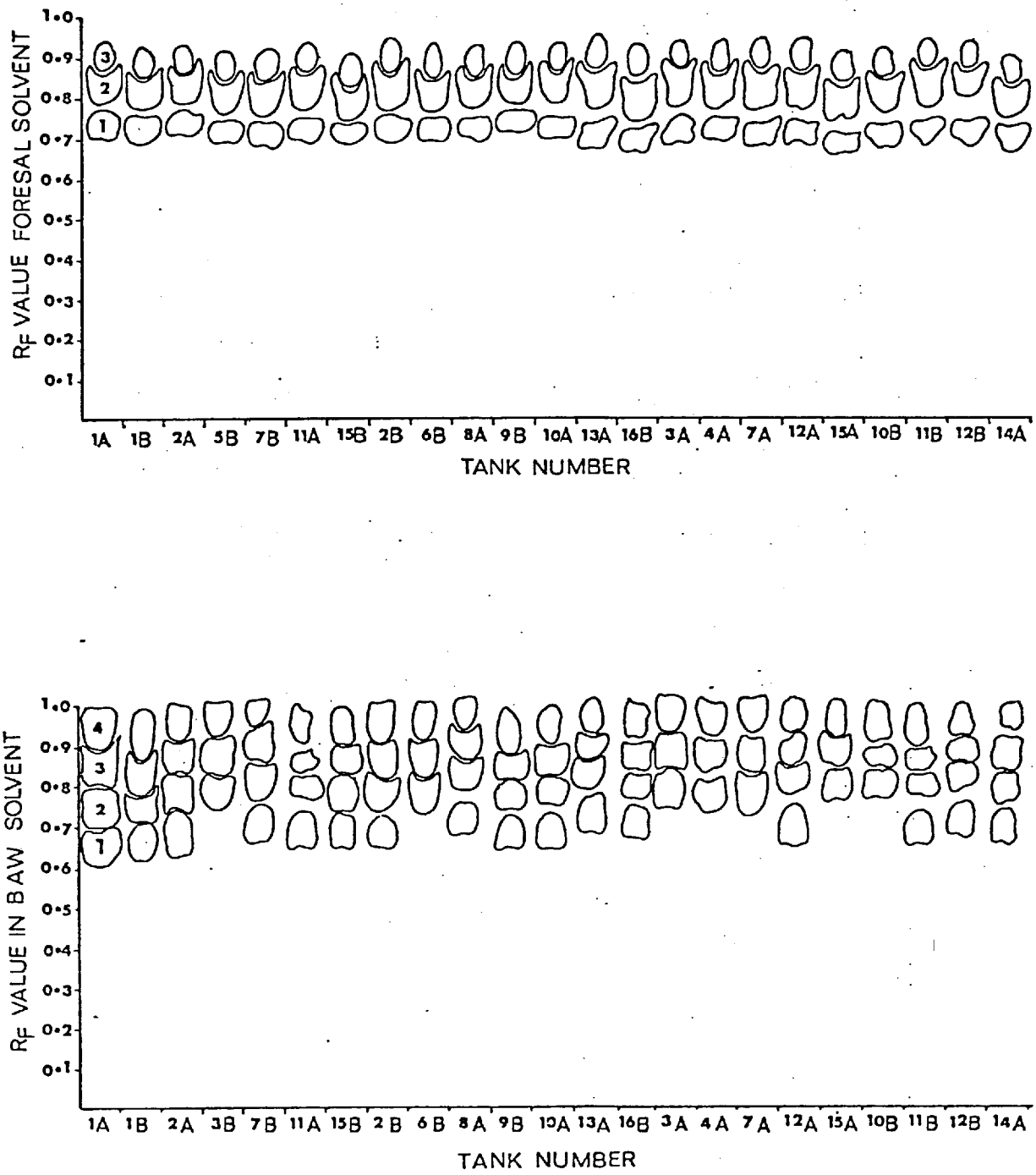


Figure 4.1 Patterns of one - dimensional chromatograms from different types of *Salicornia* in Forstal and in BAW (Butanal-acetic acid - water).

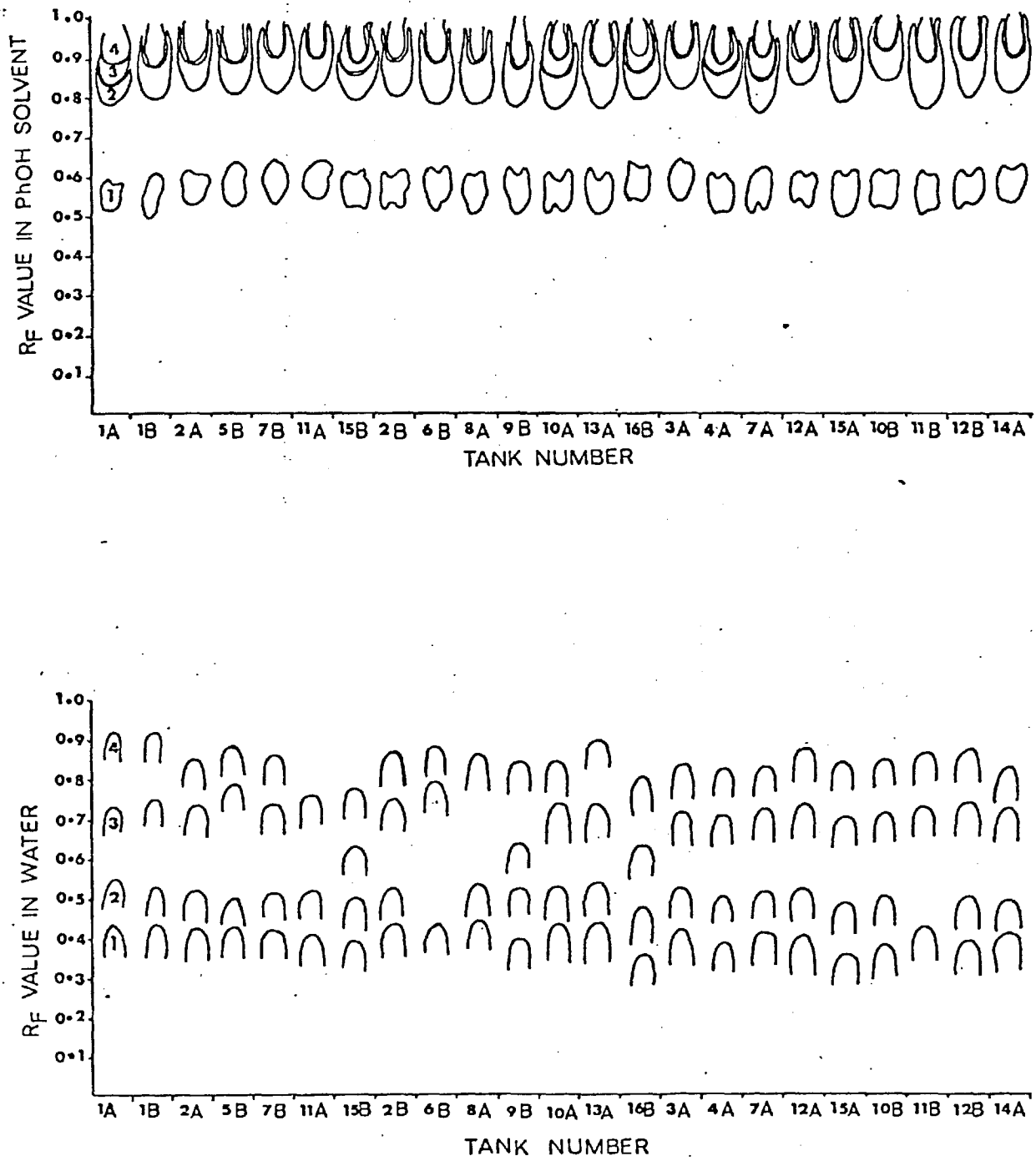


Figure 4.2 Patterns of one - dimensional chromatograms from different types of *Salicornia* in PhoH (Water - saturated phenol) and in water.

Table 4.3 Shows the R_F values and the appearence of the spots on one-dimensional chromatograms of the direct acid hydrolysates.

Solvents / Spot number	Forstal				BAW				PhoH				H_2O			
	R_F	U.V.	U.V. + NH3	Visible light	RF	U.V.	U.V. + NH3	Visible light	RF	U.V.	U.V. + NH3	Visible light	RF	U.V.	U.V. + NH3	Visible light
1	0.70	blue	yellow-ish green	not visible	0.70	blue	blue	not visible	0.58	blue	fluore-scent blue	not visible	0.36	blue	fluore-scent blue	not visible
2	0.81	blue	fluore-scent blue	"	0.78	blue	yellow-ish green	"	0.83	blue	blue	"	0.46	blue	yellow-ish green	"
3	0.87	reddish brown	reddish brown	brown	0.83	blue	fluore-scent blue	"	0.88	blue	yellow-ish green	"	0.68	blue	blue	"
4	-	-	-	-	0.90	reddish brown	reddish brown	brown	0.93	reddish brown	reddish brown	brown	0.82	blue	pale yellow	"
Rutin	0.39				0.73				0.46				0.38			

ance of the detected spots under U.V. light alone, and in the presence of ammonia fumes are shown in Table 4.3. For each plant at least three runs were made in each of the above solvents. An authentic compound, rutin, was chromatographed under the same conditions as the hydrolysates, for purposes of comparison. The patterns of the one - dimensional chromatograms of the studied individuals of *Salicornia* in the four solvents are shown in Figures 4.1-4.2 .

The acid hydrolysate chromatograms of the studied *Salicornia* specimens show quite similar patterns in the solvents, Forstal and BAW. They showed a range of 2 - 4 spots, and occasionally 5 spots. Most of these spots had a high RF value (0.70 - 0.83) and they were crowded at the front line of the solvent. In phenol all the individuals show a range of 2 - 3 spots, spot number 1 (R_F. 0.58) and number 2 (R_F 0.83) were seen in all the individuals analysed, but spot number 3 (R_F 0.88) was seen clearly in only a few individuals, it seems usually to overlap with spot 2, as both were crowded at the front line of the solvent. In H_2O, the acid hydrolysates showed a good separation (Figure4.2.). Four spots were also seen in most of the groups of *Salicornia*, but in a few individuals only 3 spots were seen. Variation in the number of detected spots seems to be irregular, as it varies from one individual to another without any correlation with the *Salicornia* type involved (Figure 4.2). In addition, spot numbers, expected to be similar, showed a little variation in their R_F values. This variation was probably due to a technical reason, as water moves relatively fast in the descending technique and the expected little variation in the temperature may result in such variations.

In general, from the results of the one - dimensional chromatograms, the detected spots in the four solvents are common to all the individuals

of *Salicornia* spp. studied.

The chromatograms of the amyl alcohol extract of the remaining direct acid-hydrolysate were developed in the solvents, Forstal and BAW, for the detection of C - glycosides or Glycosylflavone. The results of these chromatograms in BAW showed only brown spots in the visible light, with a dark absorbing appearance in U.V. light and no change in their appearance being observed in the presence of ammonia vapour. These spots have very low R_F values (R_F 0.06 - 0.09). In Forstal solvent they did not develop as well as in BAW solvent. This result may suggest that the remaining brown colour of the direct acid hydrolysate, after the extraction by ethylacetate, is mainly due to the presence of betacyanin pigment (Harborne 1973b). It may also suggest that either the annual forms of *Salicornia* do not contain C - glycosides or Glycosylflavones, or the time used for their further hydrolysis (1½ hours) was not sufficient for their hydrolysis if they were present.

4.4.2. Two - dimensional chromatography for the phenolic glycosides:-

The direct extracts obtained did not give a satisfactory separation for the phenolic glycosides on cellulose MN300 plates, whilst a very good separation was achieved on paper. Hence, the following discussion is based on the chromatographic patterns developed on paper.

The results obtained from the two - dimensional chromatography for the phenolic glycosides in the solvents, BAW and 5% HOAC on paper are presented in the form of presence/absence data (Table 4.4). The R_F values and the appearance of the detected spots in U.V. light alone, and in the presence of ammonia vapour are shown in Table 4.5. Triplicate runs and independent marking had been used as precautionary measures to minimise artefacts and spurious variations. Then on the basis of colour

Table 4.4. Showing the presence of the phenolic glycoside spots isolated in two-dimensional paper chromatography for the analysed individuals of *Salicornia* spp.

Plant reference and plant groups \ Spots colour in U.V. + NH3/spots number	1 O.Y.	2 F.YG	3 O.Y.	4 O.Y.	5 Bl.	6 O.Y.	7 F.YG	8 F.YG	9 Bl.	10 Bl.	11 Bl.	12 Bl	13 F.YG	14 YG	15 Bl	16 Bl	17 F.YG	18 F.YG	19 YG	20 O.Y.	21 O.Y.	22 Bl.	23 F.YG	24 Chlorophyll	25 F.YG	26 Y	27 Bl/YG	28 Bl	29 D.O.Y.
1A - *Salicornia pusilla*	+	+	-	-	-	-	+	+	-	+	+	+	+	-	-	-	+	+	+	-	-	-	+	+	+	-	+	-	-
16A - *S. ramosissima*	+	+	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
10A - *S. ramosissima*	+	-	-	-	-	-	+	+	+	+	-	+	+	+	-	-	-	-	-	-	-	-	+	+	-	-	+	-	-
2B - *S. europaea*	+	+	-	+	+	-	+	+	+	+	+	+	+	+	+	-	-	+	+	+	-	+	-	+	+	-	+	-	+
6B - *S. europaea*	+	-	-	-	-	-	+	+	+	+	-	-	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
8A - *S. europaea*	+	+	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-	-	-	-
16B - *S. europaea*	+	+	-	-	-	-	+	+	+	+	+	-	+	+	+	-	-	-	-	-	-	-	+	+	-	-	+	-	-
5A - *S. europaea*	+	+	-	-	+	-	+	+	+	+	-	+	+	+	+	-	-	-	-	-	+	-	-	+	+	-	-	-	-
8B - *S. europaea*	+	+	-	-	+	-	+	+	+	+	-	-	+	+	+	-	-	-	-	-	-	+	+	+	-	+	+	-	-
9A - *S. europaea*	+	+	-	-	+	-	+	+	+	+	-	+	+	+	-	-	-	-	-	-	-	-	+	+	-	-	+	-	-
13A - *S. europaea*	+	-	-	+	-	-	+	+	+	+	-	-	+	+	+	+	-	-	-	-	+	-	+	+	-	+	-	+	+
1B - *S. europaea*	+	+	-	-	+	+	+	+	+	+	+	+	-	+	-	+	-	-	-	-	-	+	-	+	-	-	-	-	-
2A - *S. europaea*	+	+	-	-	+	+	+	+	+	+	+	+	+	-	+	+	-	-	-	-	-	+	-	+	-	-	+	-	+
7B - *S. europaea*	+	+	-	-	-	-	+	+	+	+	-	-	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
11A - *S. europaea*	+	+	-	-	+	-	+	+	+	+	-	+	+	+	-	-	-	-	-	-	+	-	+	+	-	-	-	-	-
15B - *S. europaea*	+	+	-	+	-	-	+	+	+	+	-	-	+	+	+	+	-	-	-	+	-	-	-	+	-	-	-	-	+
3B - *S. europaea*	+	+	-	-	+	-	+	+	+	+	-	+	-	+	+	+	+	+	+	-	+	-	+	+	+	-	+	-	+
14B - *S. europaea*	+	+	-	+	-	-	+	+	+	+	-	-	+	+	+	+	-	-	-	+	-	+	+	+	-	+	-	-	-
4B - *S. europaea*	+	+	+	+	+	-	+	+	+	+	-	+	-	+	+	-	+	-	+	-	+	-	+	+	-	-	-	+	-
3A - *S. procumbens*	+	+	+	+	+	-	+	+	+	+	+	+	+	+	-	-	+	-	-	-	-	-	+	+	+	-	+	+	-
4A - *S. procumbens*	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	+	-	-	+	+	-	-	+	-	+	-	-	-
7A - *S. procumbens*	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	-	-	-	-	+	+	-	+	+	-	+	+	-	+
12A - *S. procumbens*	+	+	+	+	-	-	+	+	+	+	-	-	-	-	+	-	-	-	-	+	+	-	-	+	-	+	-	-	-
15A - *S. procumbens*	+	+	+	+	-	+	+	+	+	+	-	+	+	-	+	+	-	-	-	+	+	-	+	+	+	+	+	-	+
10B - *S. procumbens*	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	-	-	-	-	+	+	-	+	+	-	+	+	-	-
11B - *S. procumbens*	+	+	+	+	-	+	+	+	+	+	-	+	+	+	-	-	-	-	-	+	+	-	+	+	+	+	+	-	-
12B - *S. procumbens*	+	-	+	+	-	+	+	+	+	+	-	+	+	+	-	-	-	-	-	+	+	-	+	+	-	+	+	+	-
14A - *S. procumbens*	+	+	+	+	-	+	+	+	+	+	-	+	+	+	+	-	-	-	-	+	-	-	+	+	+	+	+	-	-
17 - *S. procumbens (nitens)*	+	+	+	+	-	+	+	+	+	+	-	+	+	+	+	-	-	-	-	+	-	-	+	+	+	-	-	-	+

*Key to the abbreviation of the spots appearance on the two-dimensional chromatograms for the phenolic glycosides:-

Bl.: Blue

Bl/YG: Mostly blue, sometimes yellowish green

Br.: Brown

D.O.Y.: Dark orange yellow

F.YG.: Fluorescent yellowish-green

O.Y.: Orange yellow

R.Br.: Reddish brown

Y.: Yellow

YG. :Yellowish green

YG/Bl: Mostly yellowish green, sometimes blue

Table 4.5 Shows the R_F values of the spots detected on two-dimensional chromatograms for the phenolic glycosides for the analysed individuals of *Salicornia* spp. (Spot number as given in the master chromatograms).

Spot number	R_F Values in BAW	R_F Values in 5% HOAC	Spot appearance*		
			in U.V. +NH3	in U.V.	in Visible light
1	0.54	0.20	O.Y	Br.	not visible
2	0.67	0.15	F.YG	Bl.	"
3	0.49	0.25	O.Y.	Br.	"
4	0.36	0.37	O.Y.	Br.	"
5	0.22	0.49	Bl.	Bl.	"
6	0.17	0.59	O.Y.	Br.	"
7	0.59	0.62	F.YG	Bl.	"
8	0.61	0.76	F.YG	Bl.	"
9	0.79	0.33	Bl.	Bl.	"
10	0.78	0.52	Bl.	Bl.	"
11	0.39	0.57	Bl.	Bl.	"
12	0.39	0.67	Bl.	Bl.	"
13	0.54	0.59	F.YG	Bl.	"
14	0.54	0.79	YG/Bl	Bl.	"
15	0.81	0.65	Bl.	Bl.	"
16	0.86	0.30	Bl.	Bl.	"
17	0.64	0.28	F.YG.	Bl.	"
18	0.66	0.39	F.YG.	Bl.	"
19	0.62	0.50	YG	Bl.	"
20	0.24	0.61	O.Y.	Br.	"
21	0.15	0.75	O.Y.	Br.	"
22	0.80	0.73	Bl.	Bl.	"
23	0.67	0.05	F.YG	Bl.	"
24	0.90	0.00	R.Br.	R.Br.	Br.
25	0.44	0.66	F.YG.	Bl.	"
26	0.14	0.84	Y		"
27	0.42	0.81	Bl/YG	Bl.	"
28	0.32	0.83	Bl.	Bl.	"
29	0.29	0.51	D.O.Y.	Br.	"
Rutin	0.24	0.41			

and position, spots assumed to be identical in two or more of the selected types were assigned the same number. However, no attempt was made to identify the compounds, as this was considered to be beyond the scope of the present investigation. A standard marker, however, rutin (supplied by Koch - light laboratory, England) was chromatographed under the same conditions of the glycosides, for purposes of comparison.

Little, if any, variation was observed in the chromatographic patterns of individual plants from the same parent. A total of 29 spots were observed from the studied groups of *Salicornia* and a master chromatogram was drawn to show the position and the common shape of the detected spots (Figure 4.3). In addition, different chromatograms were drawn to show the dominant chromatographic patterns shown by the different groups of *Salicornia* (Figure 4.4).

Based on the chromatographic analysis, the analysed individuals showed a considerable range of variation considering the number of spots which were defined per individual. In some chromatograms only 6 spots were detected (e.g. in *S. ramosissima*), while in others 20 spots were detected (e.g. *S. procumbens*) (Table 4.4).

From the chromatographic results presented here, spot number 1 (orange-yellow in ultraviolet with ammonia), spot numbers 7, 8 (fluorescent yellowish-green with ammonia) and spot numbers 9 and 10 (blue with ammonia) are common virtually to all the individuals of *Salicornia* studied, whilst spot number 24 (reddish-brown in the visible light) is probably the remaining chlorophyll in the extract.

On the other hand, spot numbers 3, 4, 6, 20, 21 and probably 29 (orange-yellow in ultraviolet with ammonia) and spot number 26

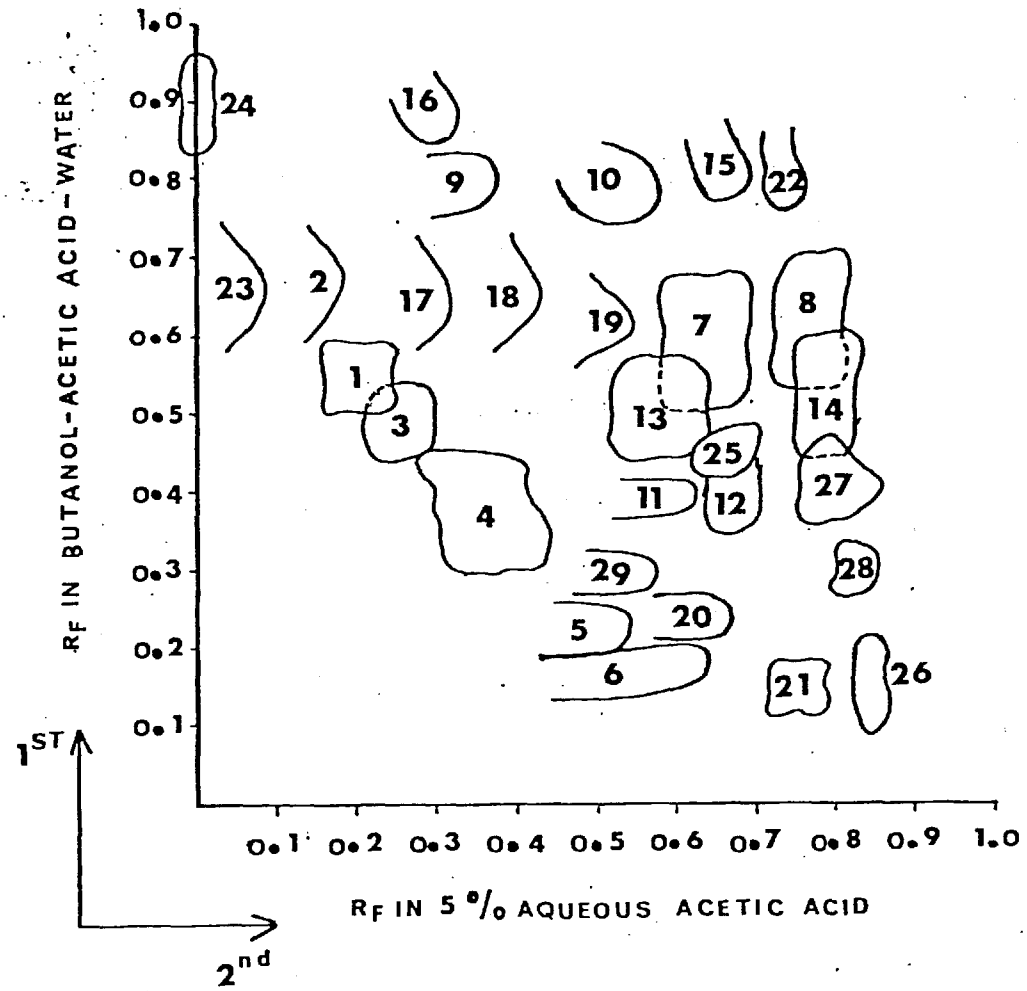
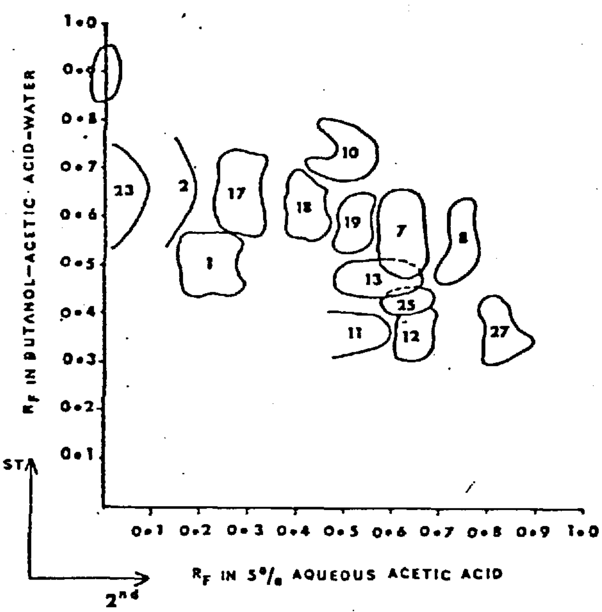
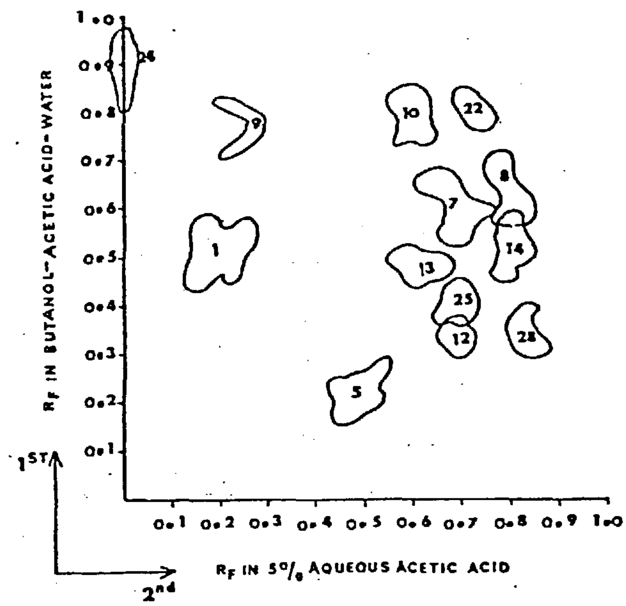


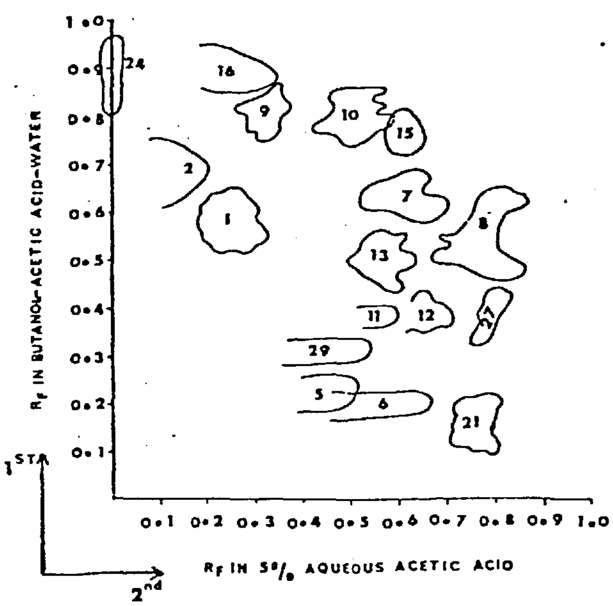
Figure 4.3 Master chromatogram of the phenolic glycosides spots detected from the 29 types of *Salicornia*.



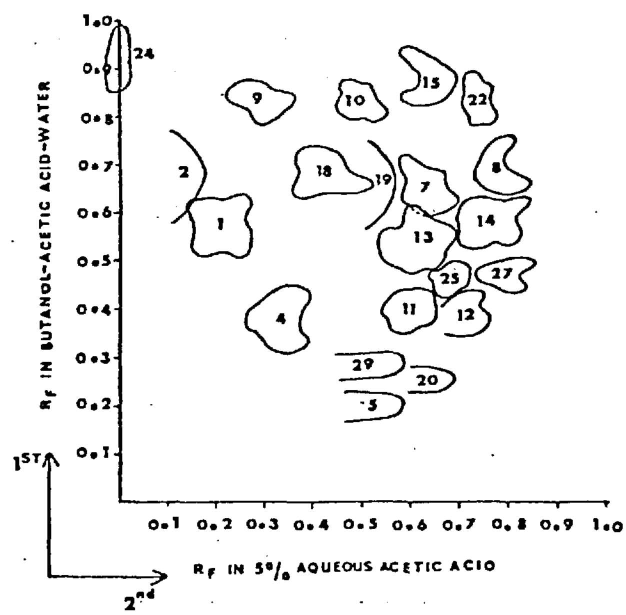
Salicornia pusilla



Salicornia europaea

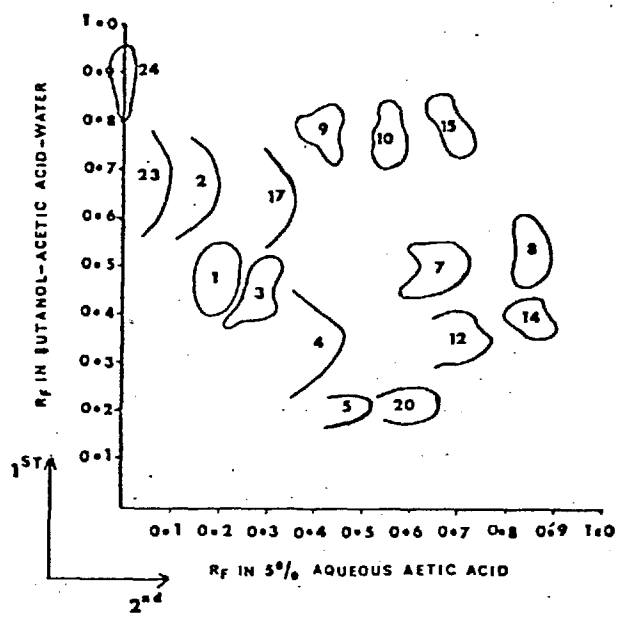


Salicornia europaea

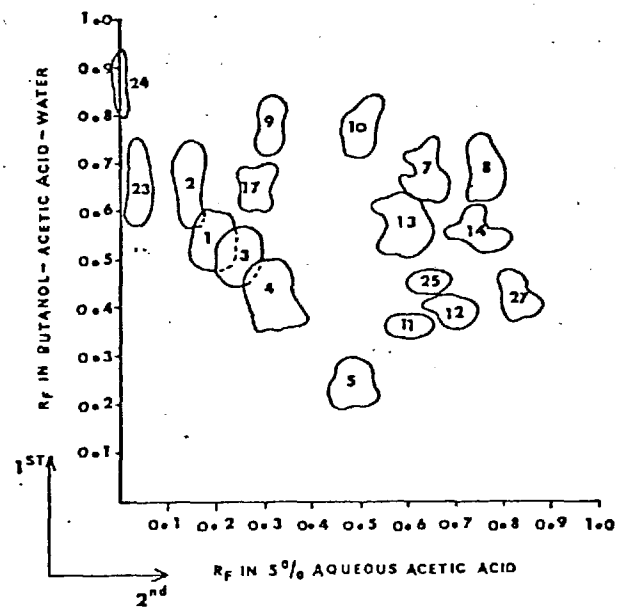


Salicornia europaea

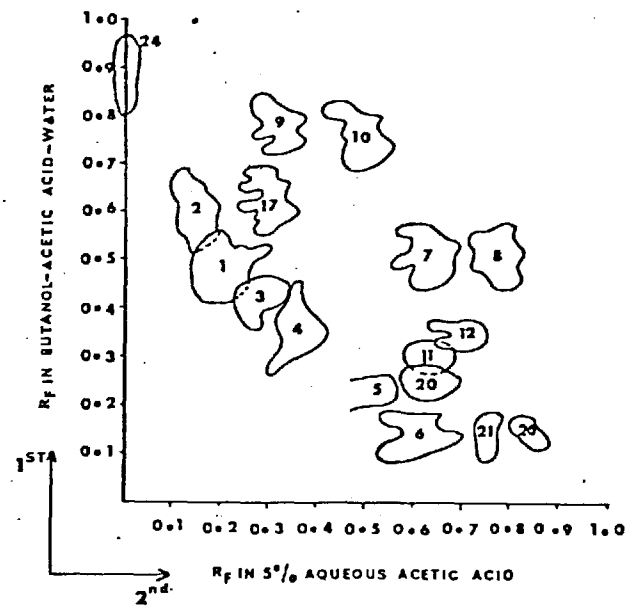
Figure 4.4 Chromatographic patterns of phenolic glycosides produced by different types of *Salicornia*.



Salicornia europaea



Salicornia dolichostachya



Salicornia dolichostachya

Figure 4.4 (Continued)

(yellow in ultraviolet with ammonia), seem to correspond with some groups of the studied *Salicornia*. For example, most, if not all of the chromatograms of the *S. procumbens* individuals contain most of these spots, and in particular spot numbers 3 and 4 (Table 4.4). Individuals belonging to the *S. pusilla* and *S. ramosissima* groups do not contain any of these orange-yellow spots, apart from the common orange-yellow one (spot number 1). Individuals of the *S. europaea* group exhibit a considerable range of variation in the number of the orange-yellow spots which their chromatograms have shown. The majority of the *S. europaea* group studied (groups belong to tank numbers 1B, 2A, 6B, 7B, 8A, 9A, and 16B) contains only the common spot of orange yellow (spot number 1), and do not show any of the extra orange-yellow spots (Table 4.4). Other members of *Salicornia europaea* (tank numbers 2B, 4B, 13A, 13B, and 15A) show sporadic number of the orange-yellow spots, ranging from 2 - 3 spots, in addition to the common one (spot number 1) (Table 4.4).

The other spot numbers, i.e. 5, 11, 12, 15, 16, 22, and 28 (blue in ultraviolet with ammonia), and the spot numbers 13, 14, 17, 23, 25, 26 (fluorescent yellowish-green in ultraviolet with ammonia) show unrelated variation in their appearance, though spot numbers 12 (blue in U.V. with ammonia), 13, 14 (fluorescent yellowish-green in U.V. with ammonia) and 15 (blue in U.V. with ammonia) are frequently detected. However, apart from the chromatographic pattern of *S. pusilla*, it is noticeable that the total number of the fluorescent yellowish-green and the blue spots are usually more frequent if the chromatogram contains an additional orange-yellow spot, to the common one (spot number 1).

One species that stands out in these studies is *S. pusilla*. It

has a relatively distinct chromatographic pattern in having only one orange yellow spot (spot number 1), whilst in addition, it consistently shows the presence of large spots of fluorescent yellowish-green, in particular spot numbers 23, 2, 17, 18 and 19, and the absence of spot numbers 16, 9, 15 and 22 (blue in U.V. with ammonia). This pattern is not common amongst the other analysed individuals, and these characteristics made the chromatogram pattern of *S. pusilla* quite distinguishable from the other chromatograms (Figure 4.4). It is interesting that *S. pusilla* is the only species which is also morpholog ically distinct from the other annual forms of *Salicornia*. Though in this study no attempt was made to identify the spots, it seems the spot number 23 (R_F 0.05 in 5% HOAC, fluorescent yellowish-green in U.V. with ammonia) is an uncommon derivative of ferulic acid (T. Swain, personal communication).

4.4.3. Phenolic acids and simple phenols in selected individuals of *Salicornia*:-

Selected individuals belonging to the *Salicornia pusilla*, *S. europaea* and *S. procumbens* groups were analysed for their phenolic acids and simple phenols. The results of the two - dimensional chromatograms for phenolic acids on cellulose MN300 plates and simple phenols on silica gel plates are presented in the form of presence/absence data (Tables 4.6 & 4.7), with a master chromatogram for each of the analyses to show the chromatographic pattern (Figures 4.5 & 4.6.).

A total of 13 well separated spots of phenolic acids were detected from the studied individuals (Figure 4.5). All the detected spots showed different shades of blue when viewed under U.V. light in the presence of ammonia vapour. The R_F values of these spots in both solvents are shown in Table 4.8. In general, the analysed individuals did not show

Table 4.6 Shows the presence/absence for the Hydroxy-cinnamic acids and Hydroxycoumarins for the analysed individuals of *Salicornia* on cellulose MN300 plates.

Spots number / Plant reference and plant groups	1	2	3	4	5	6	7	8	9	10	11	12	13
1A-*Salicornia pusilla*	+	+	+	+	+	+	+	+	+	+	+	−	−
1B-*S. europeae*	+	+	+	+	+	+	+	+	+	+	−	−	+
2B-*S. europeae*	+	−	+	+	+	+	+	+	+	+	+	−	+
8A-*S. europaea*	+	+	+	+	+	+	+	+	+	+	+	−	−
9B-*S. europaea*	+	−	+	+	+	+	+	+	+	+	+	−	+
16B-*S. europaea*	+	+	+	+	−	−	+	−	−	−	−	−	−
8B-*S. europaea*	+	−	+	+	+	+	+	+	+	+	+	+	+
3A-*S. procumbens*	+	−	+	+	+	−	+	−	−	−	+	−	−
11B-*S. procumbens*	+	+	+	+	+	+	+	+	+	+	+	+	+
12A-*S. procumbens*	+	−	+	+	+	+	+	+	+	+	+	−	+
15A-*S. procumbens*	−	−	+	+	+	+	+	+	+	+	+	+	+

Table 4.7 Shows the presence/absence for the simple phenols for the analysed individuals of *Salicornia* on silica gel plates.

Spots number / Plant reference and plant groups	1	2	3	4	5	6	7	8	9	10	11	12	13
1A-*Salicornia pusilla*	+	−	+	+	+	+	−	+	+	+	+	+	−
1B-*S. europaea*	+	+	+	+	+	−	−	+	+	+	+	+	+
2B-*S. europaea*	+	+	+	+	+	+	−	+	+	+	+	+	+
8A-*S. europaea*	+	+	+	+	+	+	−	+	+	+	+	+	−
9B-*S. europaea*	+	+	+	+	+	+	−	+	+	+	+	−	−
16B-*S. europaea*	+	+	+	+	+	+	−	+	+	+	+	+	+
8B-*S. europaea*	+	+	+	+	+	+	+	+	+	+	+	+	+
3A-*S. procumbens*	+	+	+	+	+	+	−	+	+	+	+	+	−
11B-*S. procumbens*	+	+	+	+	+	+	+	+	+	+	+	+	+
12A-*S. procumbens*	+	+	+	+	+	+	+	+	+	+	+	+	−
15A-*S. procumbens*	+	+	+	+	+	+	+	+	+	+	+	+	+

Table 4.8 Shows the R_F values for the detected spots of the Hydroxycinnamic acids and Hydroxycoumarins on cellulose MN300 plates.

Solvents / Spots number	1 benzene-acetic acid -water (6:7:3)	2 15% HOAC
1	0.27	0.13
2	0.59	0.10
3	0.07	0.37
4	0.34	0.47
5	0.03	0.48
6	0.22	0.59
7	0.15	0.65
8	0.06	0.69
9	0.80	0.56
10	0.84	0.34
11	0.78	0.16
12	0.38	0.66
13	0.05	0.59

Table 4.9 Shows the R_F values for the detected spots of simple phenols on silica gel plates.

Solvents / Spots number	1 10% acetic acid in chloroform	2 45% ethyl acetate in benzene
1	0.03	0.10
2	0.16	0.19
3	0.67	0.62
4	0.73	0.72
5	0.74	0.79
6	0.50	0.65
7	0.58	0.77
8	0.29	0.57
9	0.35	0.63
10	0.33	0.70
11	0.57	0.36
12	0.42	0.15
13	0.26	0.33

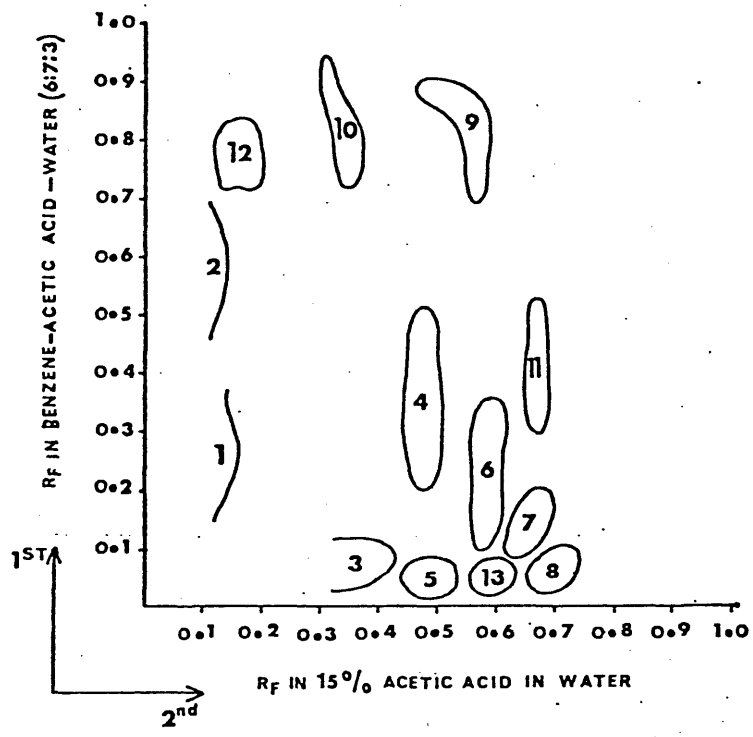


Figure 4.5 Master chromatogram of the phenolic acids (Hydroxycinnamic and Hydroxycoumarins) spots detected from selected types of *Salicornia* on cellulose MN300 plates.

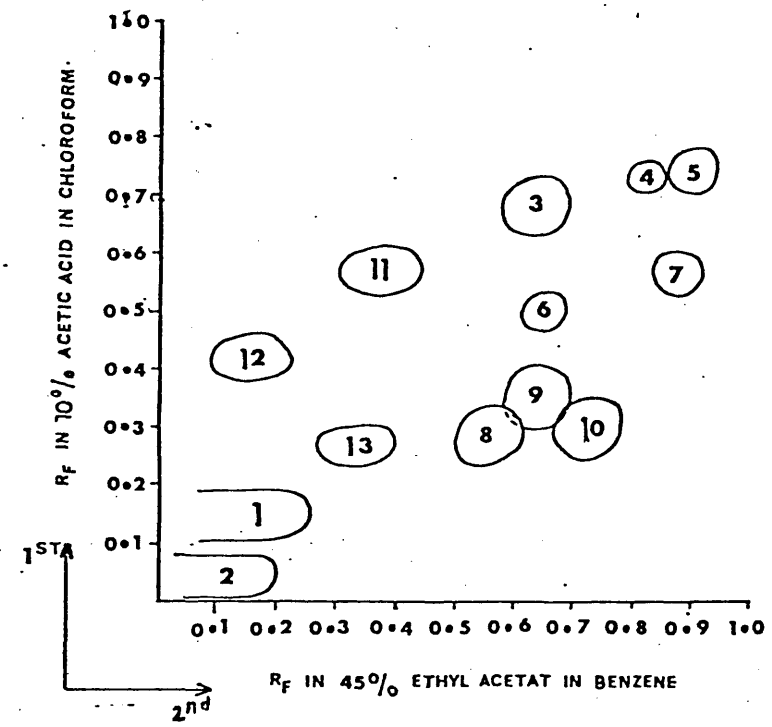


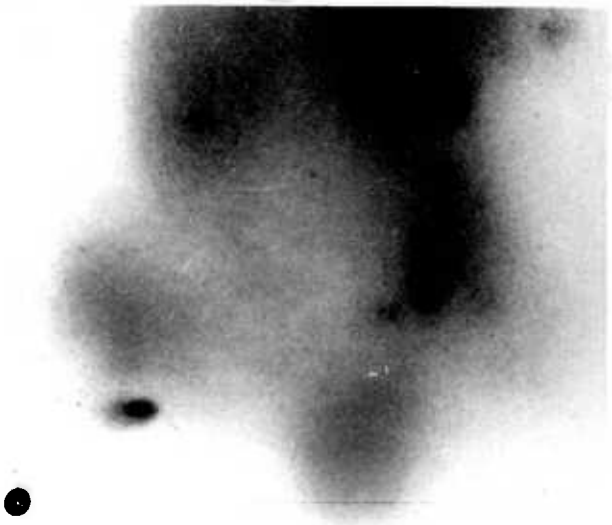
Figure 4.6 Master chromatogram of simple phenols spots detected from selected types of *Salicornia* on silica gel plates.

much variation in the number of observed spots. The analysis showed spots numbers 1, 3, 4, 5 and 7 to be very common in the plant groups studied, whilst spot numbers 2, 6, 8, 9, 10, 11, 12 and 13 showed some considerable variation considering their presence (Table 4.6).

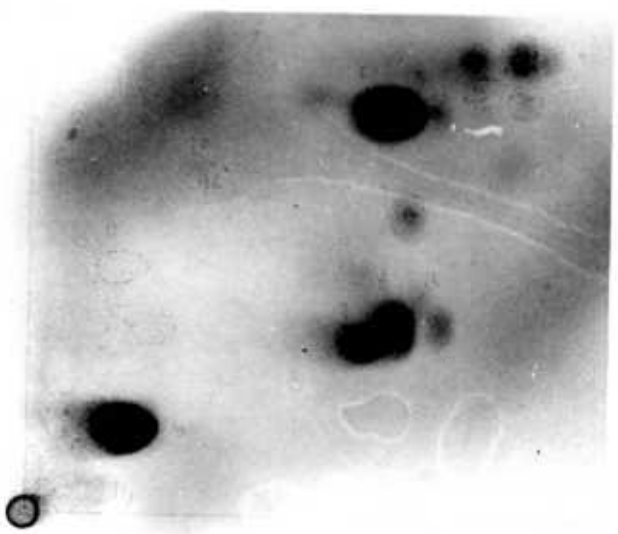
Also a total of 13 spots of simple phenols were observed on silica gel plates from the individuals studied (Figure 4.7). The R_F values of these spots in the two solvents can be seen in Table 4.9 . The individuals analysed showed considerable variation in the number of the spots they possessed. The majority of the spots (number 1, 3, 4, 5, 8, 9, 10 and 11) are common to the chromatograms of the individuals analysed. Spot number 1, 6, 7, 12 and 13 show some variation in their presence. After the silica gel plates were sprayed with Folin Ciocalteu reagent, the spots 1 and 2 (blue in the visible light) showed a quantitative variation among the groups of *Salicornia* studied. Most of *Salicornia procumbens* individuals produce more intense and larger spots (in particular spot number 2) than those of the *S. europaea* group while in *Salicornia pusilla* all the analysed individuals show that spot number 2 is completely missing and spot number 1 has been reduced very considerably in size (Photographs 4.1-4.4) Spot numbers 8, 9 and 10 also show quantitative variations between the analysed groups, but their variation did not show a clear relation to the analysed types.

4.5 The effect of nitrogen deficiency and phosphorus deficiency on the chromatographic pattern of the phenolic glycosides:-

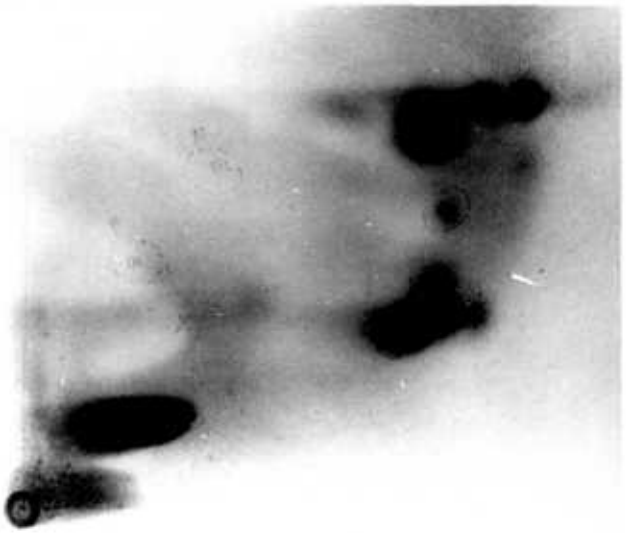
An attempt was made to determine whether the chromatographic pattern of *Salicornia* spp. could be affected by nutrient deficiency. Table 4.10 shows the chromatographic pattern of the phenolic glycosides (spot numbers are the same as on the master chromatogram, Figure 4.3) of individuals



Photograph 4.1 : Shows the chromatographic pattern of simple phenols for plant belonging to *Salicornia pusilla*, on silica gel plate.



Photograph 4.2 : Shows the chromatographic pattern of simple phenols for plant belonging to *S. europaea* group, on silica gel plate.



Photograph 4.3 : Shows the chromatographic pattern of simple phenols for plant belonging to *S. europaea* group, on silica gel plate.

Photograph 4.4 : Shows the chromatographic pattern of simple phenols for plant belonging to *S. procumbens* group, on silica gel plate.

Table 4.10 Shows the chromatographic pattern (Phenolic glycosides) of *Salicornia nitens* under the different levels of nitrogen and phosphorus treatments.

Nutrient levels	Spots No / Spots colour* in U.V. + NH3	1 O.Y.	2 F.YG.	3 O.Y.	4 O.Y.	5 Bl.	6 O.Y.	7 F.YG.	8 F.YG.	9 BL.	10 Bl.	11 Bl.	12 Bl.	13 F.YG.	14 Bl.	15 Bl.	16 Bl.	17 F.YG.	18 F.YG.	19 YG.	20 O.Y.	21 O.Y.	22 Bl.	23 F.YG.	24 Chlorapyll (R.Br.)	25 F.YG	26 Y.	27 Bl/YG	28 Bl.	29 D.O.Y.
Nitrogen treatment	tion.																													
	5p.p.m.	+	+	+	+	-	+	+	+	+	+	-	-	+	+	-	-	-	-	-	+	-	-	+	+	-	-	-	-	+
	15p.p.m.	+	+	+	+	-	+	+	+	+	+	-	-	+	+	-	-	-	-	-	+	-	-	+	+	+	-	-	-	+
	45p.p.m.	+	+	+	+	-	+	+	+	+	+	-	-	+	+	-	-	-	-	-	+	-	-	+	+	+	-	-	-	+
	135p.p.m.	+	+	+	+	-	+	+	+	+	+	-	-	+	+	-	-	-	-	-	+	-	-	+	+	+	-	-	-	+
Phosphorus treatment	2p.p.m.	+	+	+	+	-	+	+	+	+	+	-	-	+	+	-	-	-	+	+	+	-	-	+	+	+	-	-	-	+
	4p.p.m.	+	+	+	+	-	+	+	+	+	+	-	-	+	+	-	-	-	-	-	+	-	-	+	+	-	-	-	-	+
	8p.p.m.	+	+	+	+	-	+	+	+	+	+	-	-	+	+	-	-	-	-	-	+	-	-	+	+	+	-	-	-	+
	16p.p.m.	+	+	+	+	-	+	+	+	+	+	-	+	+	+	-	-	-	-	-	+	-	-	+	+	+	-	-	-	+

* See page 121.

belonging to *Salicornia nitens* (all the individuals are the progeny of one parent plant) which were grown under different growth conditions of nitrogen and phosphorus (growth experiment 1976, Chapter VI).

From the chromatographic behaviour of the individuals studied, most of the detected spots are consistently present, apart from spot numbers 12, 18, 19 and 25 which show some variation in their presence (Table 4.10). It seems that the variation of these spots is not related to the deficiency levels, and probably it is spurious in nature.

4.6. Chromosome number and the chromatographic pattern of the phenolic glycosides:-

It has been pointed out earlier that the pollen grain diameter and the anther length of tetraploids are usually larger than those of diploids, and also the fertile segment ratios, $\frac{C+D}{2B}$ and $\frac{D}{B}$, show a positive relation with the chromosome number, but that in general this relationship is not absolute.

In this study an attempt was made to relate the phenolic glycosides pattern in 16 plants of known chromosome numbers. The analysed individuals include plants grown in the greenhouse, as well as, plants harvested directly from the field. Permanent slides were prepared from the root tips of germinated seeds using the technique described in chapter III. The results of the chromatographic analysis are also presented in the form of presence/absence data (+/-) (Table 4.11) and the detected spots were given the same numbers as in the master chromatogram (Figure 4.3).

The chromatographic pattern of the phenolic glycosides produced by the plants collected from the field is almost identical with those of

Table 4.11 Shows the chromatographic pattern (Phenolic glycosides) for the diploid and tetraploid forms in *Salicornia*.

Spots colour * in U.V. + NH3 / Spots number / Plant reference and ploidy level	O.Y.	F.YG.	O.Y.	O.Y.	Bl.	O.Y.	F.YG.	F.YG.	Bl.	Bl.	Bl.	Bl.	F.YG.	Y.G.	Bl.	Bl.	F.YG.	F.YG.	Y.G.	O.Y.	O.Y.	Bl.	F.YG.	CHLOR.	F.YG.	Y.	Bl/YG.	Bl.	D.O.Y.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2A-diploid	+	+	−	−	+	+	+	+	+	+	+	+	+	−	+	+	−	−	−	−	+	−	−	+	−	−	−	−	−
7B-diploid	+	+	−	−	−	−	+	+	+	+	−	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−
10A-diploid	+	−	−	−	−	−	+	+	+	+	−	+	+	+	−	−	−	−	−	−	−	−	+	+	−	−	+	−	−
Sh1-diploid	+	+	−	−	−	+	+	+	+	+	−	−	+	+	−	−	−	−	−	−	−	−	+	+	−	−	−	−	−
Sh2-diploid	+	+	−	−	−	−	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−
Sh4-diploid	+	+	−	−	−	−	+	+	+	+	−	−	+	+	+	−	−	−	−	−	+	−	−	+	−	−	−	−	−
Sh5-diploid	+	+	−	−	−	−	+	+	+	+	−	−	+	+	+	−	−	−	−	−	−	−	−	+	−	−	−	−	−
Sh6-diploid	+	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−
Sh7-diploid	+	−	−	−	−	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−
Hay 14-diploid	+	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−
Hay 15-diploid	+	−	−	−	−	−	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	+	−	−
Hay 12-tetraploid	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	−	+	−	−	−	+	+	−	−	−	+
Hay 3-tetraploid	+	+	+	+	−	+	+	+	+	+	+	+	+	+	+	−	−	−	−	+	+	−	−	+	−	−	−	−	−
7A-tetraploid	+	+	+	+	−	+	+	+	+	+	+	+	+	+	−	−	−	−	−	+	+	−	+	+	−	+	+	−	−
Sh3 - tetraploid	+	+	+	+	−	−	+	+	−	+	+	+	+	+	+	−	−	−	−	−	−	+	+	+	−	−	+	+	+
10B-tetraploid	+	+	+	+	+	+	+	+	+	+	−	+	+	+	−	−	−	−	−	+	+	−	+	+	−	+	+	−	−

* See page 121.

the cultured plants.

Spots numbers 1 (orange-yellow in U.V. with ammonia), 7, 8 (fluorescent yellowish-green in U.V. with ammonia), and 9 and 10 (blue in U.V. with ammonia) are common to both diploids and tetraploids (Table 4.11).

From the presented data, the main difference between the diploids and the tetraploids is probably spot numbers 3 and 4 (orange-yellow in U.V. with ammonia), which are found to be missing from the analysed diploid individuals. In addition, spot numbers 6, 20, 21 and 29 (orange-yellow in U.V. with ammonia) are found to be more frequent in the tetraploid than diploid individuals.

Based on the chromatographic patterns, in general diploid forms showed more variation considering the number of the observed spots, than did the tetraploid forms such variation was observed even among diploids collected from one salt marsh (Table 4.11). The tetraploids showed relatively more uniformity in their chromatographic pattern, even between individuals collected from different marshes. These conclusions probably coincide with the morphological behaviour of the genus, as usually diploid plants show more morphological variation than the tetraploid plants.

In general, from the chromatographic pattern of the diploids and the tetraploids may suggest straight-forward inheritance between them. Also it may indicate that there is more genetic isolation between the diploid populations than between the tetraploid ones.

From the chemical results obtained, the analysed individuals could

be grouped as follows:- Group a:- individuals in which the chrom atographic pattern contained 5-6 spots (diploid), Group b:- Individuals in which the chromatographic pattern contained 10-15 spots (intermediate between the diploid and the tetraploid), Group C:- Individuals in which the chromatographic pattern contained 16-19 (may be more) spots (tetraploids). However, such a classification is not in agreement with the present classification of the chromosome number in *Salicornia*, as only diploids and tetraploids had been found with no triploid (Hamblers 1954, Ball and Tutin 1959, Dalby 1962). The intermediate groups were found to be all diploid in the present investigation. So one may suggest there is a gradation in the number of the observed spots in the diploid forms of *Salicornia*, which could be a result of genetic isolation, followed by accumulation of compounds due to the adaptive nature of the plant. Hence, it is probable that tetraploidy in *Salicornia* is the result of autopolyploidy rather than allopolyploidy.

4.7 Taxonomic considerations of the chromatographic data:-

The phenolic substances, which were investigated by means of one - dimensional chromatography, show a high uniformity in the number, size shape and concentration of the detected spots. This is especially so when one considers that the analysed material was selected to include different types of *Salicornia*, similar individuals from one population, and individuals of similar phenotypes but from different localities, and possibly they include diploid and tetraploid forms. Hence, it seems one - dimensional chromatography is of limited value as an additional tool to the bio-systematic studies. Nevertheless, such remarkable uniformity between the analysed individuals could strongly suggest that the studied types of *Salicornia* are ancestors.

On the other hand, a greater resolution was achieved by two -

dimensional chromatography for the phenolic glycosides, though the identification of observed compounds was thought to be beyond the scope of the present investigation. Alston and Turner (1963) have pointed out that this by no means eliminates the possibility of obtaining a great deal of useful systematic information. Since in this study the results obtained were mainly evaluated by means of the presence or absence of the compounds, mere tabular listing was found difficult to assess, in spite of what had been mentioned that some of the variation in the chromatographic pattern (presence or absence of the orange-yellow spots) was found to be related to some extent with *Salicornia* type.

Initially, the data was assessed by means of the similarity index technique; a method of expressing and visualizing quantitative relationships of species as proposed by many authors such as Ellison et al. (1962), and Kaltiskies and Diedo (1970). They utilized the following formula:-

$$\frac{\text{Spots in common for species A and B}}{\text{Total spots in A + B}} \times 100$$

The results of the calculations of the similarity indices for the 29 groups of *Salicornia* are presented in the form of a similarity matrix (Figure 4.7). This technique was adopted to test how far the general chromatographic pattern can be used as an additional taxonomic tool in differentiating between *Salicornia* groups.

From Figure 4.7it can be seen that the similarity matrix started from 25 percent, since the lowest similarity index obtained was 23 percent. From the Figure it can also be noticed that the majority of the analysed groups of *Salicornia* share a similarity index of 45-65

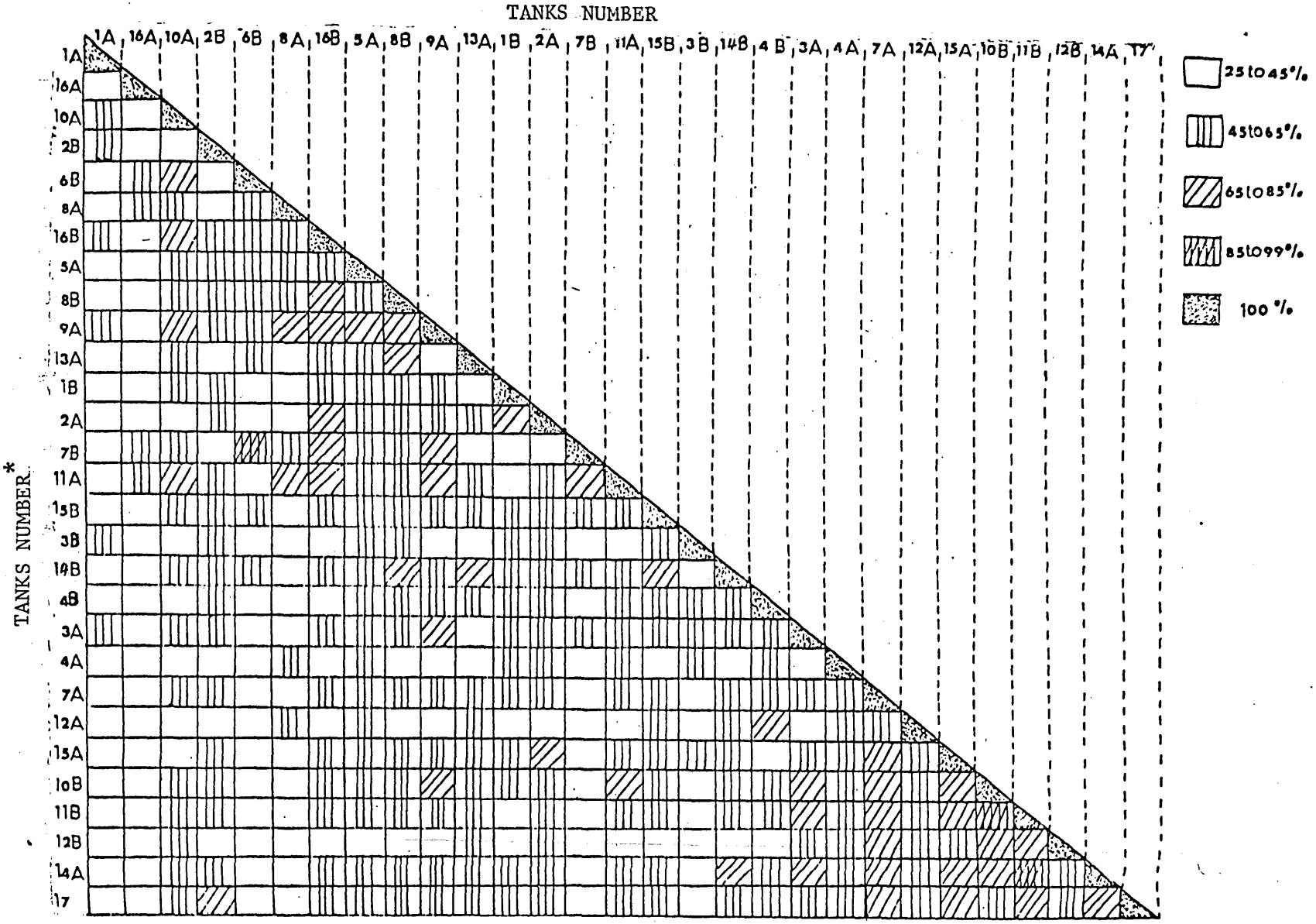


Figure 4.7 Shows the similarity matrix shaded for the 29 types of *Salicornia* analysed (Based on their similarity indices values). * See Table 4.1, page 108.

percent. Nevertheless, it can be observed that *Salicornia pusilla* shares the lowest similarity with most of the other groups of *Salicornia*. Members belonging to *S. procumbens* share a relatively higher similarity level than those of *Salicornia europaea*, particularly between the members which belong to different populations. However, from the similarity matrix presented it is difficult to assess any satisfactory groupings between the *Salicornia* spp. studied. This could be due to the strong inheritance relationship. A similar approach by Harney and Grant (1965), in a chemotaxonomic study of the genus *Lotus*, found the similarity index of more use in differentiating distantly related taxa than closely related ones.

The chromatographic results of the phenolic glycosides for the 29 groups of *Salicornia* were ordinated utilising principal components analysis which is thought to be more convenient to deal with such closely related taxa. The principal components analysis adopted in this study is based on that discussed by Orloci (1966) and Austein and Orloci (1966), which is normally applied to ecological problems, but in the present analysis a plant number (taxa) replaces the quadrats. Each plant number may be represented by a point in multidimensional space, the co-ordinates for fixing its position being the presence or absence of the chromatographic spots. The full data will form a multi-dimensional 'cloud' in which groups of plants, which are more or less similar, will form denser clusters, separated by less dense regions. The principal components, analysis picks out successive components or axes from the 'cloud', the first being the axis associated with the maximum variance. The second axis is orthogonal to (and so independent of) the first, and is associated with the maximum variance remaining and so on with successive axes. This process could, in theory, be continued until the total variance has been accounted for. However,

in practice, the first few axes will account for most of the variance akin to an analysis of variance. The results of the two ~ dimensional chromatography for the phenolic glycosides were assessed by principal components analysis (Q- type) on the CDC 6600 and CDC 6400 computers at the University of London Computer Centre (Appendix,Table A 4.1).

The result of the plant group ordination is given in Figure 4.8. Axis 1 separates the plant groups primarily into two main groups. However this separation seems a kind of gradual separation in which an overlapping between some groups is expected. It appears that the plant numbers 1 - 19, which are distributed between the points zero - 1.6 on axis 1 belong to *Salicornia europaea* (including *S. pusilla*) while the plants numbers 20 - 29 which lie between the points 1.7 - 3.5 (axis 1) belong to the *S. procumbens* group. Axis 2 appears to cluster the plant groups according to their similarity (i.e. how far the plant groups are correlated to each other). Generally it can be observed from Figure 4.8, there is more variation between the *S. europaea* groups than between the *S. procumbens* groups. Also, it can be suggested that the plants numbered 1, 19 and 11 are distinctly separated from the other groups of *S. europaea*. This is probably as pointed out earlier in this study, because plant number 1 belongs to *Salicornia pusilla* which showed a relatively distinct chromatographic pattern amont the groups of *Salicornia* spp. studied. In addition, plant numbers 19 (tetraploid) and 11 share in common some of the orange-yellow spots found in the *S. procumbens* group. The *S. ramosissima* (plant numbers 2 and 3) can produce a relatively distinct chromatographic group among *S. europaea* members.

Plant groups belonging to *Salicornia procumbens* form fewer sub groups than seen in the *S. europaea*, as a result of less observed variation in their chromatographic pattern, although there is necessarily

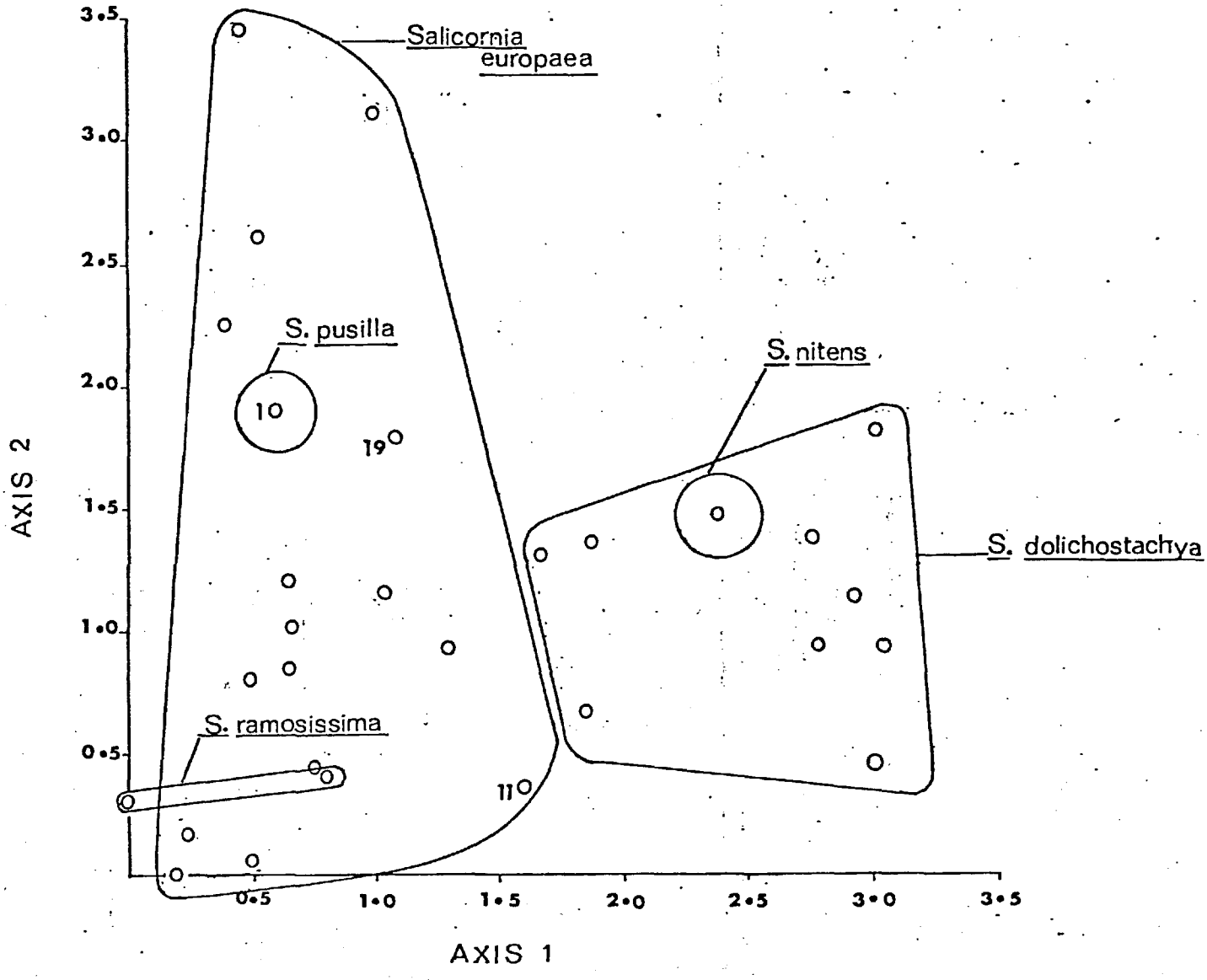


Figure 4.8 Diagram shows the scatter plots of the 29 types of *Salicornia* analysed by Principal Component Analysis (Based on their phenolic glycosides). The continuous line encloses the same named species.

some subjectivity in the visual grouping of the points. However, plant number 29 which belongs to *S. nitens* seems to fall just about the middle of the *S. dolichostachya* group. In addition, the chromatographic patterns of the both groups also show to be very similar to each other.

From the results of the principal components analysis of the phenolic glycosides, it seems possible to mark a primary biochemical separation between the *Salicornia europaea* (including *S. ramosissima)* and the *S. procumbens* (including *S. nitens*).

The results of the two - dimensional chromatography of the phenolic acids and simple phenols can be considered of little taxonomic value in discriminating between the different groups of *Salicornia*. However, the quantitative variation in the spot numbers 1 and 2 of the simple phenol, i.e. maximum concentration of both spots was observed in members of the *S. procumbens*, and the complete absence of the spot number 2, accompanied with high reduction of spot number 1 in *S. pusilla*, may have some taxonomic value.

This primary classification of the genus, based on the phenolic glycosides, is probably, in agreement with the morphological classification given by Ball, in Flora Europaea, Volume 1, 1964.

CHAPTER V

PHENOTYPIC VARIABILITY IN *SALICORNIA* SPP.

It is virtually impossible to give a precise definition of plasticity or variability because there is so much interaction between the genotype and the phenotype. But as a general rule the amount by which the expression of an individual characteristic is altered by environmental stimuli is a measure of the plasticity of this characteristic.

Plastic responses in plants are 1. Specific for a particular plant characteristic; 2. Specific in relation to a particular environmental influence; 3. Under genetic control, and therefore capable of being altered by selection, which means that the plastic response may vary from individual to individual within a species (Bradshaw 1965).

Plant growth is restricted to certain parts of the plant's body. These are the permanently meristematic regions, regions of indeterminate growth, resulting in the continuous formation and development of organs, with large surface areas provided for nutrition. The stationary habit also makes individual plants more susceptible to environmental fluctuations as they cannot escape from nutrient variation, except by the dispersal of seeds. They may also grow into different areas in space or be forced into such areas by competition.

Since characters form the basis for the description and classification of organisms, the factors which affect the plasticity of the phenotype are clearly of great concern to the taxonomist. Thus using

plastic phenotypic characters for taxonomic delimitation has given rise to a multitude of 'paper' species and varieties without any taxonomic value (Van Steenis 1973). It is thus essential to find out if variation is due to genetically inherited causes or to environmental factors. The fact that similarity in phenotype may be due either to environmental modification or to genotypic differentiation makes superficial similarities uncertain guides of genetic relationship. They are usually disregarded by evolutionists due to their possibly non-genetic nature (Davis and Heywood 1973).

5.1 Scope and purpose of the experiments:-

As outlined earlier in this thesis, the phenotypic plasticity in *Salicornia* has an important role in the taxonomic difficulties experienced in the genus. Thus one of the primary objectives of the present investigation is to search for the basic environmental factors which cause this variation in the morphology. Subsequently one can study the extent and the form of this variation in terms of the morphological behaviour of the plant under these factors, in a hope to find reliable morphological characters which might help in clearing up some of the confusion present in the classification.

In general, most of the studies on salt marsh environments have shown that most of the inorganic nutrients are present at concentrations greatly in excess of the plants needs, but some, such as nitrogen and phosphorus, occur at such a level as to be utilized almost to the point of exhaustion.

5.2 The effect of nitrogen deficiency and phosphorus deficiency on the morphology of *Salicornia*.

5.2.1. Experimental procedures:-

In the present experiment seeds of one plant of *Salicornia ramosissima* type were grown in three experimental solutions; a complete nutrient solution, a nitrogen-deficient solution (-N), and a phosphorus-deficient solution (-P). The parent plant had been cultured, the previous year, in the greenhouse, and enforced self pollination will have reduced the genotypic variability of the progeny.

For each treatment three culture tanks were used. Each tank was partitioned into two equal parts, so each treatment had six replicates. Seeds were sown in the culture tanks in the first week of May, 1975. Usually germination commenced within one week of sowing. After the formation of the first two or three sterile segments, the seedlings could be regarded as being well established. Then the plants in each half tank were thinned to 12 - 15 individuals. The composition of the nutrient solution used for the complete nutrient solution was the same as that used in the previous culturing experiment (Hoagland and Arnon 1938, Table 2.1). For the nutrient deficient treatments, the solutions were made up according to the formula of Hoagland and Arnon (1950), which basically gave the same concentrations of ions as in the above one. In the nitrogen deficient solutions (Table 5.1), the corresponding lack of potassium and calcium were made up with the addition of potassium sulphate and calcium sulphate respectively. Also ammonium dihydrogen orthophosphate ($NH_4 H_2 PO_4$) was replaced with calcium tetrahydrogen orthophosphate $Ca H_4 (PO_4)_2 H_2o$. These adjustments were calculated as follows:-

Table 5.1 Shows the macroelements and their concentrations, which were used in the preparation of nutrient solutions lacking nitrogen.

Salt	Molar	g.1L.	cc/one L. of solution
$K_2 SO_4$	0.5	0.44	5
$Ca H4 (PO_4)_2 H_{20}$	0.05	0.13	10
$CaSO_4$	0.01	0.27	200
$MgSO_4$	1.00	0.49	2

Table 5.2 The means and the range of the maximum and minimum daily temperature and relative humidity in the greenhouse.

Temperature (C^o)			Relative Humidity (%)		
	Mean	Range		Mean	Range
Maximum	29.5	27 - 30	Maximum	83.4	73 - 90
Minimum	13.5	11 - 19	Minimum	52.65	46 - 59

$$\frac{\text{Atomic weight of the ion}}{\text{molcular weight of the substance.}} \times \text{weight (g.1L)} > \times 1000 = \text{The substance concentration of the ion in p.p.m.}$$

Macro-elements in the phosphorus - deficient solution were the same as in the complete solution without ammonium dihydrogen orthophosphate $NH4\ H_2\ PO_4$. Iron and the five micro-elements were added in the same concentrations as in the complete solution (Table 2.1). The pH of the solution was between 6 - 7 which proved to be satisfactory for growth. These values were read on an Electronic Instrument Ltd. PH Meter Model 7060. For all the treatments the sodium chloride concentration was 1.5%, which was shown previously to be very satisfactory.

Daily means of the temperatures and the relative humidity in the greenhouse were recorded by a CASELLA Thermo-hygrograph, during the total growth period of 20 weeks, and can be read from Table 5.2.

The amount of nitrogen and phosphorus in the normal solution represents full dosage with respect to both elements. Therefore, all the measured morphological characters of the plants grown in the normal solution have been taken to represent the control for the both treatments. The results were expressed in terms of the morphological characters, the growth habit and the flowering time. The following morphological characters were assessed quantitatively:-

1. The vegetative characters:-
    1. Shoot length.

2. Root length.
3. Total number of terminal spikes/plant.
4. Total number of primary branches from the main axis.
5. Number of sterile segments in the main axis.
6. Terminal spike length.
7. Number of fertile segments in the terminal spike.
8. Length of the lowermost branch from the main axis.
9. Length of the uppermost branch from the main axis.

II. The fertile segment characters:-

(Using three fertile segments in the middle of the terminal spike, see Figure 3.14.

1. Maximum width of the second fertile segment (A).
2. Maximum width of the fourth fertile segment (B).
3. Minimum width of the third fertile segment (C).
4. Observed length of the segment (D).
5. Observed length of the central flower (F).
6. Total length of the central flower (E).
7. Observed length of the side flower (G).
8. The distance between the apex of the central flower and the upper margin of the segment (D-F).
9. Length of the covered part of the central flower from the segment base. (E-F) = (The scarious border width at its tip).

The experimental results of the three treatments are presented in the form of a minimum, a maximum, means, a standard deviation (S.D.), - 2 standard deviation (-2S), + 2 standard deviation (+2S), and a variance for each replicate and separately for each of the vegetative characters. These can be read in Tables A 5.1-A 5.4 in the appendix. In the text the

mean, S.D. and the range based on the means of the six replicates for each treatment are shown.

5.3 The effect of increased light intensity on the morphology of *Salicornia*.

In the salt marsh habitat the variation in light intensity may limit plant growth at both upper and lower levels. Seawards the light intensity can be reduced considerably during tidal inundation, especially if much sediment is carried in the water. In addition, both the intensity and the quality of light are markedly reduced by a layer of water (Weaver and Clements 1938). At the landward limit the growth of the taller plants may shade out the shorter plants, where the marsh is ungrazed (Ranwell 1972). However, light has not yet been subjected to much study in the salt marsh habitat, (Chapman 1976) even though most species are probably light demanding, and intolerant of shade.

Salicornia species can occur throughout a salt marsh. The low marsh plants are subjected to daily tidal immersion, particularly during spring tides, whilst the upper marsh plants may be shaded by the taller plants, such as *Suaeda*, *Halimione* Aell. and *Spartina* Schreb. Because of these factors the present experiment was carried out to investigate the effect of light intensity on the morphology of *Salicornia*. A secondary objective was to find out whether increased light intensity could stimulate the development of the red coloration in the plant (betacyanin).

5.3.1 Experimental procedures:-

This experiment was carried out in the greenhouse in conjunction with the nitrogen - deficiency, phosphorus - deficiency and complete

nutrient solution treatments. Also the seeds of the same parent plant (*S. ramosissima*) were used. This facilitated the use of the same morphological characters of the plants grown in the complete nutrient solution, under normal greenhouse illumination, as a control to compare with the results of this treatment. In this experiment the light intensity was increased to almost double the normal greenhouse illumination. The design and the general planning of this treatment was the same as those for the nutrient deficient treatments. The three culture tanks used for the light treatment were positioned at one side of the culture bed. This helped to partition them easily from the other treatments. This partition did not result in any shading which might affect the light regime of the other experiments. The levels of the lamps on the tops of these culture tanks were lowered to half the distance as that for the other treatments. The level of the light bank was about 40 cm. from the sand surface. It consisted of 10 long cool fluorescent tubes, each of 80 watts. In addition, four mercury tungsten lamps, each of 200 watts, were added. Each lamp was mounted under a white round reflector of 38 cm. diameter. These four lamps were positioned about 15 - 20 cm. above the fluorescent light bank. These lamps, with their reflectors, were placed so that each of the three culture tanks would receive as even an amount of light as possible. Though the greenhouse was naturally illuminated, a fixed day length of 14hr. light was used (6.00 - 20.00hrs.). To avoid the extra heat, which would be produced by the mercury tungsten lamps, an air blower was installed. Precautions were taken to ensure that the temperature at the plant level was the same as in the greenhouse. This light regime gave the plant almost double the light intensity normally found in the greenhouse. The light levels at plant height were determined with a photometer.

The plants for this treatment was grown in a complete nutrient solution (Hoagland and Arnon 1938). All the other growth conditions were exactly the same as those explained earlier in this chapter.

5.4 Results and discussion:-

Table 5.5 shows the measurements for each of the vegetative characters of the plants grown without nitrogen. It shows that lack of nitrogen had a very significant effect on all of these characters. Generally the shoot system had been reduced to a high degree, whilst the adventitious root system had been limited to two or three filaments. Plant height showed a mean of 2.8 cm. in comparison with those which were grown in full nitrogen which showed a mean of 11.7 cm. (Table 5.3). The branching habit had been depressed almost completely, apart from the occasional production of 2 - 3, almost sessile, fertile segments which sometimes developed on one side of the main axis. Terminal spike length was also reduced from 3.07 cm. in full nitrogen to 0.59 cm. in the nitrogen deficient solution, with two or one, and occasionally with three, fertile segments. On the other hand the number of sterile segments in the main axis was the least affected by nitrogen deficiency in comparison with the other vegetative characters. It had a range from 4.9 - 9.4 in comparison with that of the control plants, which had a range of 12.6 - 16.3 sterile segments (Tables 5.3 & 5.5). However, its length had been reduced to less than $1/_3$ of those grown with a full nitrogen dosage. In addition, all the plants grown in the nitrogen deficient solution developed an 'erect' growth habit, whilst those grown in the complete solution developed a 'prostrate' growth habit, (Photographs 5.1 & 5.2).

In contrast to the vegetative characters, the fertile segment components of the plants grown in nitrogen deficient solutions showed

Table 5.3. Vegetative characters for *Salicornia ramosissima* type grown in a complete nutrient solution. These figures are based on the mean values of the six replicates .

The vegetative morphological characters	Min.	Max.	mean.	S.D.
1-Shoot length	12.52	14.47	11.69	± 0.99
2-Root length	7.62	9.37	7.32	± 0.70
3-Total number of terminal spikes/plant	56.54	150.00	80.29	± 27.63
4-Terminal spike length	1.95	3.34	3.07	± 0.20
5-Number of fertile segments in the terminal spike.	8.36	13.00	12.27	± 1.25
6-Total number of primary branches from the main axis.	23.54	29.08	23.79	± 2.69
7-Number of sterile segments in the main axis.	12.62	16.30	11.92	± 1.27
8-Length of the lowermost branch from the main axis.	6.72	8.62	6.69	± 0.79
9-Length of the uppermost branch from the main axis.	2.29	2.90	3.02	± 0.09

Table 5.4 Fertile segment components measurements (mm) for *S. ramosissima* type grown in a complete nutrient solution.

Fertile segments components	mean	S.D.
A	3.11	± 0.38
B	2.83	± 0.41
C	2.47	± 0.15
D	1.76	± 0.10
E	1.57	± 0.11
F	1.53	± 0.10
G	0.97	± 0.12

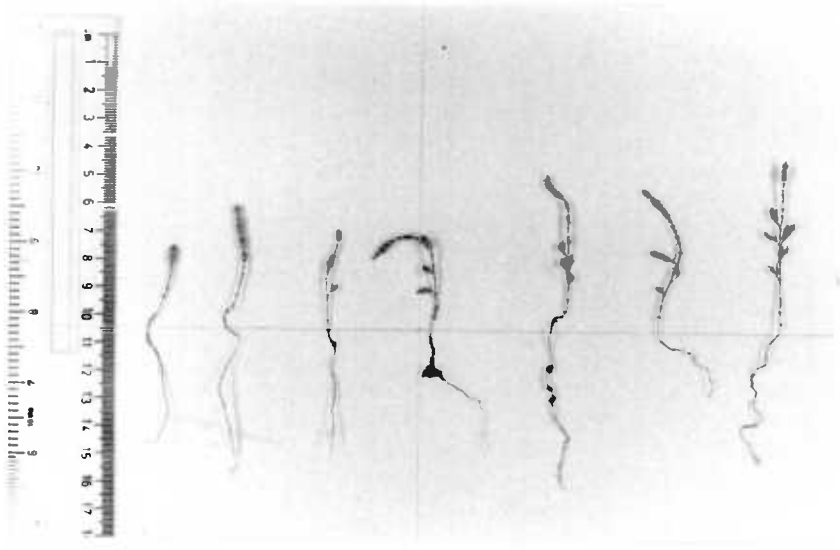
Table 5.5 Vegetative characters for *Salicornia ramosissima* type grown in a nutrient solution lacking nitrogen (-N). These figures are based on the mean values of the six replicates .

The vegetative morphological characters	Min.	Max.	Mean.	S.D.
1-Shoot length	1.41	3.90	2.84	± 1.15
2-Root length	5.09	7.45	6.34	± 0.76
3-Total number of terminal spikes/plant	1.00	1.92	1.27	± 0.38
4-Terminal spike length	0.32	0.90	0.59	± 0.22
5-Number of fertile segments in the terminal spike.	1.11	3.77	2.25	± 0.99
6-Total number of primary branches from the main axis.	0.54	0.92	0.37	± 0.43
7-Number of sterile segments in the main axis.	4.89	9.39	7.50	± 2.09
8-Length of the lowermost branch from the main axis.	0.00	0.00	0.00	± 0.00
9-Length of the uppermost branch from the main axis	0.00	0.00	0.00	± 0.00

Table 5.6 Fertile segment components measurements (mm) for *S. ramosissima* type grown in a nitrogen-deficient (-N) nutrient solution.

Fertile segment components	Mean	S.D.
A	3.29	± 0.20
B	3.10	± 0.22
C	2.46	± 0.08
D	2.17	± 0.14
E	2.05	± 0.14
F	1.75	± 0.13
G	1.04	± 0.07

Photograph 5.1 : Shows *Salicornia ramosissima* plants grown in the complete nutrient solution.



Photograph 5.2 : Shows *Salicornia ramosissima* plants grown in a nutrient solution lacking nitrogen(-N).

a considerable increase in their measurements,(Tables 5.4 & 5.6), especially the length of the fertile segment (D), the total length of the central flower (E), and the length of the side flower (G). This,probably, means that the plants in the nitrogen deficient solution could produce relatively larger seeds than those grown in the nutrient solution with normal levels of nitrogen. However, nitrogen deficiency caused a marked early flowering; about 2 weeks earlier than those grown in the complete nutrient solution.

The visual symptoms of the plants grown in the nutrient solution lacking phosphorus were not so obvious as those grown in the nitrogen deficient solution (in comparison with those grown in the complete nutrient solution),however, most of the measured vegetative characters of the plants grown in the phosphorus deficient solution showed a significant deviation from those grown in the nutrient solution with normal levels of phosphorus. However, from Tables 5.3 & 5.7 it can be seen that the characters; the total number of sterile segments in the main axis, the shoot length, and the total number of terminal spikes per plant are the most significantly affected by the lack of phosphorus. The lack of phosphorus also resulted in some growth abnormality. As has been noticed, quite often a clump of two or more short terminal spikes were developed in a normal terminal spike originating from one fertile segment (Photograph 5.3). In addition, constrictions can be observed in some of the terminal spikes. It seems this may be due to the failure of some fertile segments to form flowers and seeds. Wallace (1961) reported that one of the main effects of phosphorus deficiency was that a plant may fail to develop seeds. It seems that some of the phosphorus deficient plants developed longer terminal spikes than those grown in the complete nutrient solution due to this abnormality.

Table 5.7 Vegetative characters for *Salicornia ramosissima* type grown in a nutrient solution lacking phosphorus (-P). These figures are based on the means value of the six replicates.

The vegetative morphological characters	Min.	Max.	Mean.	S.D.
1-Shoot length	10.50	13.23	13.55	± 0.78
2-Root length	6.20	8.23	8.29	± 0.78
3-Total number of terminal spikes/plant.	44.67	180.83	93.89	± 32.69
4-Terminal spike length.	2.79	3.34	2.86	± 0.52
5-Number of fertile segments in the terminal spike.	11.46	14.00	11.42	± 1.61
6-Total number of primary branches from the main axis.	19.83	27.85	26.62	± 2.29
7-Number of sterile segments in the main axis.	10.00	13.77	14.26	± 1.39
8-Length of the lowermost branch from the main axis.	5.48	7.49	7.69	± 0.69
9-Length of the uppermost branch from the main axis.	2.92	3.17	2.58	± 0.19

Table 5.8 Fertile segment components measurements (mm) for *S. ramosissima* grown in phosphorus-deficient (-P) nutrient solution.

Fertile Segment Components	Mean	S.D.
A	2.77	± 0.14
B	2.65	± 0.15
C	2.01	± 0.10
D	1.87	± 0.05
E	1.69	± 0.07
F	1.65	± 0.10
G	0.97	± 0.12

Photograph 5.3 : Shows *Salicornia ramosissima* plants grown in a nutrient solution lacking phosphorus(-P).

Fertile segment components of the phosphorus-deficient plants showed quite similar results to those grown in the nutrient solution with normal levels of phosphorus, in comparison with equivalent measurements made on normal segments. (Tables 5.4 & 5.8). Most of the plants grown in the phosphorus deficient solution developed an 'erect' growth habit, though some showed a 'prostrate' tendency.

Table 5.9 shows the results for the vegetative characters for the plants grown under the light treatment. The increased light intensity resulted in a significant increase in all the measured vegetative characters. However, some characters such as the length of the upper and lower branches, the total number of terminal spikes in the plant, and the shoot and the root length, showed a significant increase in their measurements, in comparison with those grown in the normal light regime of the greenhouse, Table 5.3 . However, the terminal spike length, the number of fertile segments in the terminal spike, and number of sterile segments in the main axis showed significantly less increase than the above mentioned characters, Table 5.11.

The most obvious effect of increased light intensity was the total number of branches which developed from the primary branches. Consequently, since in *Salicornia* spp. each branch is terminated with a terminal spike, the total number of terminal spikes also increased to a high degree. Table 5.9 shows that the total number of terminal spikes increased almost three times over those grown under the normal greenhouse light conditions. In other words, light intensity resulted in a marked increase in the numbers of flowers and seeds per plant. Also it resulted in a marked delay in the flowering time, this being about 10 days later than those that had grown under the normal greenhouse light regime.

Table 5.9 Vegetative characters for *Salicornia ramosissima* type grown under an increased light intensity. These figures are based on the mean values of the six replicates.

The Vegetative morphological characters	Min.	Max.	Mean.	S.D.
1-Shoot length	13.78	17.32	14.79	± 1.69
2-Root length	8.76	10.60	10.02	± 0.77
3-Total number of terminal spikes/plant	155.18	447.0	270.77	±87.39
4-Terminal spike length	2.79	4.10	3.300	± 0.50
5-Number of fertile segments in the terminal spike.	11.85	15.92	13.20	± 1.57
6-Total number of primary branches from the main axis.	22.60	30.00	25.20	± 3.14
7-Number of sterile segments in the main axis.	12.50	15.00	13.70	± 1.10
8-Length of the lowermost branch from the main axis.	9.63	13.45	11.62	± 1.55
9-Length of the uppermost branch from the main axis.	3.85	5.94	4.81	± 0.70

Table 5.10 Fertile segment components measurements (mm) for *S. ramosissima* grown under an increased light intensity treatment.

Fertile Segment Components	Mean	S.D.
A	2.66	±0.03
B	2.56	±0.07
C	1.92	±0.05
D	1.96	±0.06
E	1.65	±0.05
F	1.47	±0.04
G	0.93	±0.02

Table 5.11 Shows in percentages the dis-similarity in the replicates of each treatment (nitrogen deficient, -N; phosphorus deficient, -P; and increased light intensity, +L) with those of the control treatment.

Vegetative morphological characters \ The treatments	-N	-P	+L
1. Shoot length.	100	55.6	75
2. Root Length.	27.8	13.9	77.8
3. Total number of terminal spikes/plant.	100	41.7	96.7
4. Terminal spike length.	100	25.0	33.3
5. Number of fertile segments in the terminal spike.	97.2	25.0	22.2
6. Total number of primary branches from the main axis.	100.0	27.8	25.0
7. Number of sterile segments in the main axis.	86.1	58.4	38.9
8. Length of the lowermost branch from the main axis.	100.0	25.0	94.4
9. Length of the uppermost branch from the main axis.	100	36.1	97.2

The above figures were calculated by application of the following formula:-

The dis-similarity percentage between means value of two treatments. $= \frac{\text{number of significantly different * means}}{\text{Total number of means (significantly different means + significantly similar** means.)}} \times 100$

* Significantly different = The value of one or both 'F' and 't' test show a probability of less than 0.05.

** Significantly similar = The values of both 'F' and 't' test are not significant, or if they possessed a probability greater than 0.05.

Generally, the increased light intensity brought about vigorous vegetative growth, as well as a system of well developed adventitious roots. The plants were darker green, probably due to the increased chlorophyll content, and they did not show any sign of red colouration (betacyanin) in their superficial tissues. Also it was noticed that the main axis, and the axis of the secondary branches, became relatively thicker and more woody in nature. (Photograph 5.4).

In spite of the large increase in the total number of terminal spikes per plant, the measurements of the fertile segment components did not show a marked deviation from those grown under the normal light level of the greenhouse, Tables 5.4 & 5.10. All the plants grown under increased light intensity showed a 'prostrate' growth habit, which could be due to the increased weight of the plant as a result of the increase in the vegetative growth.

From the tables and the photographs of the present investigation, it is obvious that nitrogen-deficiency has the most significant effect on almost all the vegetative morphological characters of *Salicornia*, and hence can be considered as the main limiting factor for its growth. Also this wide range in the morphological characters, between plants grown in the nitrogen-deficient solution and those grown in the normal nitrogen levels of the complete solution, shows that *Salicornia* plants respond sensitively to nitrogen levels. Such results are in support with the conclusions of most people who worked on the nutrition of salt marsh plants, that nitrogen has the priority as a growth limiting factor, (e.g.Tyler 1967, Pigott 1969).

However, *Salicornia* plants showed a remarkable flexibility to cope with such a deficiency of an important macronutrient growth element.

Photograph 5.4 : Shows *Salicornia ramosissima* plants grown under an increased light intensity

In spite of the marked fall in the physiological activity, and thus overall reduction in the vegetative characters, the plant is still able to complete its life cycle successfully in producing flowers and seeds. It seems that when *Salicornia* is under stress through low external levels of nitrogen, the small amount available from the seeds is used to produce flowers and seeds, which are essential for reproduction and not for increased vegetative growth. Such an adaptation can be visualized by the plants ability to form terminal spikes with relatively larger fertile segments than those grown in the normal level of nitrogen of the complete nutrient solution, whilst the other morphological characters hardly have been developed, an ability constituting a kind of compensating mechanism (i.e.the advantageous modifications of the phenotype in response to environmental changes, Whitehead.1962).

On the other hand, phosphorus deficiency resulted in some significant effect on the morphology of *Salicornia*, but these were much less than those of nitrogen deficiency. Nevertheless, the most obvious effect of phosphorus was the stimulation of some growth abnormality, especially the considerable increase in the length of the terminal spike, though it did not affect the general shape of the fertile segment, apart from those specimens which failed to produce seeds. This narrow range of variation of *Salicornia* plants in response to phosphorus deficiency may follow from the plant being physiologically well buffered against such changes or variation in phosphorus levels.

CHAPTER VI

MORPHOLOGICAL BEHAVIOUR OF *SALICORNIA* SPP. IN RELATION TO DIFFERENT LEVELS OF NITROGEN, PHOSPHORUS AND SODIUM CHLORIDE:-

To give precision and usefulness to various taxonomic categories, particularly at or below the level of species, it is desirable that their scale of variation should be studied quantitatively. This scale of variation and the range of tolerance of the genotype in question is the range within which it can grow successfully and produce flowers and seeds. It is well known that every genotype has not one but a range of environmental tolerances when viewed in terms of its ecological amplitudes. 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 a limited number of physical factors because so many variable are 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 experiment is to establish certain cardinal points in which can be done by varying single component in turn whilst the others are kept constant.

Phenotypic variability in the plants, as pointed out earlier, may be caused by variation either in the environment and/or the genotype. So comparative culturing of plants raised from seeds from various parts of the tolerance range may help, partially, in separating heritable from non heritable variables.

In the present experiment seeds belonging to different types of *Salicornia* were grown at different levels of nitrogen, phosphorus

and sodium chloride. They are described here under two headings, 1. nitrogen and phosphorus, and 2. sodium chloride, though all the experiments were in fact carried out simultaneously.

6.1 Material for the experiment:-

Eight plant groups occurring naturally on the salt marshes of Hayling Island were collected in summer, 1975, and each plant was wrapped in a newspaper and tagged. They were stored in a relatively humid, dark place over the winter, for the next growing season.

The plants were chosen to be representative of the major taxonomic groups of *Salicornia* found on Hayling Island. Following the classification of Chapman et al. (1962), these plants were identified as *Salicornia dolichostachya*, *S. nitens* and *S. ramosissima*. Their general morphology was recorded immediately after their collection. These measurements can be seen in Table A 6.1, in the appendix.

6.2 The effects of different levels of nitrogen and phosphorus on the morphology of *Salicornia*:-

6.2.1 Experimental procedures:-

The levels of nitrogen and phosphorus used in this experiment were determined by the results of the last experiment. Their effects on plant morphology were tested in the range of 5 - 135 p.p.m. (N_1 - N_4) and 2 - 16 p.p.m. (P_1 - P_4), respectively. These ranges were considered wide enough to evaluate the effects of these elements on plant morphology. The actual concentrations used were spaced logarithmically, being 5, 15, 45 and 135 p.p.m. for nitrogen and 2, 4, 8 and 16 p.p.m. for phosphorus. The seeds of the specimens number 3, 12 and 15 were

used (Appendix, Table A6.1).

In this experiment each culture tank was equally partitioned into three sections, referred to as A, B, and C. The sections are referred to as 3A, 3B, 3C etc.. Each section was sown with seeds of one of the three species in the following sequence:- Section 'A' with seeds of *S. dolichostachya*, Section 'B' with seeds of *S. nitens* and Section 'C' with seeds of *S. ramosissima*. Care was taken that there was no mixing of seeds during the irrigation period, particularly at the early stages of growth where loose seeds might easily be washed about.

For each species seeds of one parent plant were used in all the treatments of nitrogen and phosphorus. So for each level of nutrient treatment one culture tank was used. Tanks numbered 3, 4, 5 and 6 were used for the nitrogen treatments, and 7, 8, 9 and 10 for the phosphorus treatments.

The nutrient solutions were made up according to Hoagland and Arnon (1950) for solutions with different levels of nitrogen and phosphorus, with decreasing concentrations of the relevant element for each treatment and appropriate substitution. The reduction in the amounts of potassium and calcium were compensated by the addition of potassium sulphate and calcium sulphate respectively, giving the same quantity of potassium and calcium as in the normal solution (Hoagland and Arnon 1938). Ammonium dihydrogen orthophosphate had been replaced with calcium tetrahydrogen diorthophosphate ($CaH_4 (PO4)_2 H_2O$) to give the same amount of phosphate in the normal solution. These adjustments for nitrogen and phosphate can be read from Tables 6.1-6.3. Iron and the five micronutrients elements are the same as in the complete

Table 6.1 The weight (g/1L.) of the macronutrient salts used in preparation of the nutrient solution in the four levels of nitrogen.

Nitrogen level / The salt	5 p.p.m.	15 p.p.m.	45 p.p.m.	135 p.p.m.
KNO_3	0.015	0.050	0.145	0.435
$Ca(NO_3)_2$	0.018	0.047	0.147	0.441
$CaH_4(PO_4)_2H_2O$	0.130	0.130	0.130	0.130
$MgSO_4\ 7H_2O$	0.490	0.490	0.490	0.490
K_2SO_4	0.536	0.508	0.447	0.146
$CaSO_4$	0.272	0.459	0.435	0.108

Table 6.2 The amount of nitrogen (p.p.m.) from KNO_3 and $Ca(NO_3)_2$ at the four levels of nitrogen treatment.

Source of Nitrogen / Nitrogen level	KNO3		Ca(NO3)2	
	p.p.m.	g.1L.	p.p.m.	g.11
5 p.p.m.	2	0.015	3	0.018
15 "	7	0.050	8	0.047
45 "	20	0.145	25	0.147
135 "	60	0.435	75	0.441

Table 6.3 The weights (g./1L)of calcium tetrahydrogen diorthophosphate used in the preparation of the four levels of phosphorus *.

Phosphorus level / The Salt	2 p.p.m.	4 p.p.m.	8 p.p.m.	16 p.p.m.
$CaH_4(PO_4)_2 \quad H_2O$	0.008	0.016	0.033	0.065

* The other macronutrient salts are the same as of the complete solution (Hoagland and Arnon 1938).

Table 6.4 Mean, and range of the temperature and relative humidity in the greenhouse.

Temperature (C^o)			Relative humidity (%)		
	$\overline{X}$	Range		$\overline{X}$	Range
Maximum	29.5	28. - 32.0	Maximum	84.8	76 - 96
Minimum	6.9	4.0- 12.0	Minimum	53.5	50 - 59

nutrient solution (Hoagland and Arnon 1938). Changing the concentration of the salts did not bring about any significant change in the pH of the solution. These readings were about pH6 and were assumed to be approximately uniform for the work. These values were read on an Electronic Instrument Ltd. pH meter Model 7060.

Each culture tank reservoir was supplied with 17 litres of the appropriate nutrient solution. The solutions were changed after the first six weeks, with subsequent changes after each two weeks until the plants were harvested. Sodium chloride was added after germination had commenced in a concentration equal to that of average sea water (2.5%).

The experiment started by sowing the seeds on 30th April, 1976. Usually germination commenced within one week. After the establishment of the seedlings was ensured, their numbers were reduced to 13-15 plants of equal size and, to give the experiment a greater degree of uniformity, the distances between the seedlings were kept as similar as possible. All the other experimental conditions were described in Chapter II. The range and means of temperature and relative humidity in the greenhouse during the 20 weeks of the growth period, as recorded by a CASELLA Thermohygrograph are shown in Table 6.4 (Page 171).

6.2.2 Results:-

Tables (6.5-6.8), Figures (6.1-6.20) and Photographs (6.1-6.3) show the effect of the different levels of nitrogen and phosphorus on the measured characters. Each morphological character in each of the employed levels of nitrogen and phosphorus was expressed as a mean, together with 95% confidence limits. For more statistical

information about the vegetative characters, Tables A.6.2-A.6.7. in the appendix give the minimum, maximum, means, standard deviation and variance values. In addition, the statistical significance levels within the nitrogen treatments, and within the phosphorus treatments for each of the measured vegetative characters are shown in Figures 6.51 - 6.46). The effects of the various levels of nitrogen and phosphorus on morphology of the fertile segment components are presented as means with their standard deviations.

6.2.2.1. The effect of nitrogen treatments on the morphology:-

It can be seen that the three types of *Salicornia* i.e. *S. dolichostachya*, *S. nitens* and *S. ramosissima*, showed a significant response to the levels of nitrogen in terms of their vegetative characters. In each, the plant length, root length, number of sterile segments in the main axis, total number of primary branches and the length of the lowermost branch showed a significant increase in their measurements, up to a maximum of 45 p.p.m. nitrogen level, (N_3) above which there was no positive effect on their growth. The terminal spike length, number of fertile segments in the terminal spike and the length of the uppermost branch show an increase in their measurements, up to a maximum of 15 p.p.m. nitrogen level (N_2), again additional amounts of nitrogen did not show a positive response. However, Figures 6.9 & 6.10 also show that the nitrogen did not bring about any effect on the angle of branching, both of the upper and lower branch, with the main axis.

Figures 6.1-6.10, clearly illustrate that the three types of *Salicornia* have a remarkably similar growth pattern, however, they

Table 6.5 Shows the mean values for the vegetative characters for each of the selected types of *Salicornia* in the four levels of nitrogen.

	Salicornia type and treatments / Vegetative character	*S. dolichostachya* (A)				*S. nitens* (B)				*S. ramosissima* (C)			
		5 p.p.m.	15 p.p.m.	45 p.p.m.	135 p.p.m.	5 p.p.m.	15 p.p.m.	45 p.p.m.	135 p.p.m.	5 p.p.m.	15 p.p.m.	45 p.p.m.	135 p.p.m.
1.	Shoot length	11.55	17.22	20.94	18.29	19.43	26.28	24.50	25.10	14.89	21.98	24.59	18.43
2.	Root length.	6.95	7.91	9.67	7.8	9.83	10.77	11.63	11.09	6.63	6.93	7.46	6.61
3.	Total number of primary branches from the main axis.	26.67	34.20	40.00	35.60	35.17	40.00	46.17	42.00	29.93	34.53	36.27	30.67
4.	Number of sterile segments in the main axis.	13.33	17.17	20.13	17.67	17.50	19.92	22.75	20.92	13.53	17.27	17.87	15.33
5.	Terminal spike length	1.23	1.87	1.73	1.16	1.01	1.76	1.65	1.08	0.90	1.10	1.25	0.53
6.	Number of fertile segments in the terminal spike.	4.25	6.75	6.13	4.60	5.33	8.58	8.33	4.67	4.33	5.53	6.73	3.00
7.	Length of the lower most branch from the main axis.	2.95	7.68	9.88	8.01	3.67	7.66	12.33	10.84	2.02	3.00	6.22	5.83
8.	Length of the upper most branch from the main axis.	0.66	0.94	0.99	0.78	0.88	1.29	1.03	0.90	0.63	0.66	0.79	0.47
9.	Angle of the upper most branch with the main axis.	32.50°	34.17°	42.00°	36.67°	35.83°	32.08°	38.33°	48.18°	36.33°	29.67°	54.00°	51.67°
10.	Angle of the lower most branch with the main axis.	38.75°	40.00°	33.67°	32.00°	40.00°	35.83°	40.83°	54.55°	40.67°	32.00°	-	-

Figures 6.1-6.10 Effect of the four levels of nitrogen on shoot length, root length, total number of primary branches from the main axis, total number of sterile segments in the main axis, terminal spike length, number of fertile segments in the terminal spike, length of the uppermost branch from the main axis, length of the lowermost branch from the main axis, angle of the uppermost branch with the main axis and angle of the lowermost branch with the main axis, in the three types of *Salicornia*, with 95% confidence limits to show the physiological differences between these types at each level of nitrogen.

Note: The means and confidence limits at each nutrient level are slightly separated laterally to avoid overlap of the lines.

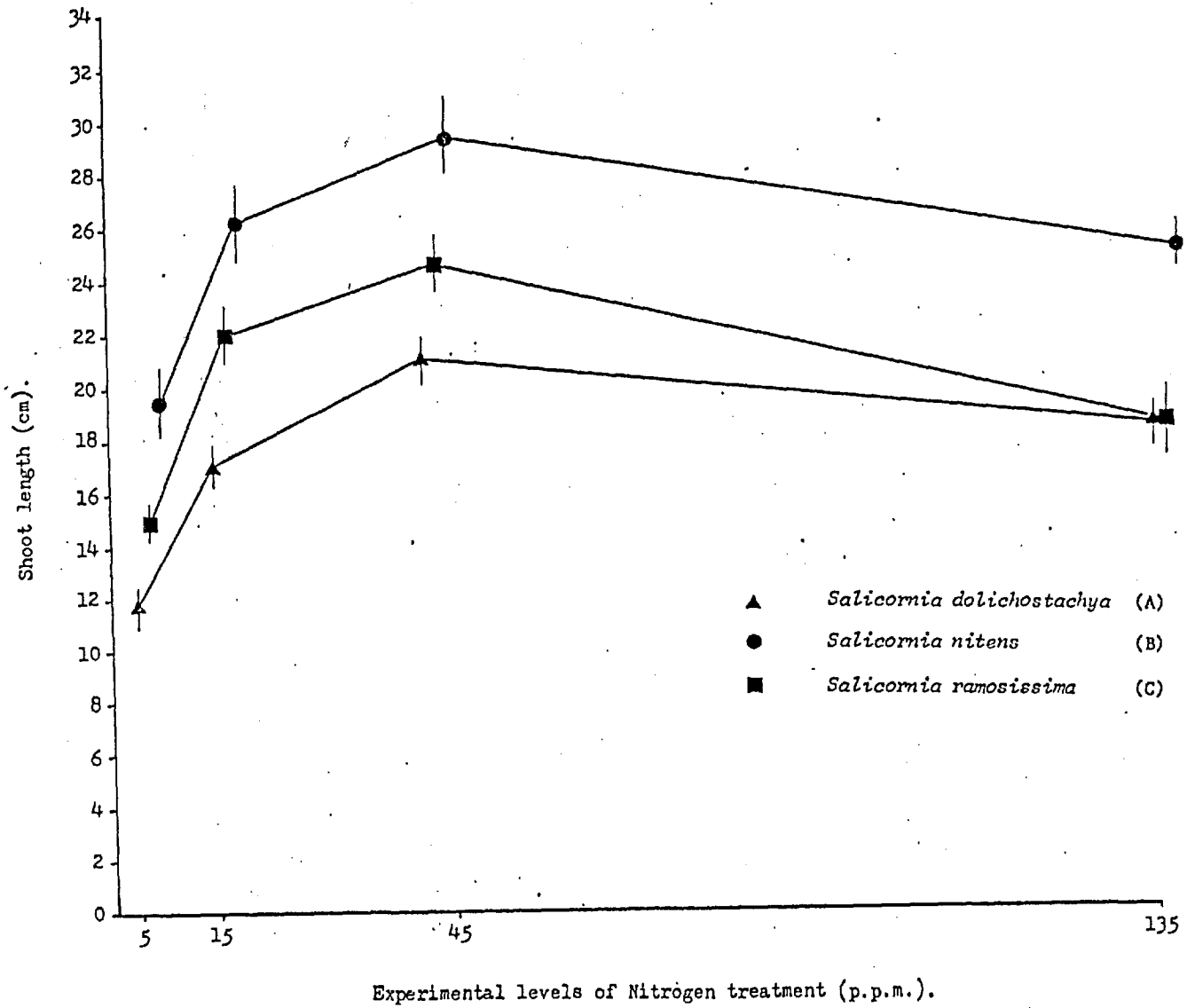

Shoot length (cm).
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
5
15
45
135
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)
Experimental levels of Nitrogen treatment (p.p.m.).

Figure 6.1

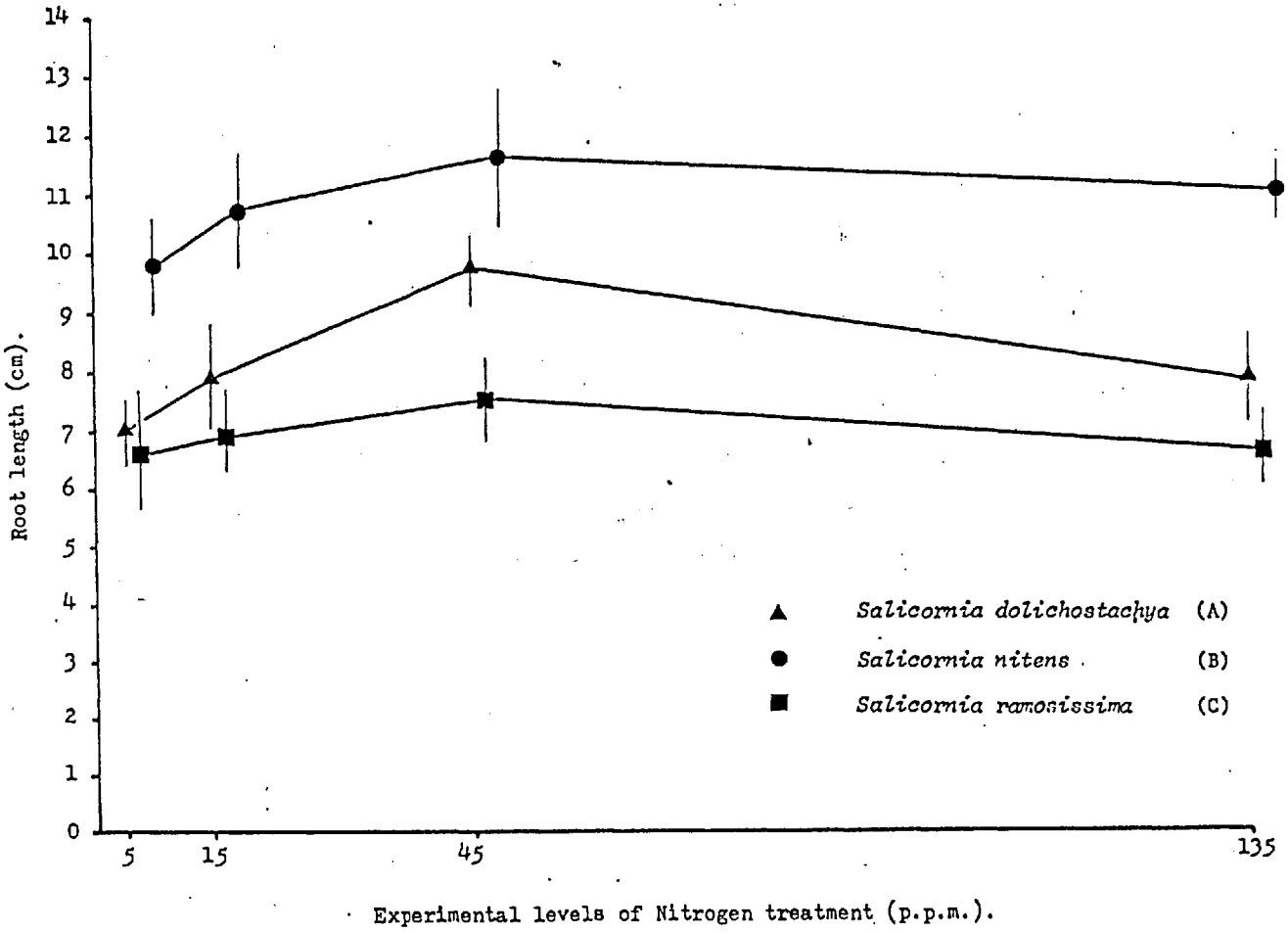

Root length (cm).
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
5
15
45
135
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)
Experimental levels of Nitrogen treatment (p.p.m.).

Figure 6.2

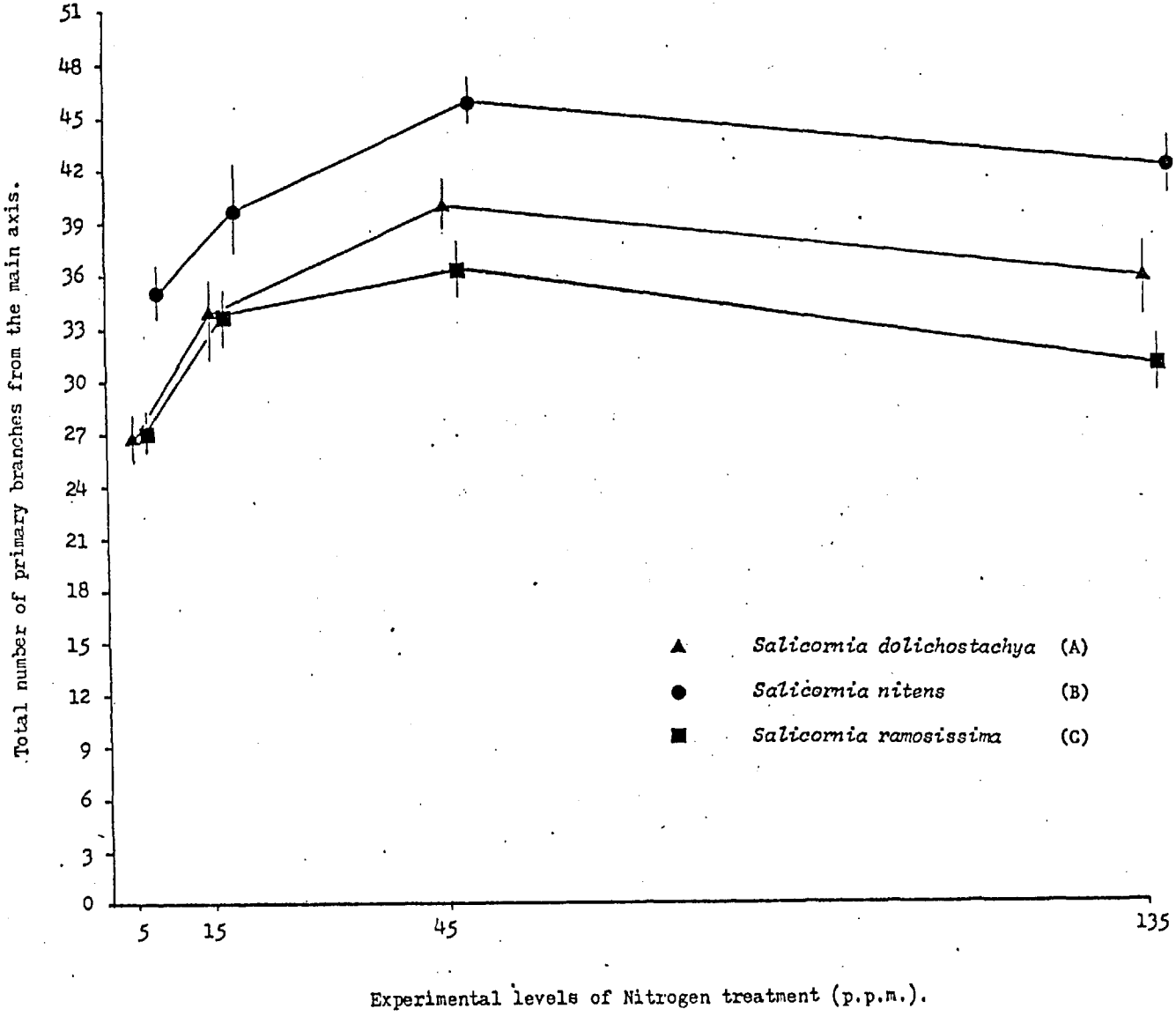

Total number of primary branches from the main axis.
51
48
45
42
39
36
33
30
27
24
21
18
15
12
9
6
3
0
5
15
45
135
Experimental levels of Nitrogen treatment (p.p.m.).
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)

Figure 6.3

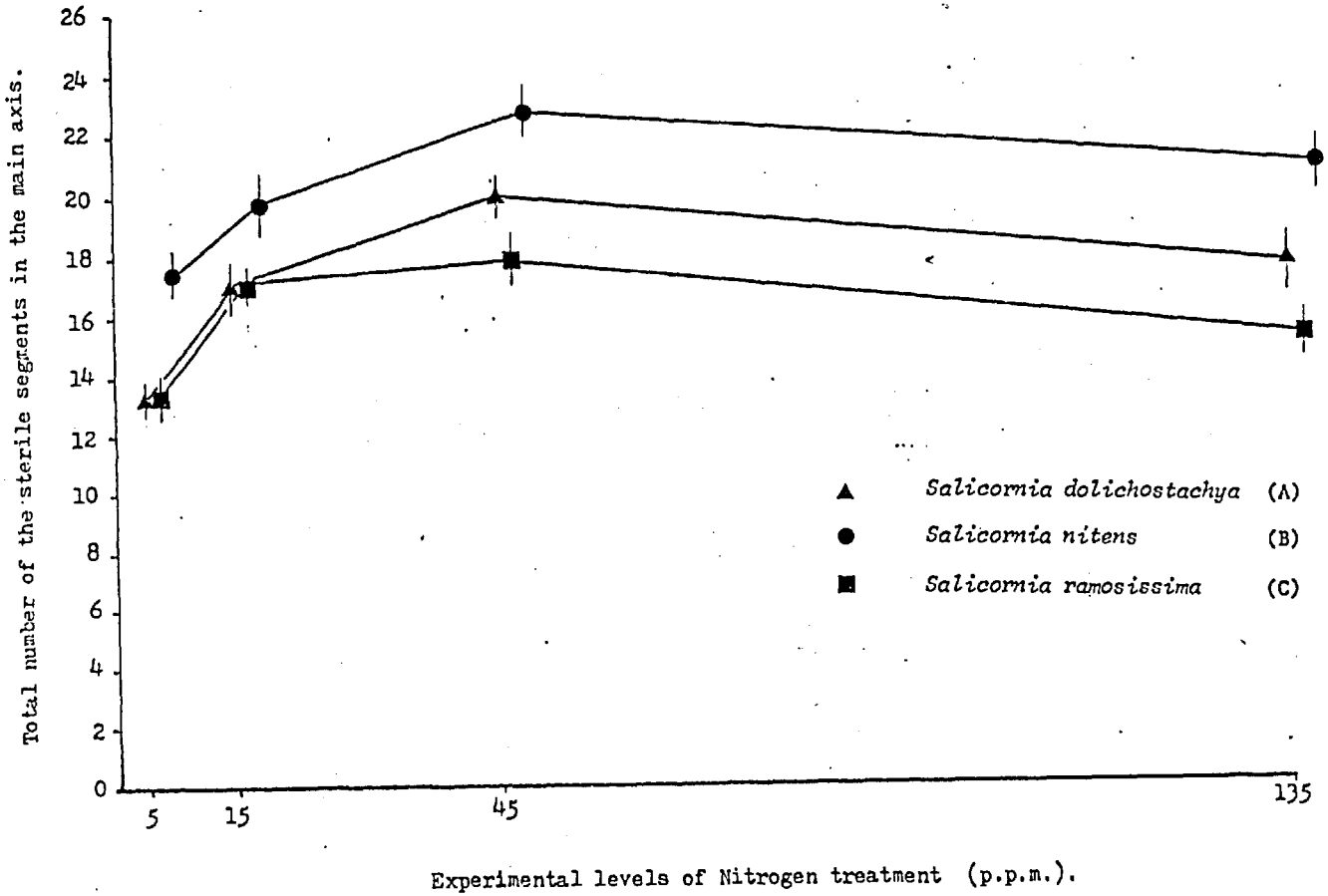

Total number of the sterile segments in the main axis.
26
24
22
20
18
16
14
12
10
8
6
4
2
0
5
15
45
135
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)
Experimental levels of Nitrogen treatment (p.p.m.).

Figure 6.4

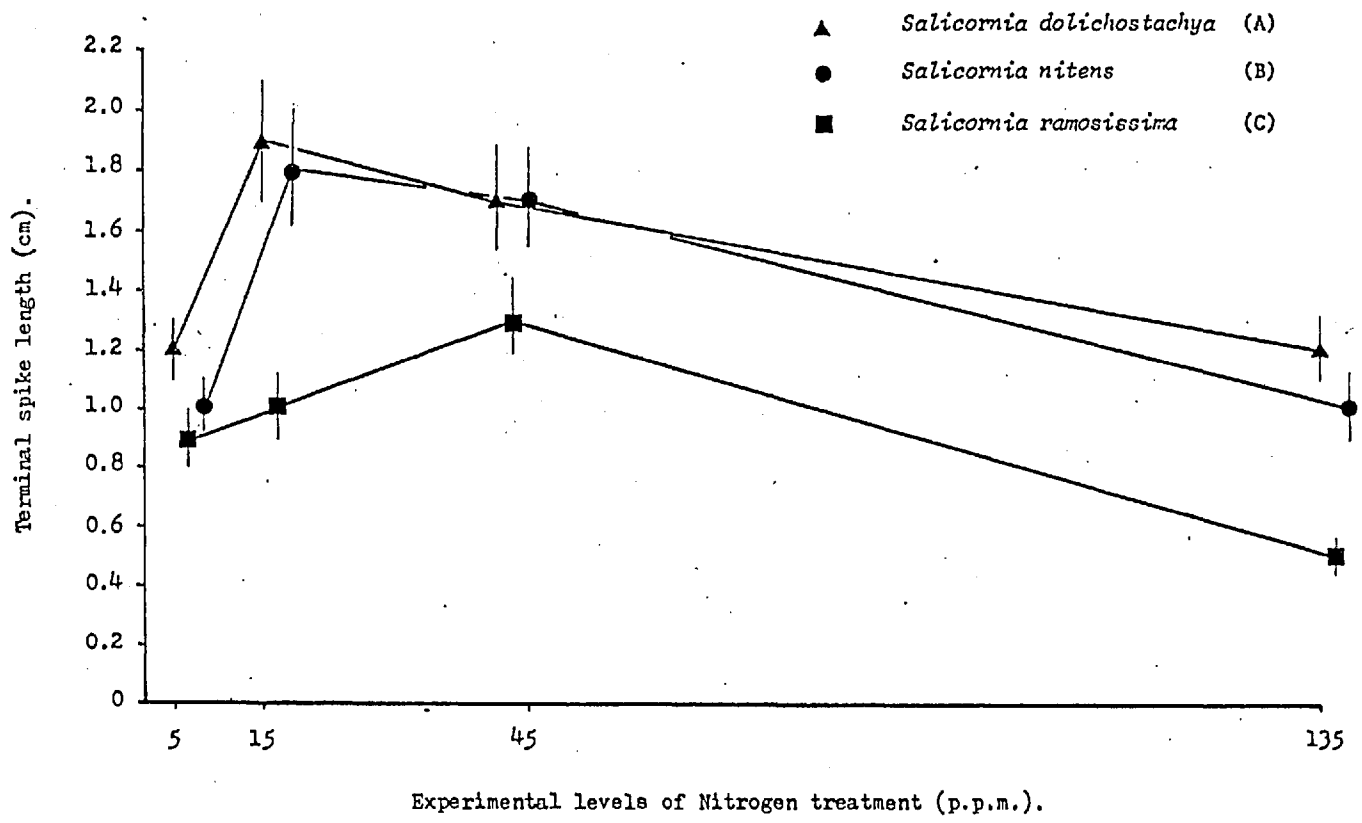

Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)
Terminal spike length (cm).
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
5
15
45
135
Experimental levels of Nitrogen treatment (p.p.m.).

Figure 6.5

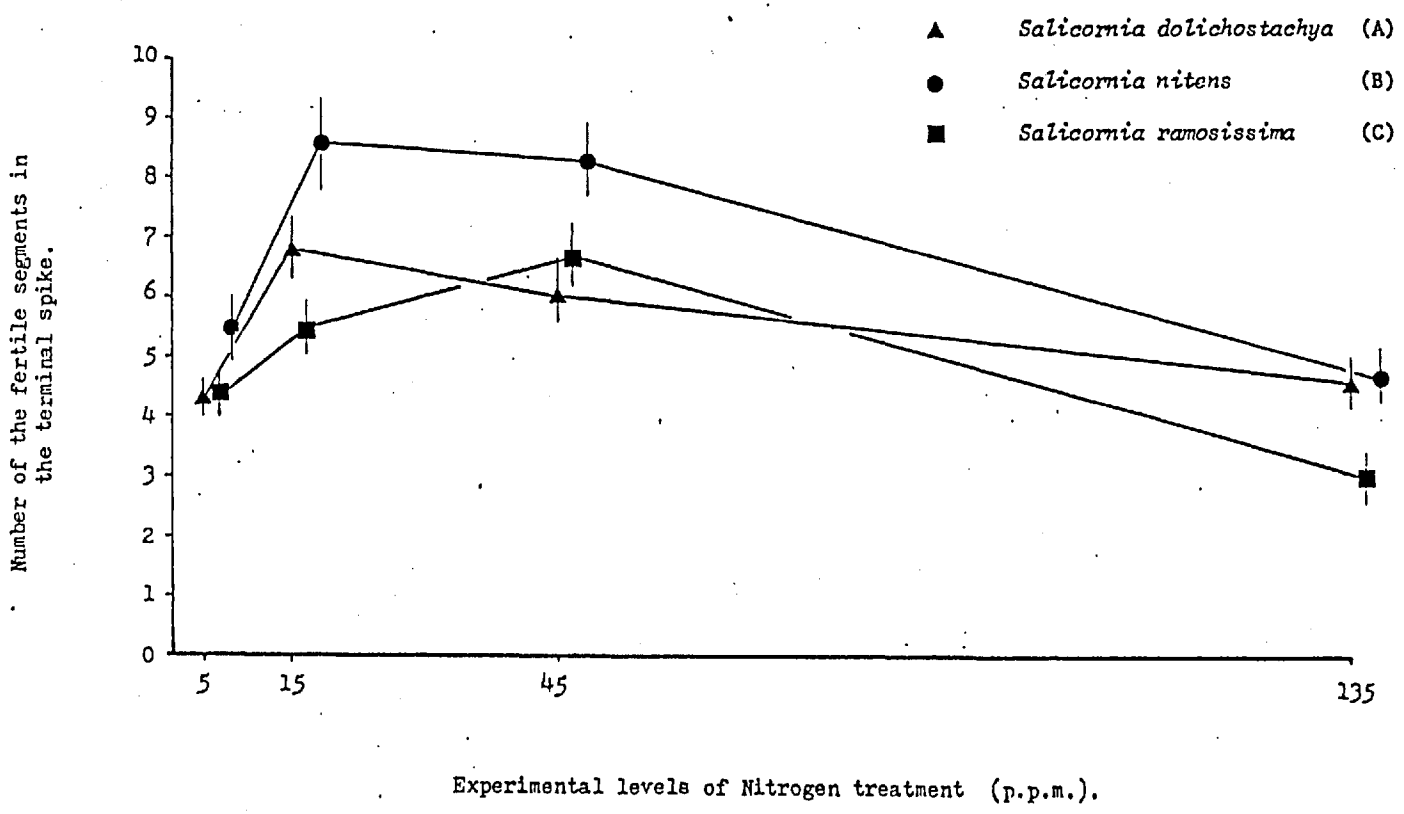

▲ Salicornia dolichostachya (A)
● Salicornia nitens (B)
■ Salicornia ramosissima (C)
Number of the fertile segments in the terminal spike.
0
1
2
3
4
5
6
7
8
9
10
5
15
45
135
Experimental levels of Nitrogen treatment (p.p.m.).

Figure 6. 6

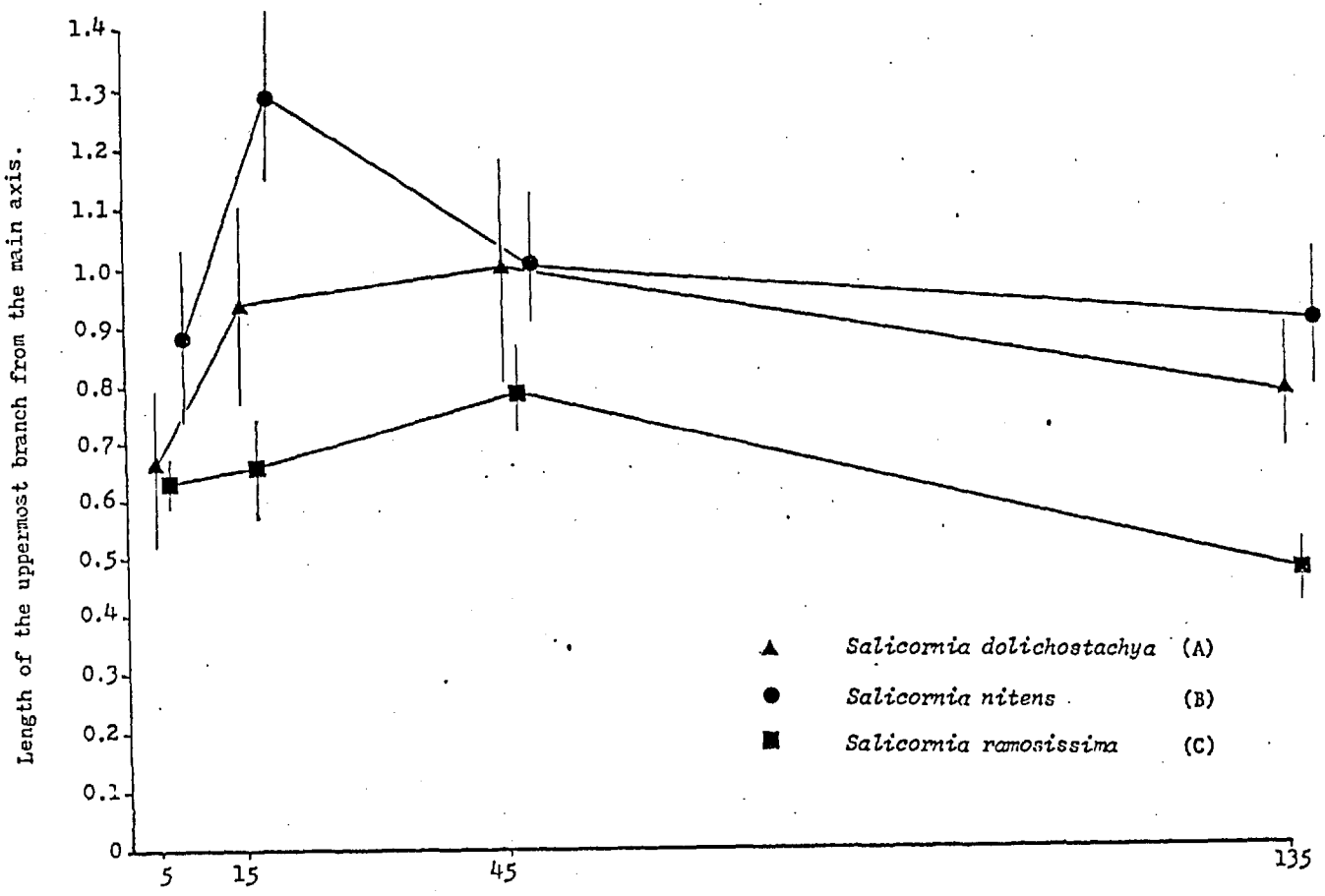

Length of the uppermost branch from the main axis.
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
15
45
135
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)
Experimental levels of Nitrogen treatment (p.p.m.).

Figure 6.7

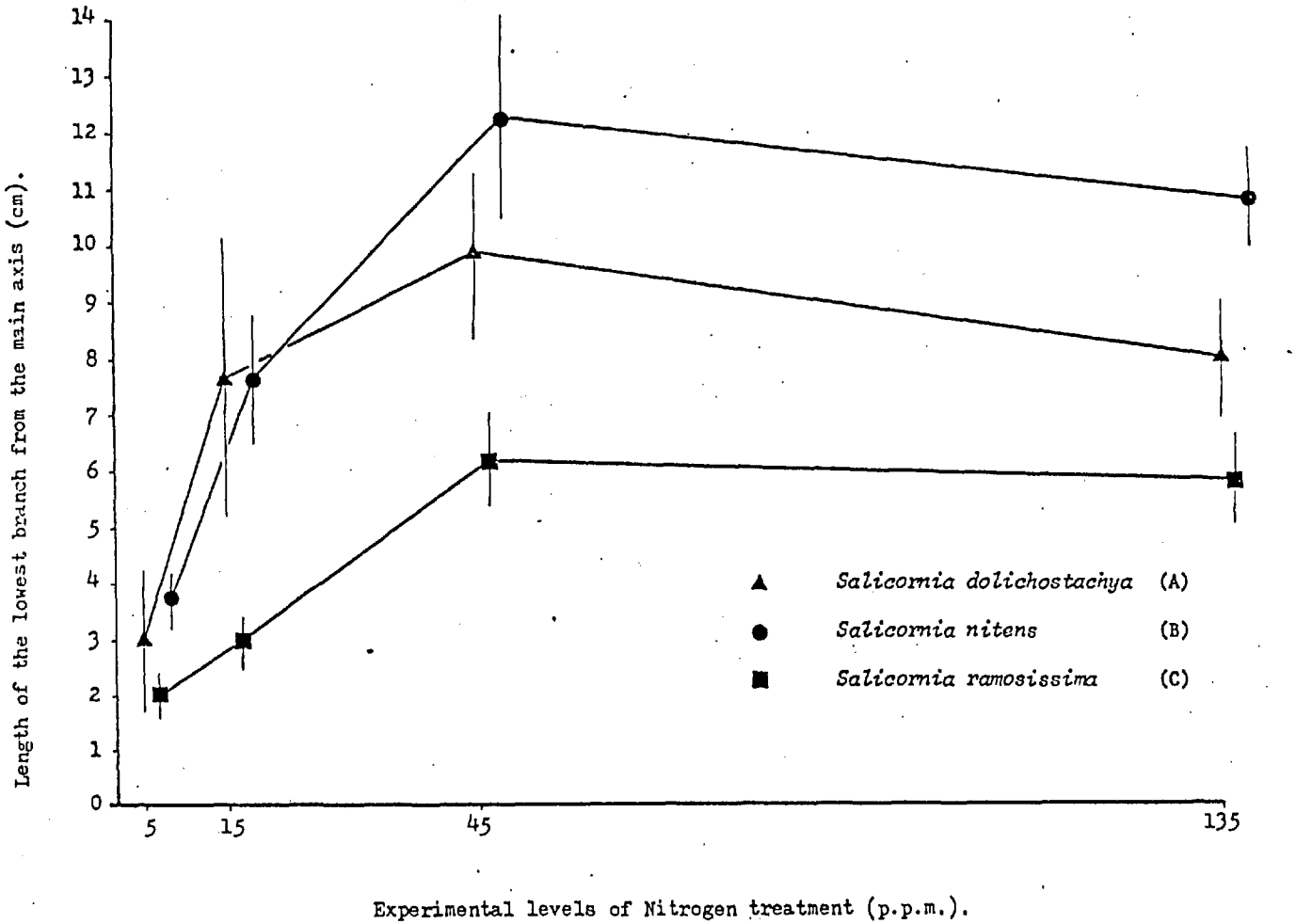

Length of the lowest branch from the main axis (cm).
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
5
15
45
135
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)
Experimental levels of Nitrogen treatment (p.p.m.).

Figure 6.8

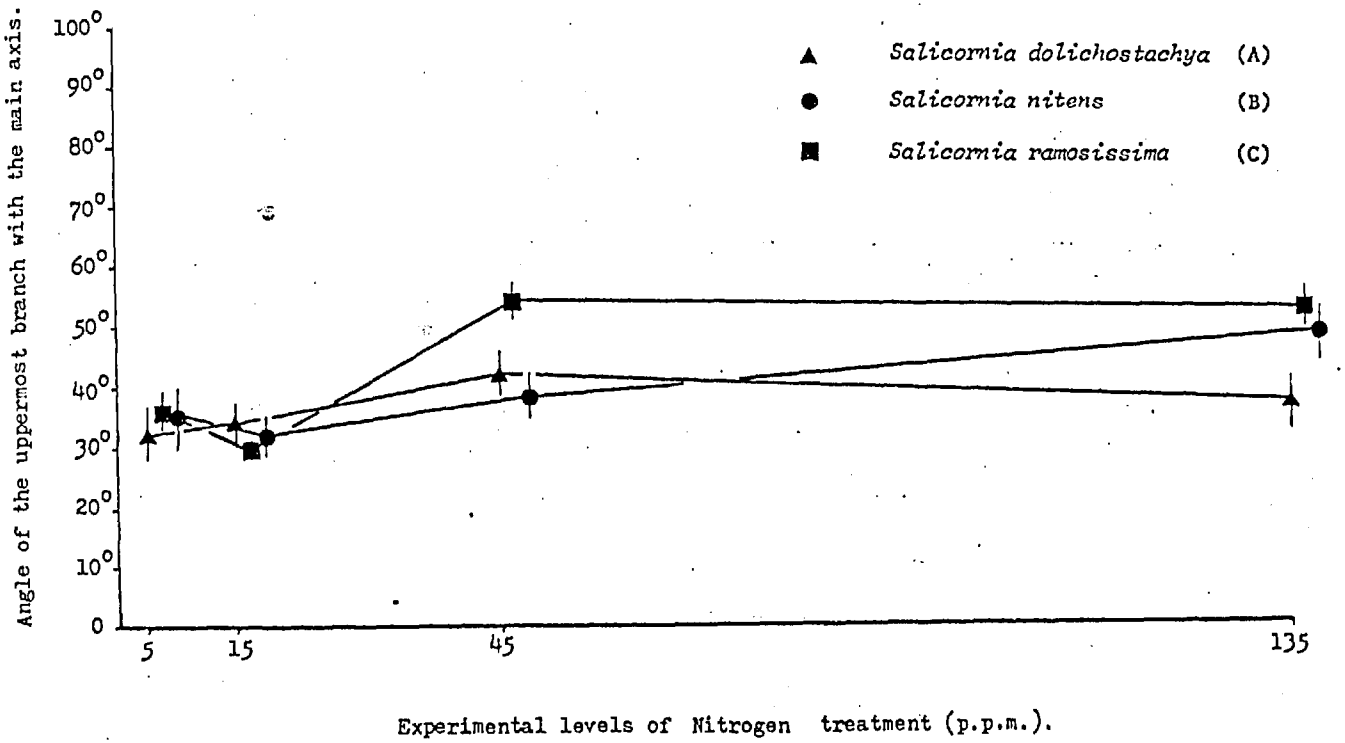

Angle of the uppermost branch with the main axis.
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0
5
15
45
135
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)
Experimental levels of Nitrogen treatment (p.p.m.).

Figure 6.9

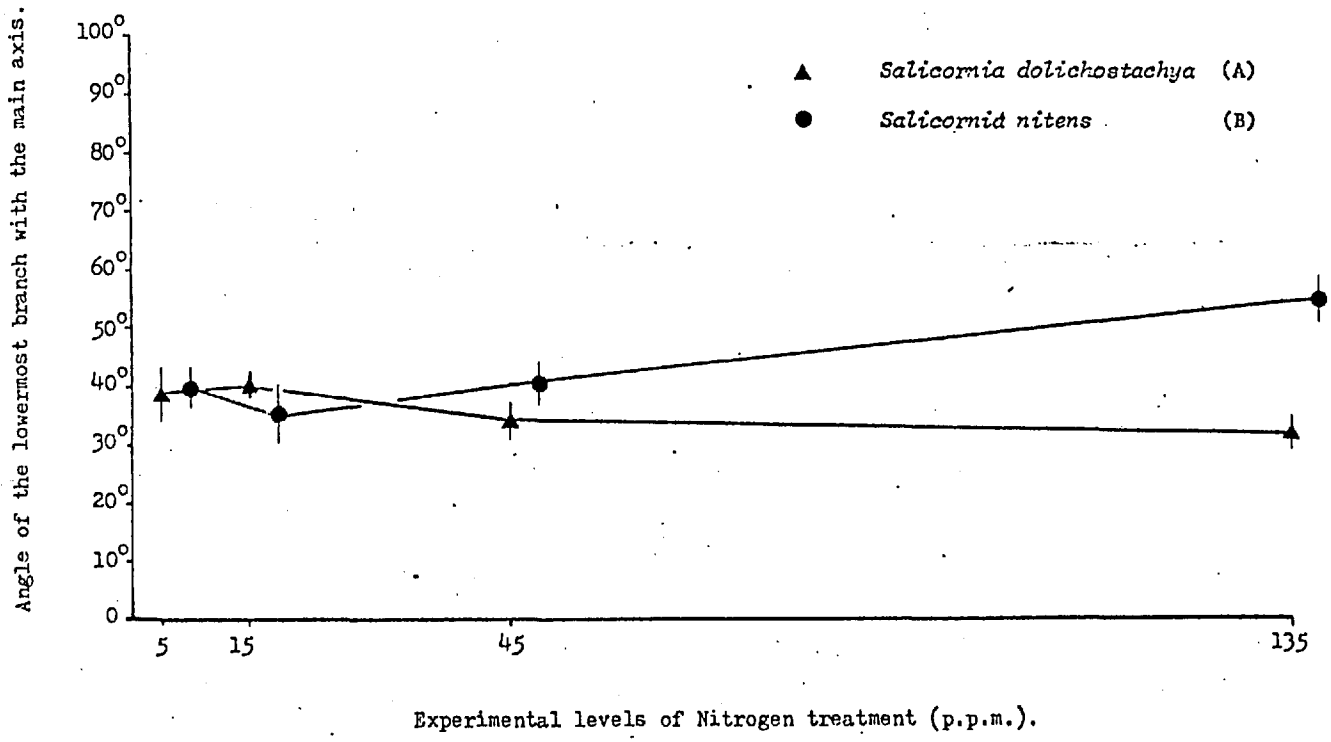
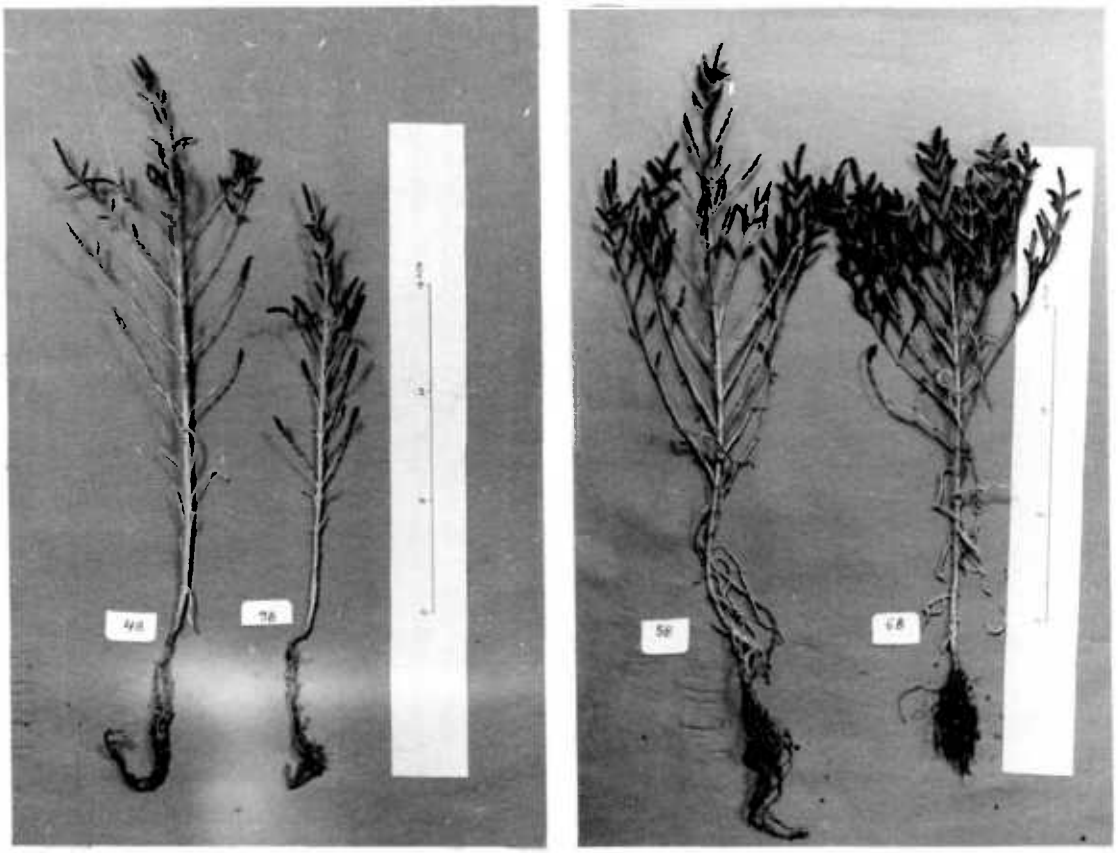

Angle of the lowermost branch with the main axis.
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0
5
15
45
135
▲ Salicornia dolichostachya (A)
● Salicornid nitens (B)
Experimental levels of Nitrogen treatment (p.p.m.).

Figure 6.10



Photograph 6. 1 : Shows *Salicornia nitens* plants grown in the four levels of nitrogen treatement:-

3B: plant grown in 5 p.p.m. nitrogen level.

4B: plant grown in 15 p.p.m. nitrogen level.

5B: plant grown in 45 p.p.m. nitrogen level.

6B: plant grown in 135 p.p.m. nitrogen level.

showed considerable difference in their nitrogen utilisation or in other words in their general growth rate. The 95% confidence limits reveals that the three types of *Salicornia* show their maximum differences in their nitrogen utilization at the nitrogen level of their optimum growth. Simply the three *Salicornia* types can be ranked as follows:- *S. nitens*, *S. dolichostachya* and then *S. ramosissima*, (Figures 6.1-6.8). This order can be seen in almost all the vegetative characters. However, the figures clearly show that at 5 p.p.m. nitrogen level (N_1) the three types of *Salicornia* show their minimum differences in growth rate, though the three types of *Salicornia* show a significant difference in their height at 5, 15 and 45 p.p.m. nitrogen level.

The relationship between the development of the secondary branches and the nitrogen level is quite distinct (photograph 6.1.). Almost no secondary branches are developed at the 5 p.p.m. nitrogen level. At the 15 p.p.m. nitrogen level very few short secondary branches were developed. It seems that the secondary branches usually start to develop well at the 45 p.p.m. nitrogen level and better at the 135 p.p.m. nitrogen level. This reinforces the conclusion reached in the previous chapter, that this character is of little value taxonomically.

Table 6.6 , shows the mean values for the fertile segment components in the four treatment of nitrogen. The data clearly shows that the experimental levels of nitrogen did not exert a marked effect on the dimensions of the fertile segment components; In addition, observations on the flowering time, showed that there was little effect on the flowering time either, though there was a difference of three to four days between those plants grown at the 5 p.p.m. and those at

Table 6.6 Shows the means ($\bar{x}$) and standard deviation (S.D.) values for the fertile segment components of the three types of *Salicornia* in the four levels of nitrogen (Measurements expressed as mm).

S. dolichostachya
(A)

Fertile Segment * Components	N_1 5.p.p.m.		N_2 15 p.p.m.		N_3 45 p.p.m.		N_4 135 p.p.m.	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
A	3.77	±0.22	–	± –	3.44	±0.25	3.52	±0.29
B	3.62	±0.24	–	± –	3.31	±0.19	3.36	±0.32
C	2.55	±0.07	–	± –	2.36	±0.12	2.56	±0.13
D	2.32	±0.10	–	± –	2.11	±0.18	2.22	±0.23
E	2.35	±0.16	–	± –	2.06	±0.19	2.26	±0.18
F	1.97	±0.13	–	± –	1.74	±0.18	1.86	±0.26
G	1.29	±0.09	–	± –	0.95	±0.13	1.34	±0.23
E-F	0.38	±0.06	–	± –	0.32	±0.09	0.36	±0.13
D-F	0.35	±0.12	–	± –	0.37	±0.20	0.36	±0.11

S. nitens
(B)

Fertile Segment * Components	N_1 5.p.p.m.		N_2 15 p.p.m.		N_3 45 p.p.m.		N_4 135 p.p.m.	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
A	3.68	±0.17	3.57	±0.10	3.51	±0.18	3.57	±0.17
B	3.45	±0.18	3.33	±0.10	3.28	±0.19	3.37	±0.29
C	2.27	±0.14	2.32	±0.11	2.10	±0.13	2.48	±0.11
D	1.53	±0.19	1.87	±0.16	1.76	±0.18	1.61	±0.19
E	2.62	±0.23	2.08	±0.12	2.09	±0.12	2.21	±0.19
F	1.43	±0.14	1.59	±0.17	1.51	±0.18	1.42	±0.16
G	0.62	±0.11	0.78	±0.12	0.77	±0.19	0.67	±0.15
E-F	0.59	±0.19	0.50	±0.18	0.60	±0.13	0.79	±
D-F	0.10	±0.10	0.29	±0.09	0.25	±0.13	0.19	±

Table 6.6 (Continued)

S. ramosissima (C)								
Fertile Segment Components*	N_1 5.p.p.m.		N_2 15 p.p.m.		N_3 45 p.p.m.		N_4 135 p.p.m.	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
A	3.14	±0.14	-	± -	2.96	±0.16	2.79	±0.16
B	2.92	±0.17	-	± -	2.91	±0.13	2.73	±0.17
C	2.28	±0.16	-	± -	2.11	±0.12	2.09	±0.12
D	1.68	±0.24	-	± -	1.56	±0.17	1.64	±0.24
E	2.12	±0.09	-	± -	1.89	±0.1	1.84	±0.14
F	1.51	±0.19	-	± -	1.36	±0.08	1.37	±0.23
G	0.66	±0.18	-	± -	0.65	±0.09	0.71	±0.19
E-F	0.61	±0.14	-	± -	0.55	±0.17	0.47	±0.18
D-F	0.17	±0.15	-	± -	0.20	±0.14	0.29	±0.07

* See Figure 3.14

the 135 p.p.m. nitrogen level. However, *S. dolichostachya* type plants usually flower earlier than *S. nitens* and *S. ramosissima* by about seven to ten days. This difference in flowering was observed in all the four levels of nitrogen treatment.

Nitrogen levels produce a considerable effect on the colouration of the plant. At the lower concentrations of nitrogen, particularly between 5 - 15 p.p.m.,a red colouration (betacyanin) was developed at the end of seed maturation. Due to the importance of this phenomenon, it will be discussed later in this Chapter. Also the three types of *Salicornia* show some differences in their green colouration. In general plants of *S. dolichostachya* and *S. nitens* were bright-green to yellowish-green, whilst those of *S. ramosissima* were green to dark-green in colour, though at the lower concentrations of nitrogen (5 - 15 p.p.m.) the plants used to lose their green colour much earlier than those at 45 and 135 p.p.m. nitrogen respectively.

6.2.2.2 The effect of phosphorus treatments on the morphology:-

The effects of different phosphorus levels on the three types of *Salicornia* are not so obvious as those produced by the nitrogen treatments (Photographs 6.2 and 6.3, Page 201&202).

Table 6.7 and the Figures 6.11-6.20 illustrate that plant height, number of sterile segments in the main axis, number of primary branches from the main axis and the length of the lowermost branch show a significant response up to a maximum with 4 p.p.m. phosphorus. Figures 6.11, 6.13 & 6.14, reveal that any additional application of phosphorus in excess of this level has no positive effect on them, though the figures indicate a non-significant increase in their measurements at 16 p.p.m.

Table 6.7 Shows the mean values for the vegetative characters for each of the selected types of *Salicornia* in the four levels of phosphorus.

	Salicornia type and treatments / Vegetative character	*S. dolichostachya* (A)				*S. nitens* (B)				*S. ramosissima* (C)			
		2 p.p.m.	4 p.p.m.	8 p.p.m.	16 p.p.m.	2 p.p.m.	4 p.p.m.	8 p.p.m.	16 p.p.m.	2 p.p.m.	4 p.p.m.	8 p.p.m.	16 p.p.m.
1.	Shoot length	18.29	22.34	15.25	16.19	27.18	31.72	25.20	29.16	20.09	24.93	24.00	25.93
2.	Root length	7.63	6.92	6.00	5.67	9.08	9.28	9.29	10.50	7.15	7.33	8.30	9.64
3.	Total number of primary branches from the main axis.	35.86	42.80	30.27	31.20	45.17	49.19	39.33	46.73	32.67	37.00	33.73	41.82
4.	Number of sterile segments in the main axis.	17.79	21.33	15.27	15.33	22.42	24.58	19.67	23.09	16.20	18.40	16.80	20.82
5.	Terminal spike length.	1.74	1.83	1.57	1.69	1.65	1.74	1.64	1.16	0.94	0.70	1.40	0.56
6.	Number of fertile segments in the terminal spike.	6.33	6.60	6.00	6.47	7.83	8.00	8.58	5.36	6.13	4.30	8.07	3.36
7.	Length of the lower most branch from the main axis.	8.44	11.50	10.10	9.02	10.60	12.79	15.65	12.58	6.96	6.50	12.40	11.60
8.	Length of the upper most branch from the main axis.	1.29	1.02	1.25	1.17	1.18	1.32	1.10	0.87	0.95	0.55	1.10	0.49
9.	Angle of the upper most branch with the main axis.	30.00°	34.33°	33.67°	29.67	52.50	52.50	35.00	49.55	55.33	35.00	50.67	42.73
10.	Angle of the lower most branch with the main axis.	34.00°	37.33°	40.67°	40.67	51.25	52.50	45.83	55.46	—	48.75	56.33	55.46

Figures 6.11-6.20 Effect of the four levels of phosphorus on shoot length, root length, total number of primary branches from the main axis, number of sterile segments in the main axis, terminal spike length, number of fertile segments in the terminal spike, length of the uppermost branch from the main axis, length of the lowermost branch from the main axis, angle of the uppermost branch with the main axis and angle of the lowermost branch with the main axis respectively in the three types of *Salicornia* with 95% confidence limits to show the physiological differences between these types at each level of phosphorus. (See note on page 175).

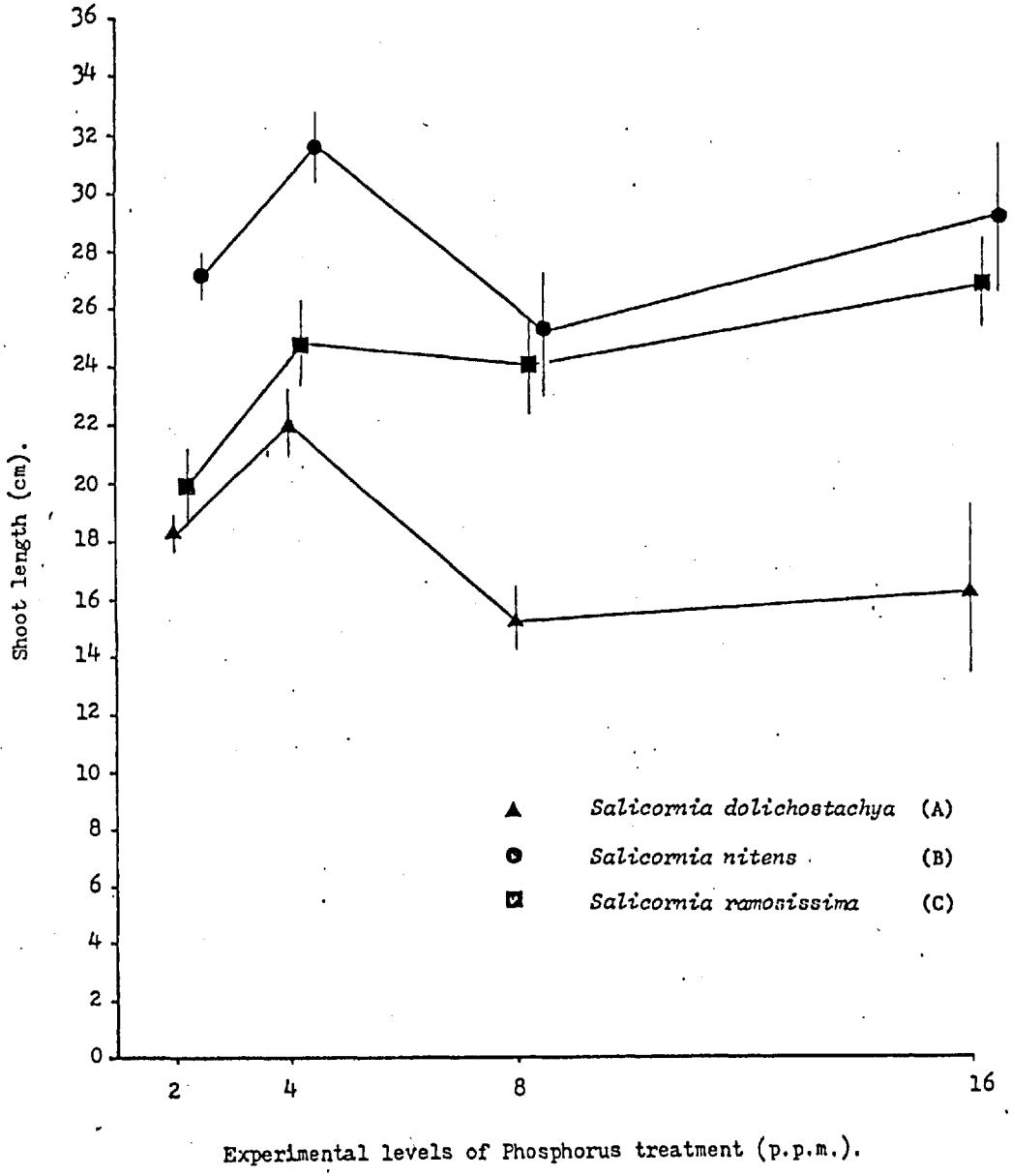

Shoot length (cm).
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
2
4
8
16
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)
Experimental levels of Phosphorus treatment (p.p.m.).

Figure 6.11

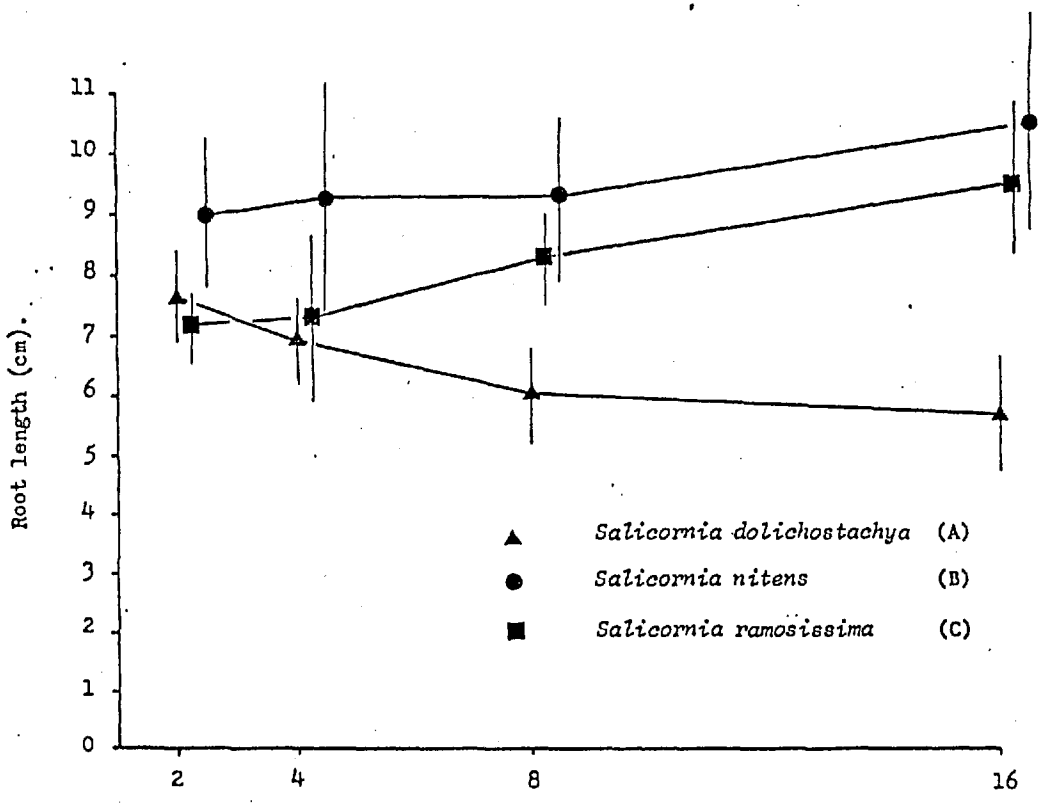

Root length (cm).
0
1
2
3
4
5
6
7
8
9
10
11
2
4
8
16
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)
Experimental levels of Phosphorus treatments (p.p.m.).

Figure 6.12

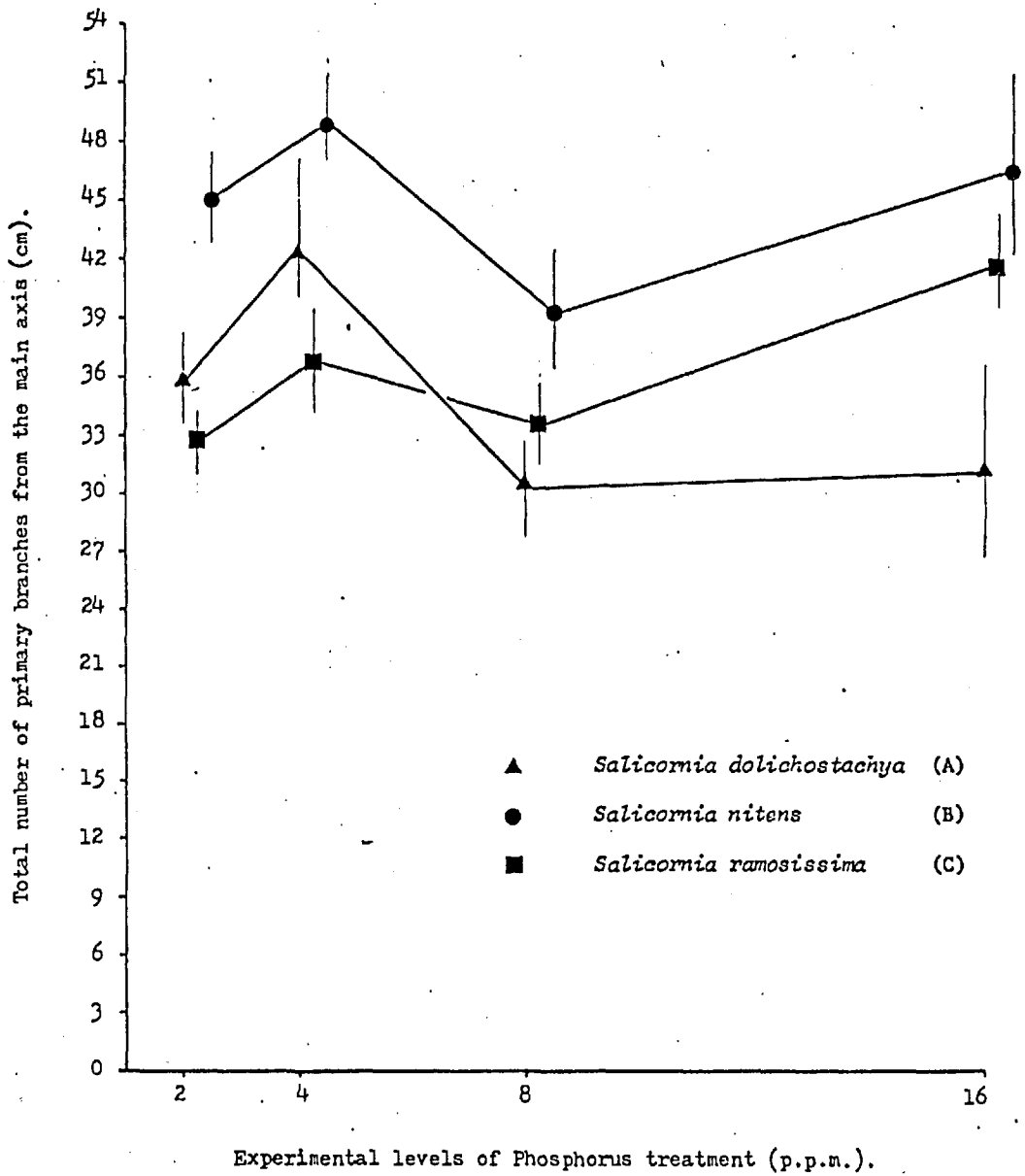

54
51
48
45
42
39
36
33
30
27
24
21
18
15
12
9
6
3
0
2
4
8
16
Total number of primary branches from the main axis (cm).
Experimental levels of Phosphorus treatment (p.p.m.).
▲ Salicornia dolichostachya (A)
● Salicornia nitens (B)
■ Salicornia ramosissima (C)

Figure 6.13

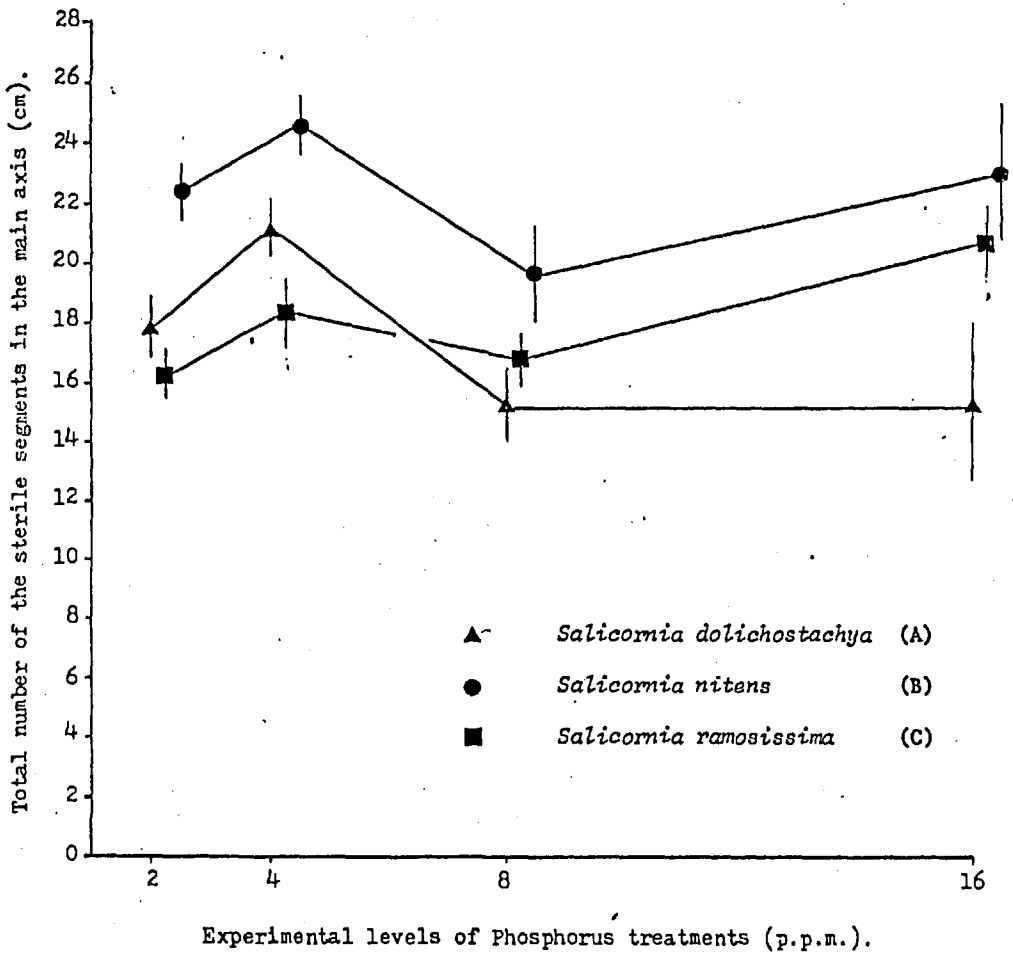
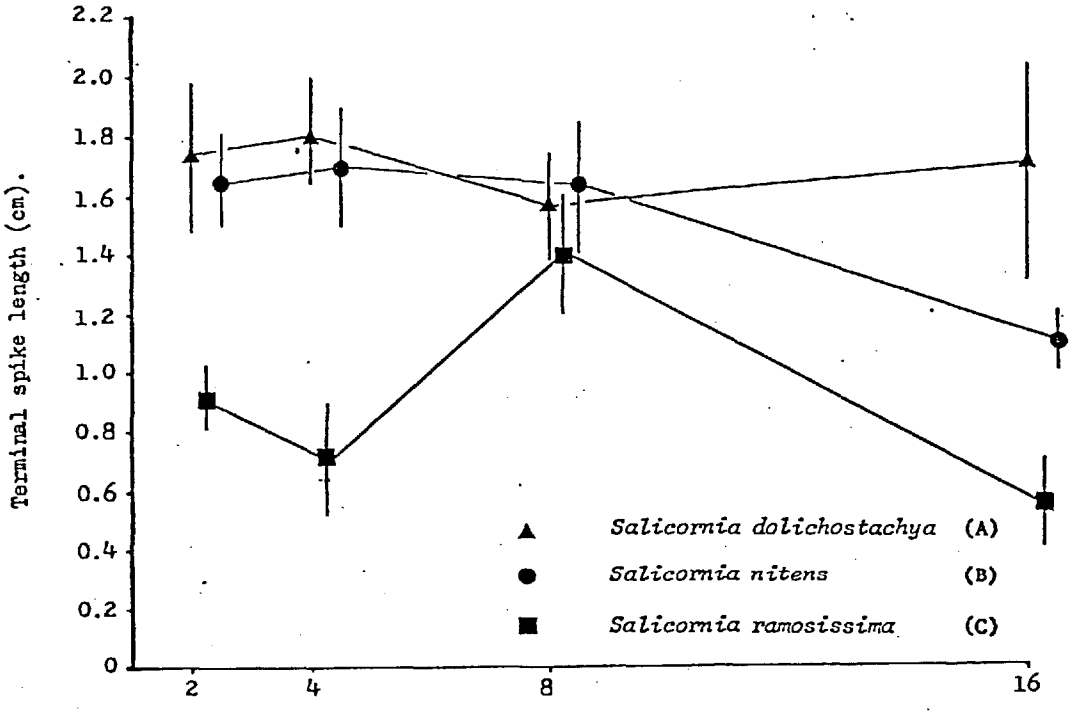
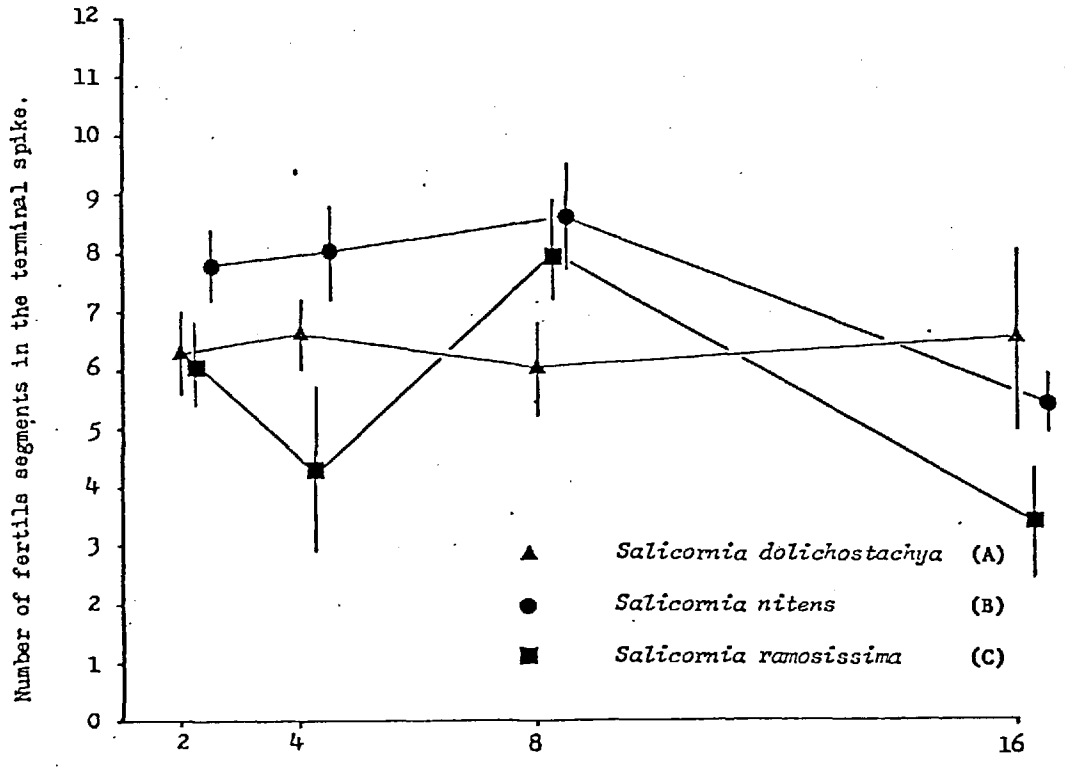

Total number of the sterile segments in the main axis (cm).
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
2
4
8
16
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)
Experimental levels of Phosphorus treatments (p.p.m.).

Figure 6.14



Experimental levels of Phosphorus treatment (p.p.m.).

Figure 6.15



Experimental levels of Phosphorus treatment (p.p.m.).

Figure 6. 16

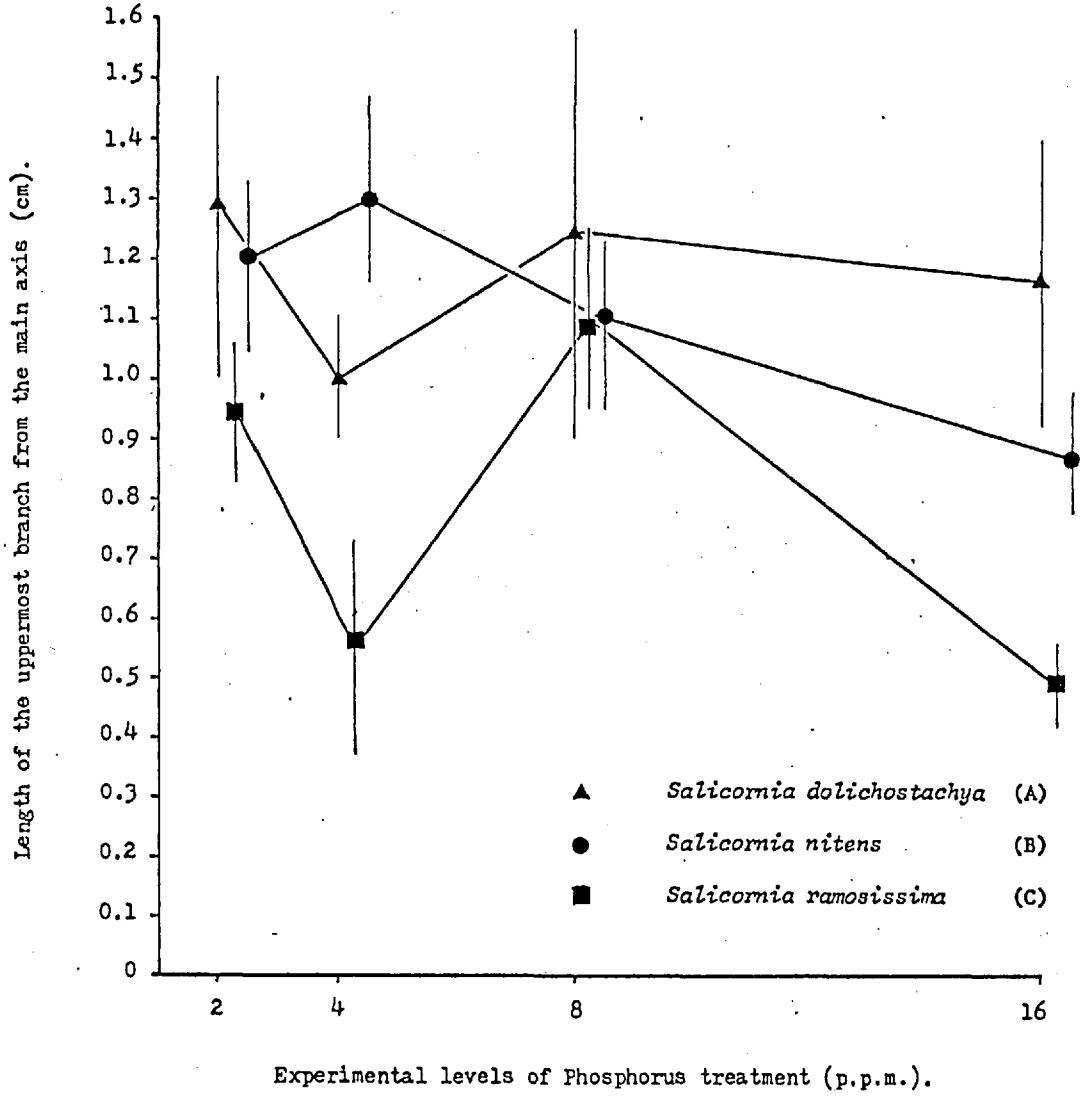

Length of the uppermost branch from the main axis (cm).
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2
4
8
16
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)
Experimental levels of Phosphorus treatment (p.p.m.).

Figure 6.17

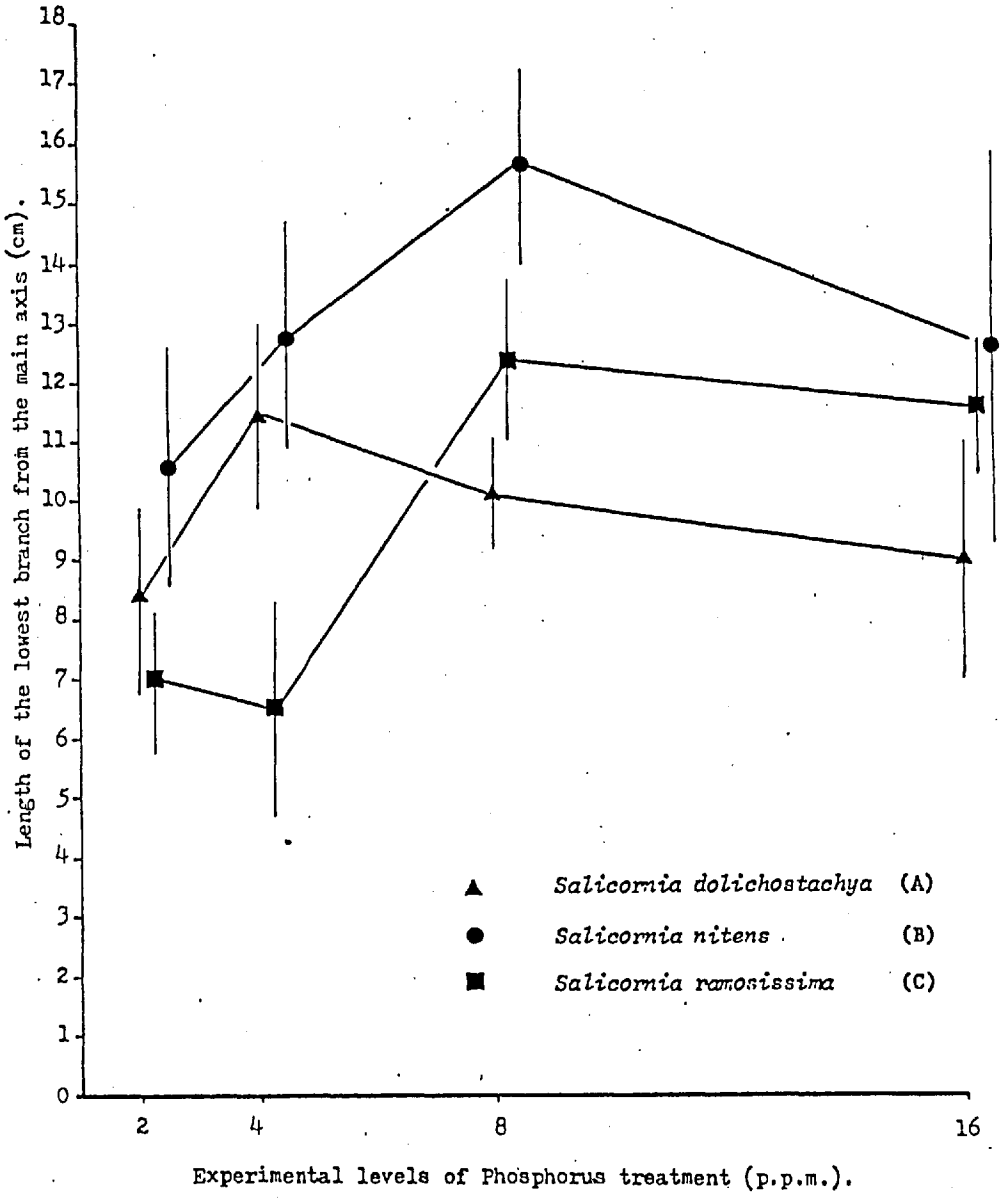

Length of the lowest branch from the main axis (cm).
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
2
4
8
16
Experimental levels of Phosphorus treatment (p.p.m.).
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)

Figure 6.18

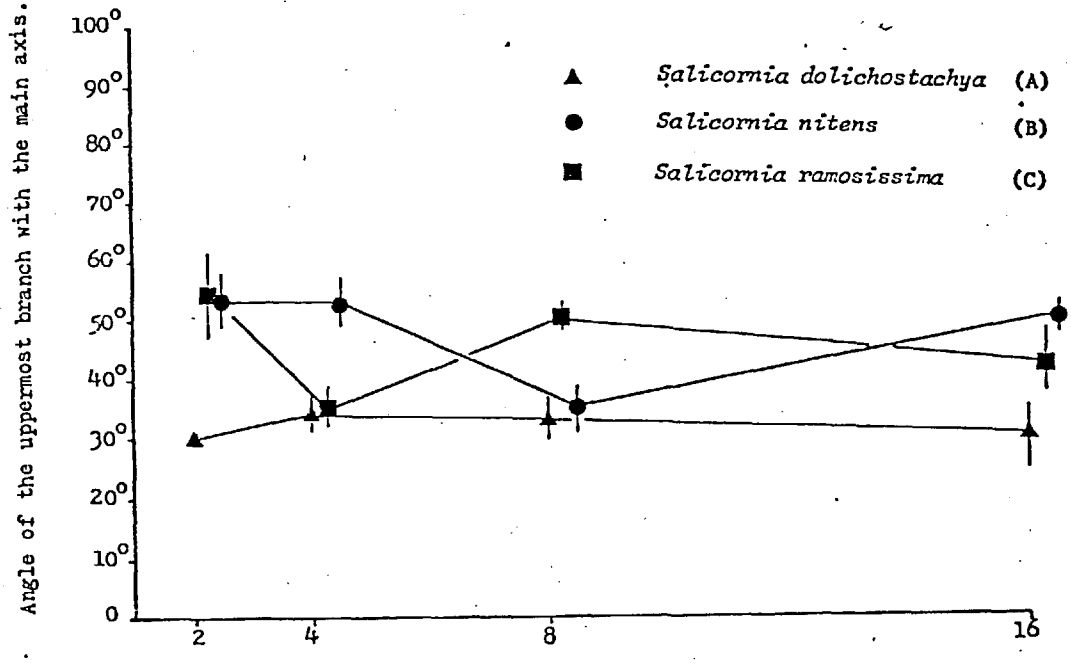


Figure 6.19

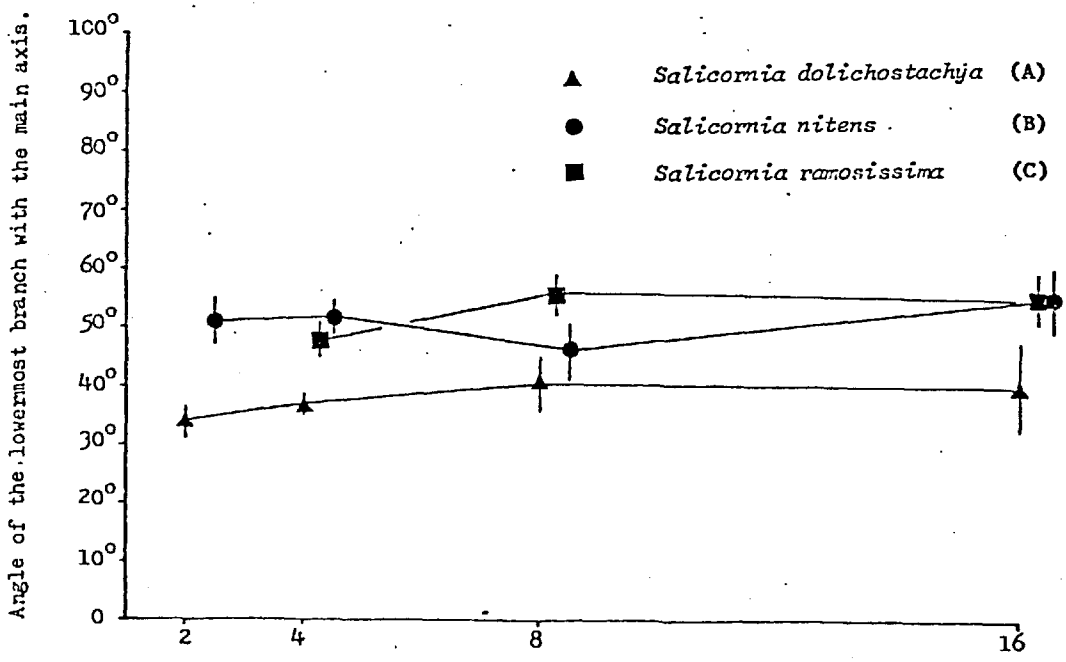
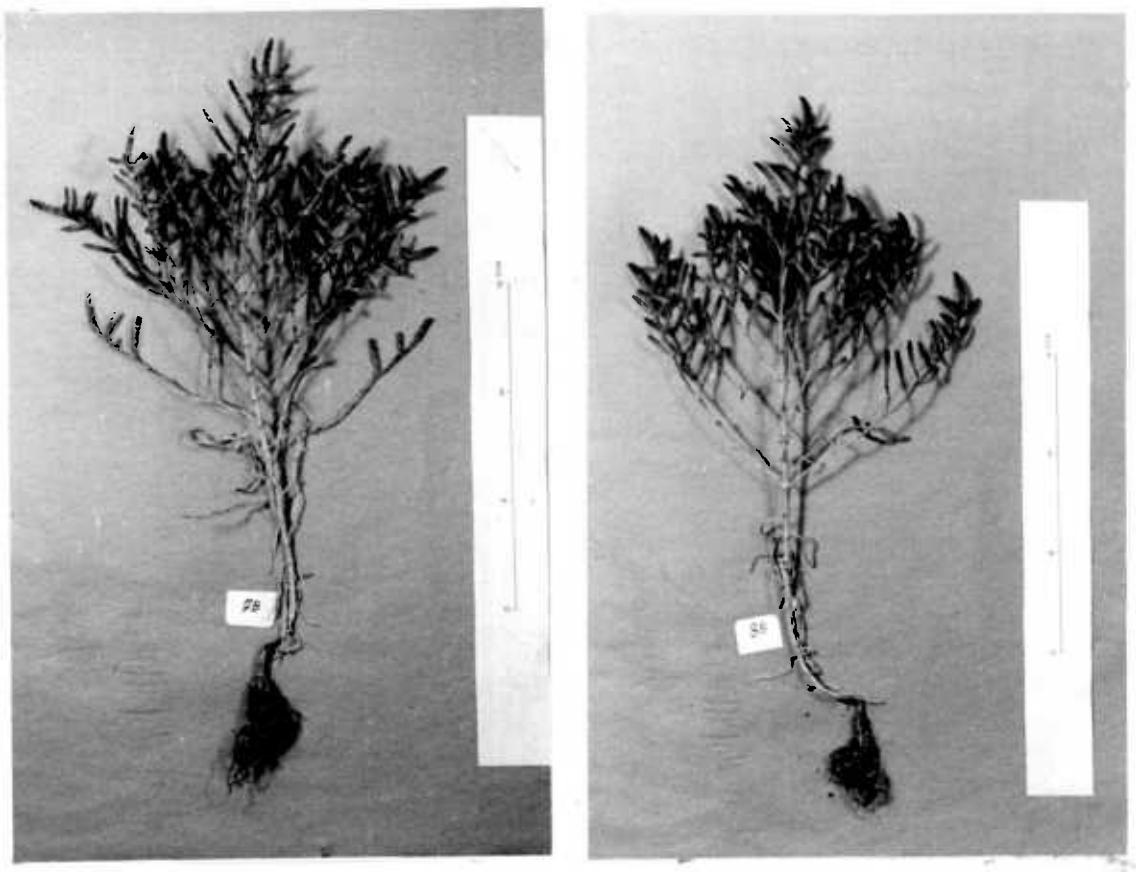


Figure 6.20



Photograph 6.2 : Shows *Salicornia nitens* plants grown in 2 p.p.m. phosphorus level(7B) and in 4 p.p.m. phosphorus level(8B).

Photographs 6.3 : Show *Salicornia nitens* plants grown in 8 p.p.m. phosphorus level (9B) and in 16 p.p.m. phosphorus level (10B).

The characters, terminal spike length, number of the fertile segments in the terminal spike and the length of the upper branch (all concerned with the shoot apices) did not show any response to the different phosphorus levels (Figures 6.15-6.17). Also, it can be noticed from the presented figures and tables that increasing the phosphorus level, especially above 8 p.p.m., resulted in a significant decrease in overall growth. Figures 6.19 & 6.20 clearly show that the angle of branching, both of the uppermost and the lowermost branches, with the main axis, and the root length have no response to the experimental levels of phosphorus.

Phosphorus treatments did not show any significant effect on the morphology of the fertile segments (Table 6.8). Also, these treatments did not have any effect on the flowering time, though plants of *S. dolichostachya* flowered earlier than those of *S. nitens* and *S. ramosissima* by 12 - 14 days. However, this is about two times the difference in the flowering time observed for nitrogen treatments.

6.2.3 Discussion:-

Nitrogen deficiency proved to affect all the vegetative characters measured apart from the angle of branching of both uppermost and lowermost branches with the main axis. Most of the morphological characters showed a positive relation to the increased dosage of nitrogen upto 45 p.p.m.. Any increase in nitrogen content, above this level, did not produce a noticeable effect on growth, though the development of the lateral secondary branches increased. On the whole, the vegetative characters can be grouped into two categories, in relation to the nitrogen level at which the characters measured show their optimum expression. The first group are the apical characters which consist of the terminal spike length, number of fertile segments in the terminal spike, and

Table 6.8 Shows the mean($\bar{x}$) and standard deviation(S.D.) values for fertile segment components of the three types of *Salicornia* in the four levels of phosphorus(Measurements expressed as mm).

S. dolichostachya (A)								
Fertile Segment Components*	P_1 2 p.p.m.		P_2 4 p.p.m.		P_3 8 p.p.m.		P_4 16 p.p.m.	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
A	3.24	±0.23	-	± -	3.51	±0.32	-	± -
B	3.12	±0.18	-	± -	3.19	±0.25	-	± -
C	2.40	±0.10	-	± -	2.46	±0.20	-	± -
D	2.16	±0.33	-	± -	2.12	±0.12	-	± -
E	2.12	±0.18	-	± -	1.98	±0.14	-	± -
F	1.86	±0.18	-	± -	1.73	±0.17	-	± -
G	0.96	±0.09	-	± -	1.03	±0.3	-	± -
E-F	0.26	±0.11	-	± -	0.25	±0.09	-	± -
D-F	0.30	±0.21	-	± -	0.39	±0.17	-	± -

S. nitens (B)								
Fertile Segment Components*	P_1 2 p.p.m.		P_2 4 p.p.m.		P_3 8 p.p.m.		P_4 16 p.p.m.	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
A	3.61	±0.16	4.07	±0.28	3.69	±0.23	3.53	±0.22
B	3.37	±0.13	3.87	±0.34	3.69	±0.23	3.46	±0.31
C	2.23	±0.20	2.77	±0.26	2.59	±0.18	2.46	±0.20
D	1.58	±0.18	1.96	±0.26	1.71	±0.36	1.56	±0.20
E	2.17	±0.10	2.31	±0.16	2.12	±0.20	2.11	±0.10
F	1.34	±0.15	1.72	±0.20	1.57	±0.25	1.47	±0.20
G	0.61	±0.17	0.62	±0.16	0.66	±0.19	0.65	±0.16
E-F	0.83	±0.17	0.59	±0.19	0.54	±0.17	0.64	±0.20
D-F	0.24	±0.09	0.24	±0.08	0.19	±0.09	0.1	±0.10

Table 6.8 (Continued)

S. ramosissima (C)								
Fertile Segment Components *	P_1 2 p.p.m.		P_2 4 p.p.m.		P_3 8 p.p.m.		P_4 16 p.p.m.	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
A	2.55	±0.30	2.73	±0.15	2.91	±0.10	2.70	±0.21
B	2.55	±0.24	2.70	±0.30	2.79	±0.17	2.62	±0.23
C	1.92	±0.20	1.87	±0.12	2.02	±0.10	1.99	±0.23
D	1.63	±0.34	1.67	±0.16	1.66	±0.22	1.61	±0.14
E	1.72	±0.16	2.13	±0.12	1.90	±0.13	1.86	±0.15
F	1.30	±0.22	1.60	±0.10	1.53	±0.21	1.39	±0.14
G	0.62	±0.10	0.70	±0.20	0.78	±0.92	0.73	±0.09
E-F	0.42	±0.31	0.53	±0.15	0.37	±0.19	0.47	±0.13
D-F	0.33	±0.15	0.07	±0.06	0.13	±0.11	0.22	±0.07

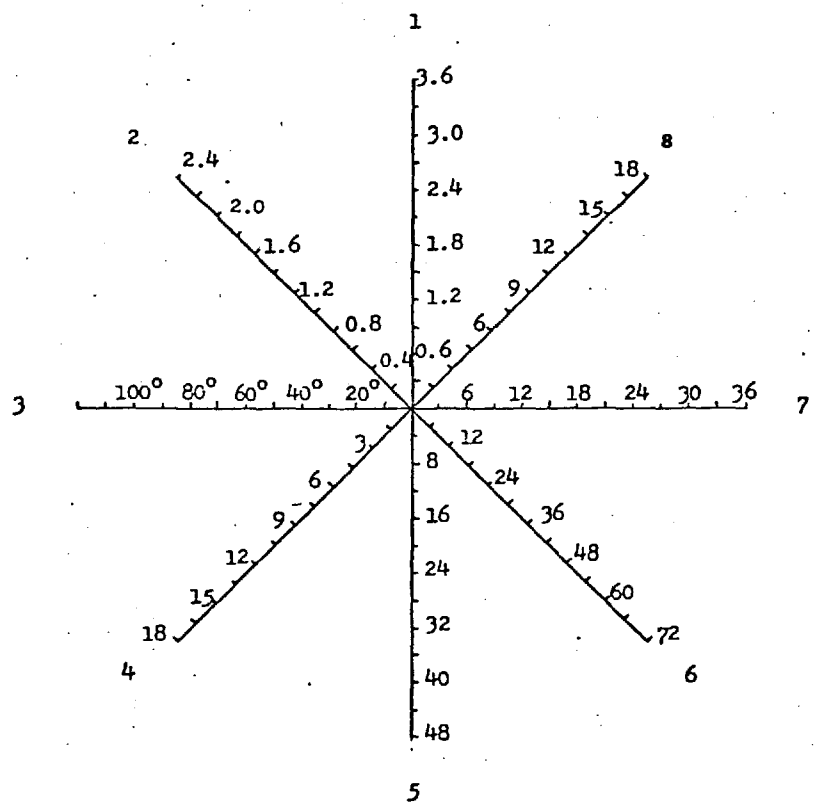
* See Figure 3.14

the length of the uppermost branch. These characters produce their optimum growth at 15 p.p.m. nitrogen (N_2), any additional dosage of nitrogen having an inhibitory effect (Table 6.5 and Figures 6.5, 6.6 and 6.7). In contrast the second group such as plant height, number of sterile segments in the main axis, total number of primary branches from the main axis, and the length of the lowermost branch showed their optimum development at 45 p.p.m. nitrogen (N_3), any additional dosage of nitrogen, above this level, resulted in an obvious increase of the lateral secondary branches.

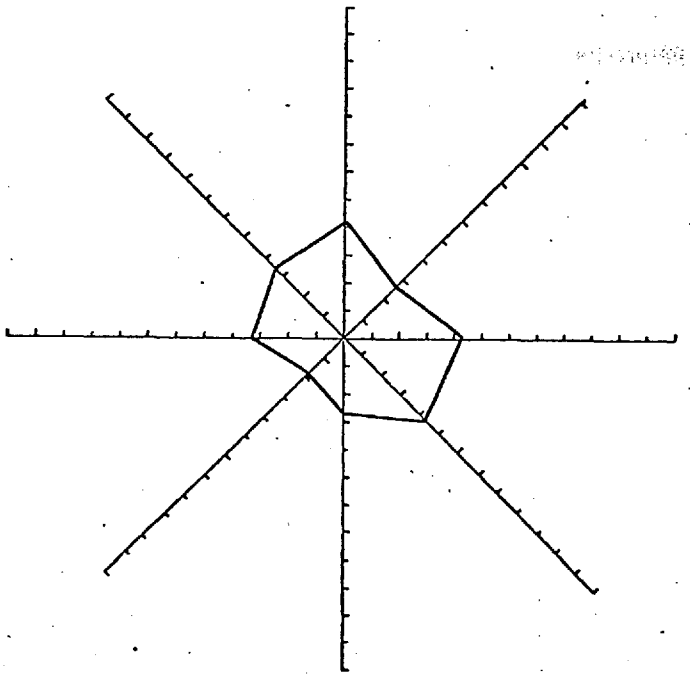
From the previous nitrogen experiment (Chapter V) and the present one it can be concluded that within the experimental range of nitrogen concentrations, i.e. zero - 45 p.p.m., the annual forms of *Salicornia* spp. showed quite distinct differences in their general morphology and appearance (Photographs 5.2 & 6.1). Moreover at low nitrogen levels the three types of *Salicornia* cultured look very similar to each other. Such conclusions can also be drawn from the polygonal graphs (Figures 6.21-6.23) which show quite similar shapes at 5 p.p.m. nitrogen. It is very likely that such variation in the morphology and appearance of *Salicornia* spp. in relation to soil nitrogen content in the salt marsh, plays an important role in the taxonomic confusion experienced in the genus. However, at this point it would be dangerous to apply these experimental results directly to those in the field without field evidence regarding the actual concentrations and variation of nitrogen in the *Salicornia* zones. Nevertheless, most of the studies in the field have shown that the availability of the inorganic nitrogen is a limiting factor for the growth of the most salt marsh species (e.g. Tyler 1967, Pigott 1969), and hence the competition for it is severe. Such competition is probably most severe for those plants which grow in the upper marsh, particularly during the summer season

Figures 6.21-6.23 Polygonal graphs of eight morphological characters of *Salicornia dolichostachya*, *S. nitens* and *S. ramosissima* respectively, grown in the four levels of nitrogen.

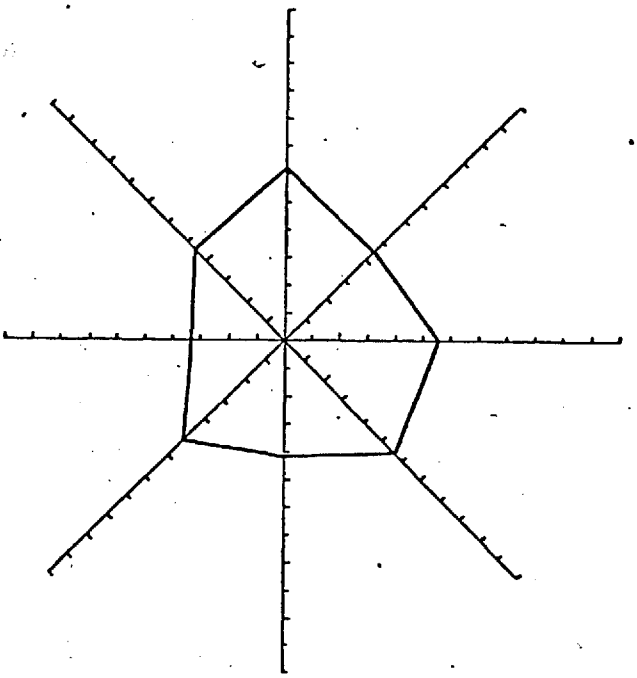
Note: The eight morphological characters represented by the polygonal diagrams as follows:-



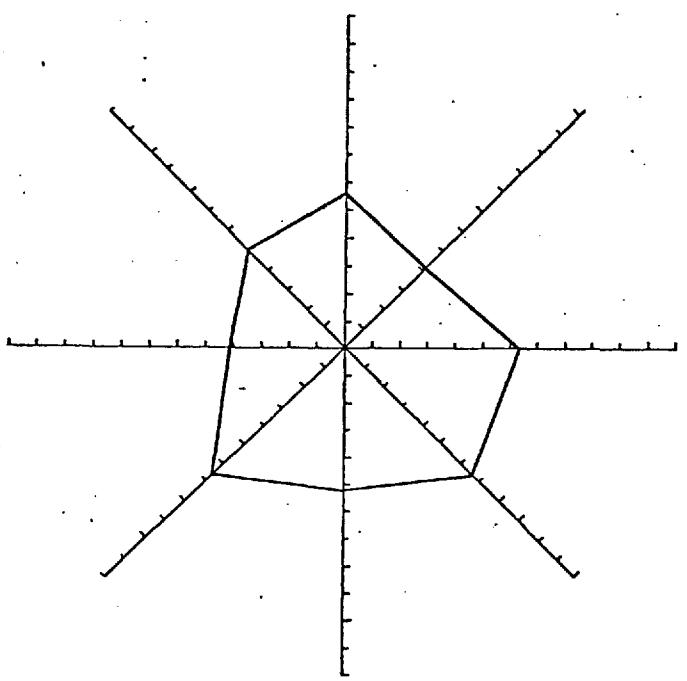
1. Terminal spike length.
2. Length of the uppermost branch from the main axis.
3. Angle of the uppermost branch with the main axis.
4. Lenght of the lowermost branch from the main axis.
5. Shoot length.
6. Total number of primary branches from the main axis.
7. Number of sterile segments in the main axis.
8. Number of fertile segments in the terminal spike.



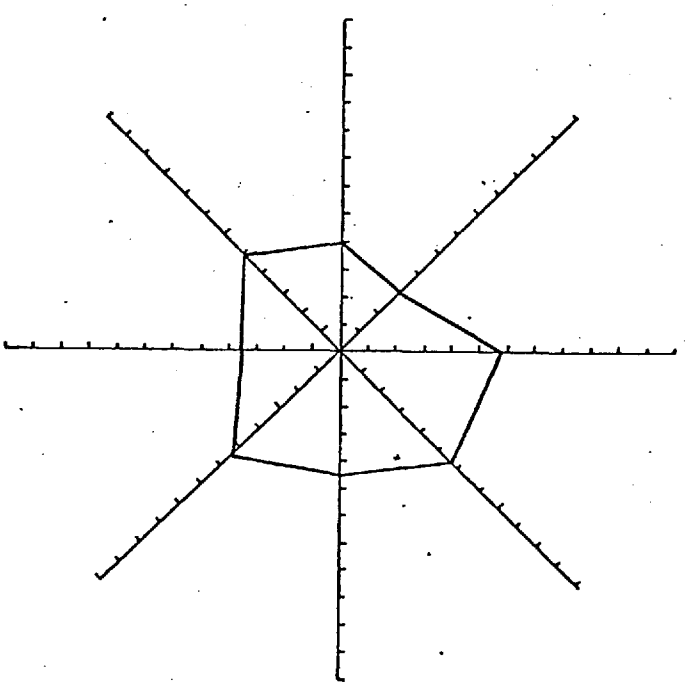
Nitrogen level - 5 p.p.m.



Nitrogen level - 15 p.p.m.



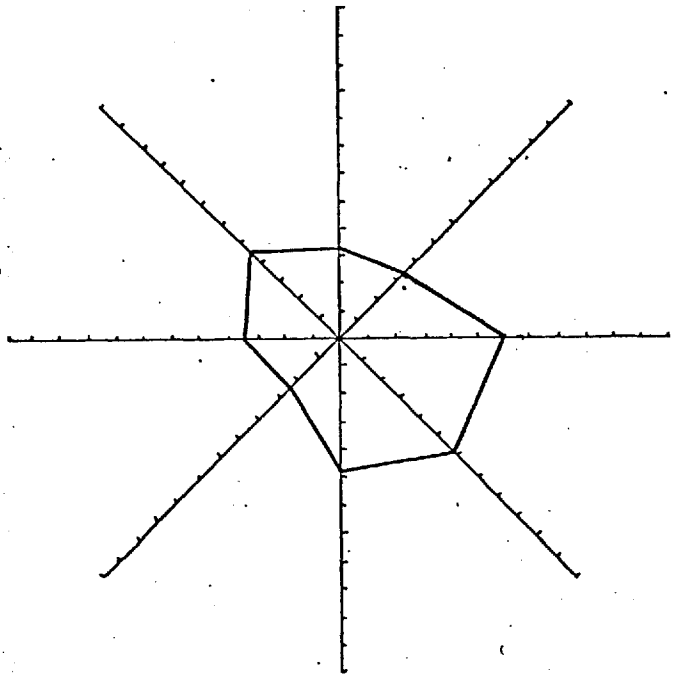
Nitrogen level - 45 p.p.m.



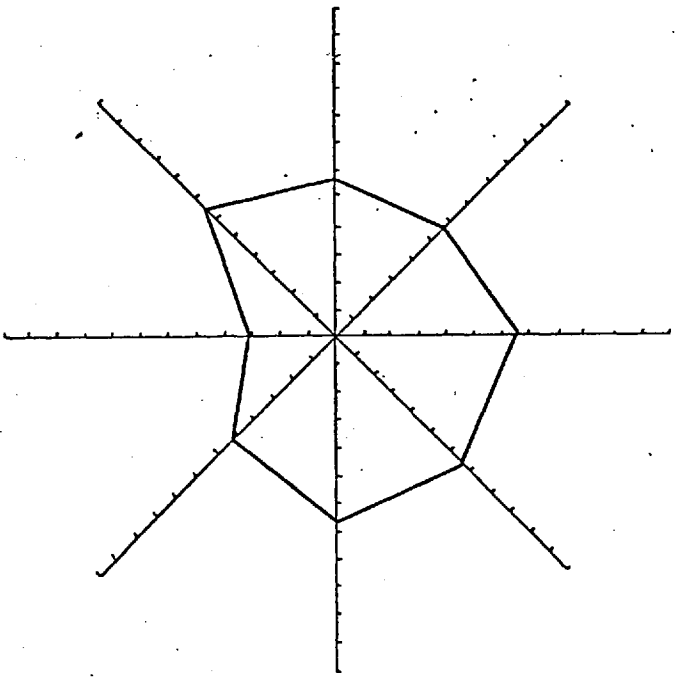
Nitrogen level - 135 p.p.m.

Salicornia dolichostachya

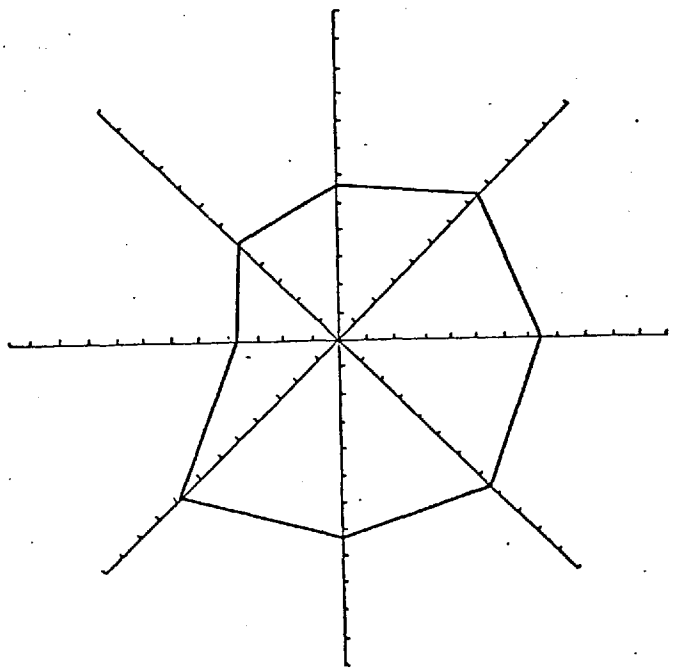
Figure 6.21



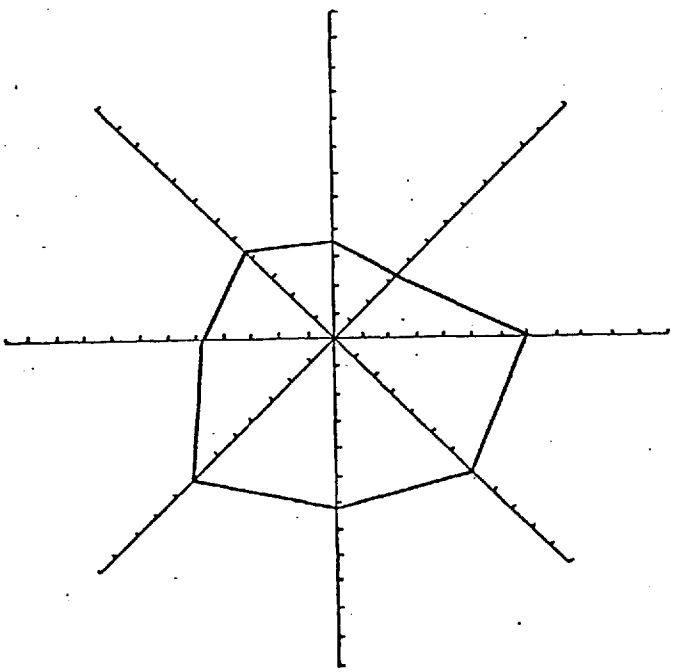
Nitrogen level - 5 p.p.m.



Nitrogen level - 15 p.p.m.



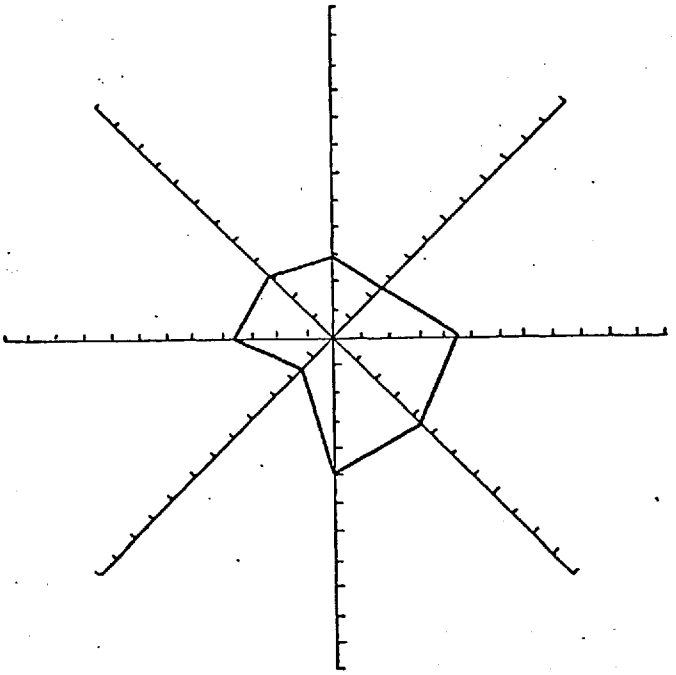
Nitrogen level - 45 p.p.m.



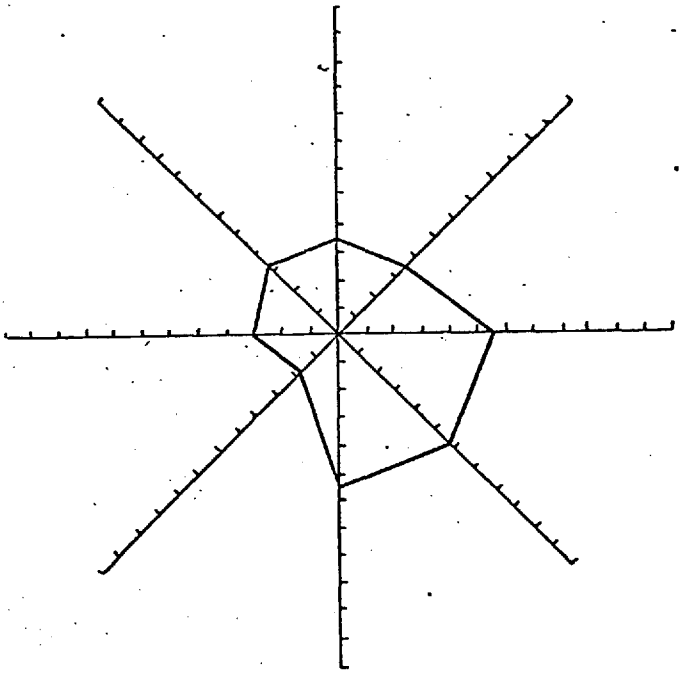
Nitrogen level - 135 p.p.m.

Salicornia nitens

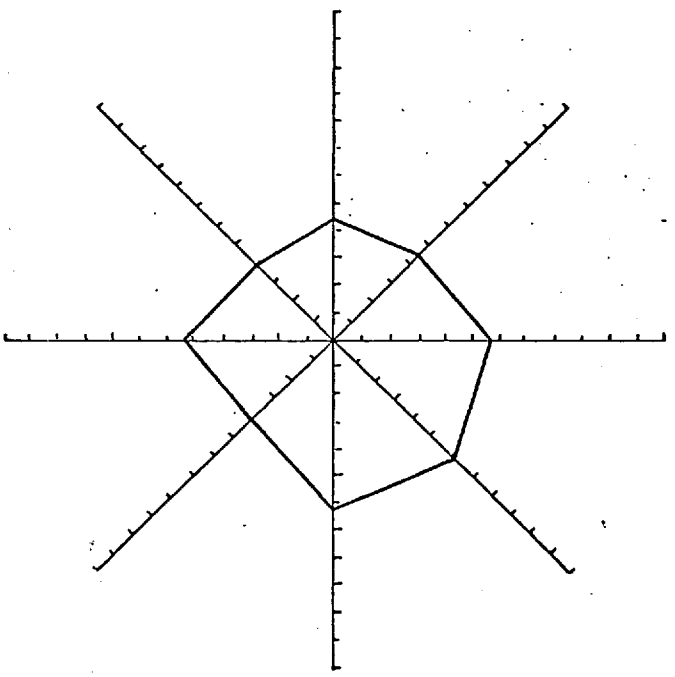
Figure 6.22



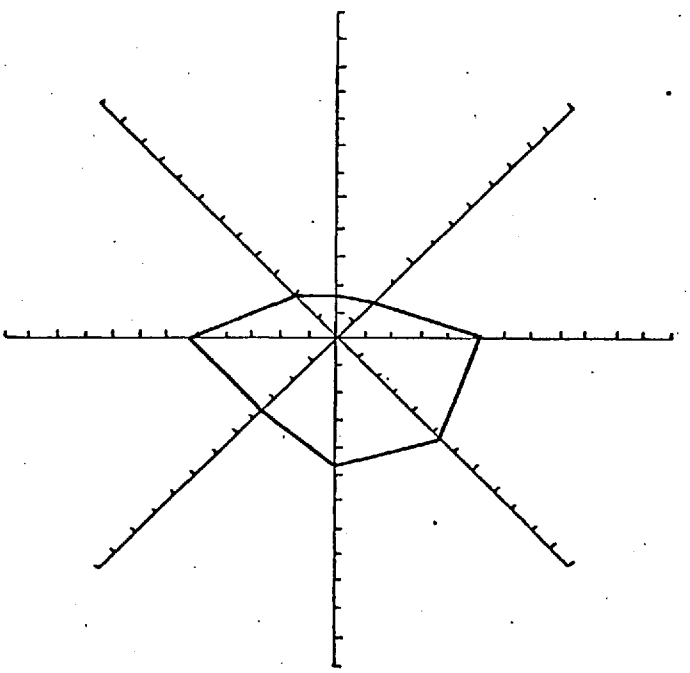
Nitrogen level - 5 p.p.m.



Nitrogen level - 15 p.p.m.



Nitrogen level - 45 p.p.m.



Nitrogen level - 135 p.p.m.

Salicornia ramosissima

Figure 6.23

when hypersaline conditions as a result from the infrequent tidal coverage together with high rates of evaporation (Chapman 1960, Ranwell et al. 1964, Tyler 1971b).

From the results of the present experiment it can be clearly seen that the three types of *Salicornia* studied, i.e. *S. dolichostachya*, *S. nitens* and *S. ramosissima*, which are from different parts of the marsh, show very consistent trends for most of the characters measured in relation to the employed levels of nitrogen used (Figures 6.1-6.8.). However, these figures differ significantly in their absolute values, and the maximum difference between these types in their ability to utilize the available nitrogen in the culture solution, is at the nutrient level of their optimum growth for each of the characters. It is interesting to see that the curves for *S. ramosissima* are always below the curves of the other two types. Since such a phenomenon occurred in almost all the vegetative characters studied, under a quite uniform growth condition, consequently it is likely that there is a significant genetic component to these absolute differences. This, in part, may be explained as a result of genetic differentiation in relation to the actual nitrogen contents in their natural habitat, since genetic differentiation in salt marsh species in response to the environmental heterogeneity is well established (Gregor 1930, 1946, Chapman 1960; Aston and Bradshaw 1966, Sharrock 1967, Hannon and Bradshaw 1968, Waisel 1972, Grey 1974). Stewart et al. (1972), also relate the variability in nitrogen content in the annual species of *Salicornia* and *Suaeda* to the gradient in supply of nitrogen which they suggested to be increasing toward seaward end of the marsh. Durrant (1972) and Hill (1967) also pointed out, that phenotypic modifications can be transmitted through seeds for several generations. The other factor which could help in the development of such genetic differentiation,

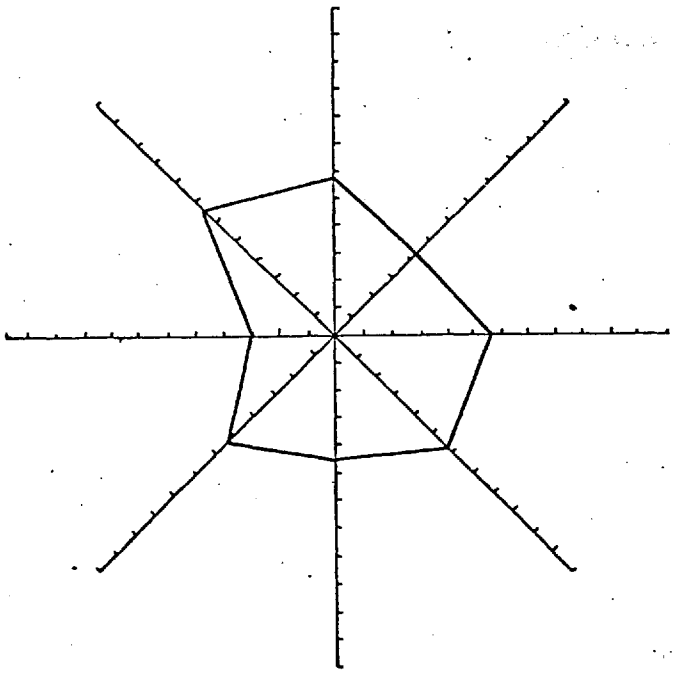
among the annual forms of *Salicornia* spp., may be the presence of a breeding barrier between the populations, particularly between those at upper and lower levels on the marsh. As pointed out earlier in this study, this breeding barrier, among the annual forms of the genus is due, in part, to the high proportion of seeds by self-fertilization (Dalby 1962, Ranwell 1972). In addition, the high number of individuals produced by *Salicornia*, particularly in the lower marsh and the low elevation areas of the upper marsh, and the advanced flowering of the lower marsh populations in relation to those of the high marsh. Differences in flowering time between the populations may reduce the effect of gene flow on the genetic composition of the populations.

On the other hand, the experimental levels of phosphorus showed a less significant effect on the general morphology of the plant. Plant length, total number of primary branches from the main axis, number of sterile segments in the main axis, and the length of the lowermost branch showed a significant response only up to the 4 p.p.m. level (P_2). The terminal spike length, number of fertile segments in the terminal spike, and the length of the uppermost branch (all concerned with the shoot apices) did not show any significant response to any of the experimental phosphorus levels. It may be supposed that when the external supply of phosphorus is very low, a large proportion of it may be trans-located from the older parts of the plant to the developing part which need phosphorus the most (Russell 1973). However, the polygonal graphs (Figures 6.24-6.26) also show that the three types of *Salicornia* are still distinct from each other even at the lowest levels of phosphorus employed (2 p.p.m.).

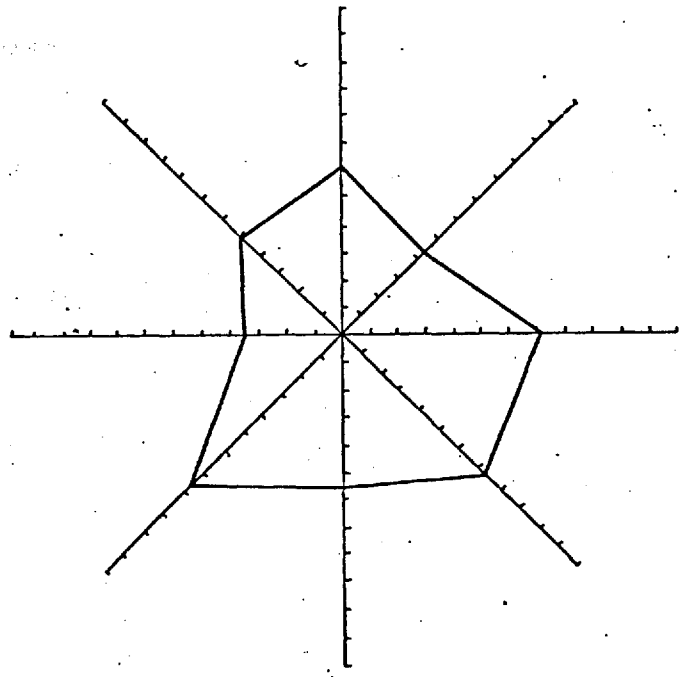
Generally, from this experiment it can be concluded that nitrogen, rather than phosphorus, is the critical limiting growth factor for

Figures 6.24 – 6.26 Polygonal graphs of eight morphological characters of *Salicornia dolichostachya*, *S. nitens* and *S. ramosissima* respectively, grown in the four levels of phosphorus.

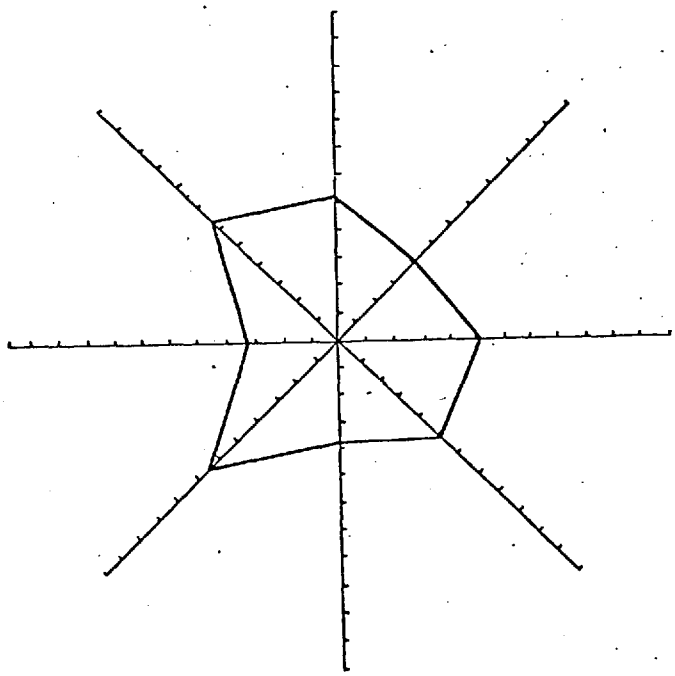
(see note on page 207).



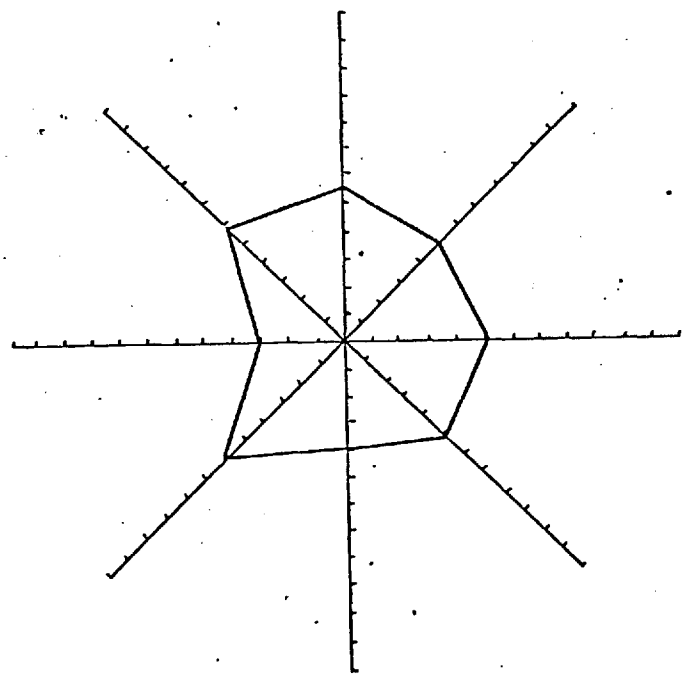
Phosphorus level - 2 p.p.m.



Phosphorus level - 4 p.p.m.



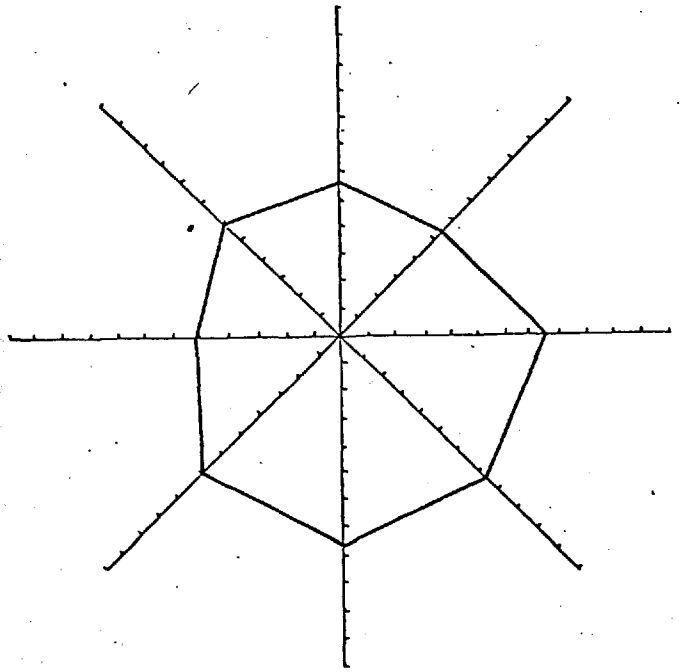
Phosphorus level - 8 p.p.m.



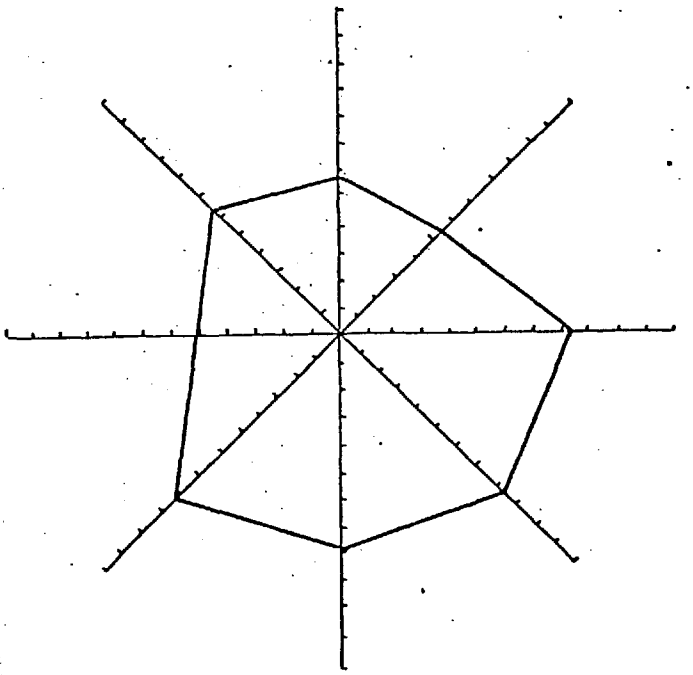
Phosphorus level - 16 p.p.m.

Salicornia dolichostachya

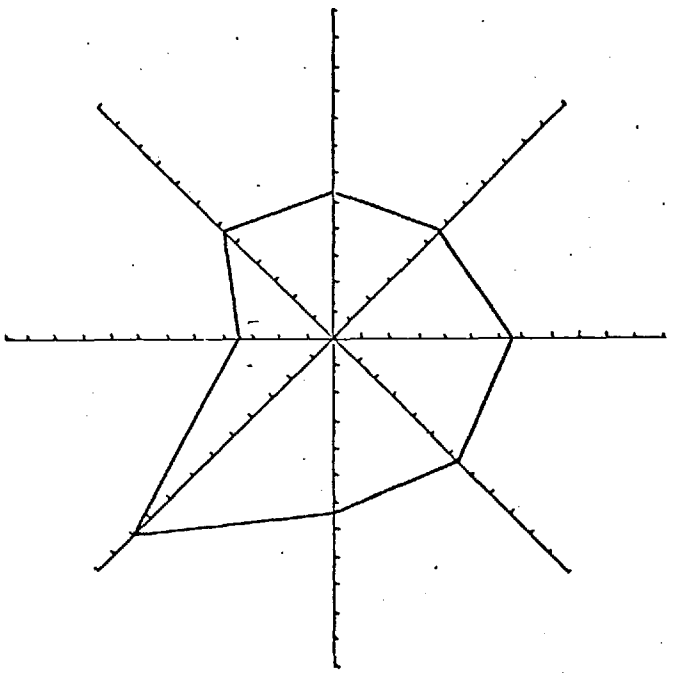
Figure 6. 24



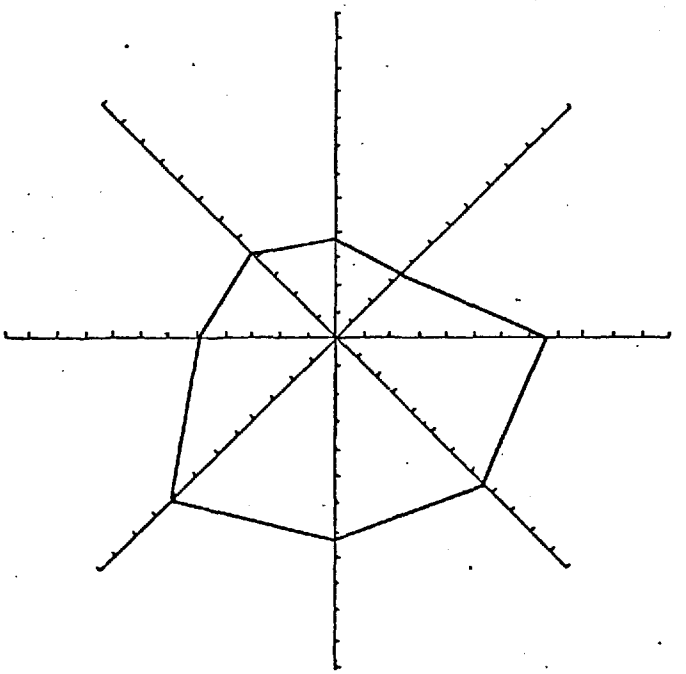
Phosphorus level - 2 p.p.m.



Phosphorus level - 4 p.p.m.



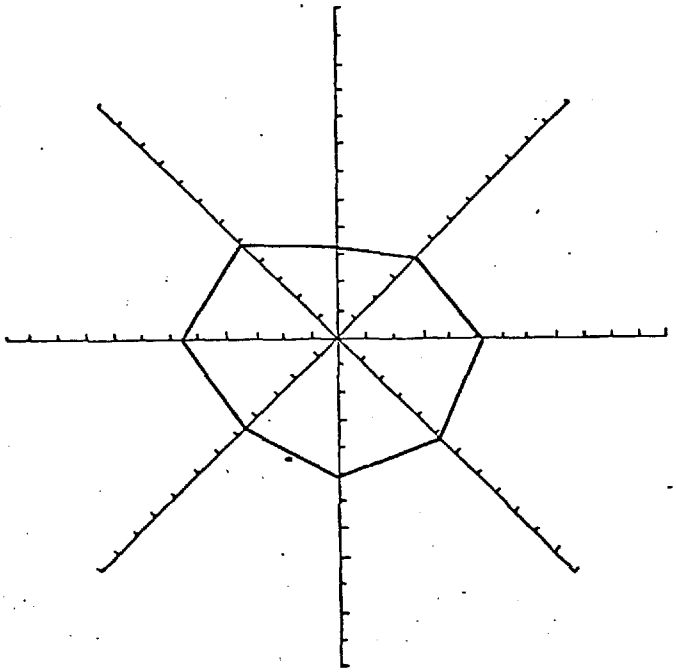
Phosphorus level - 8 p.p.m.



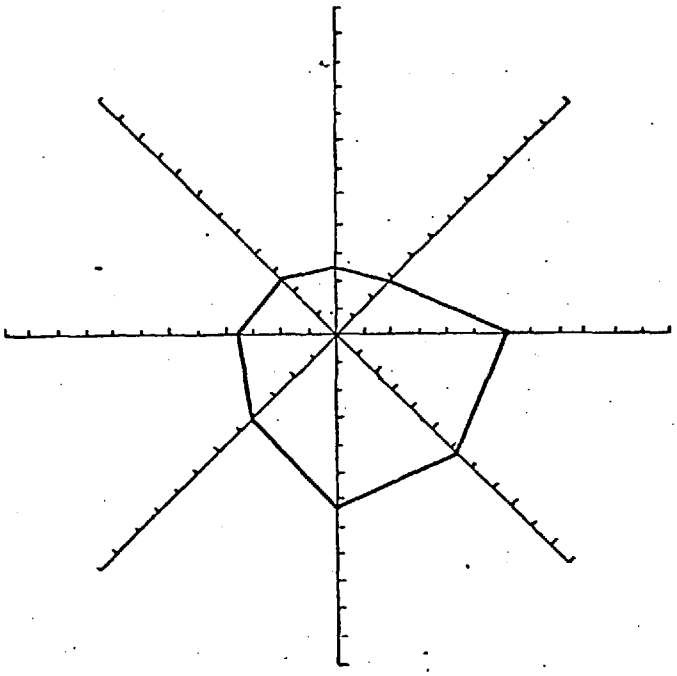
Phosphorus level - 16 p.p.m.

Salicornia nitens

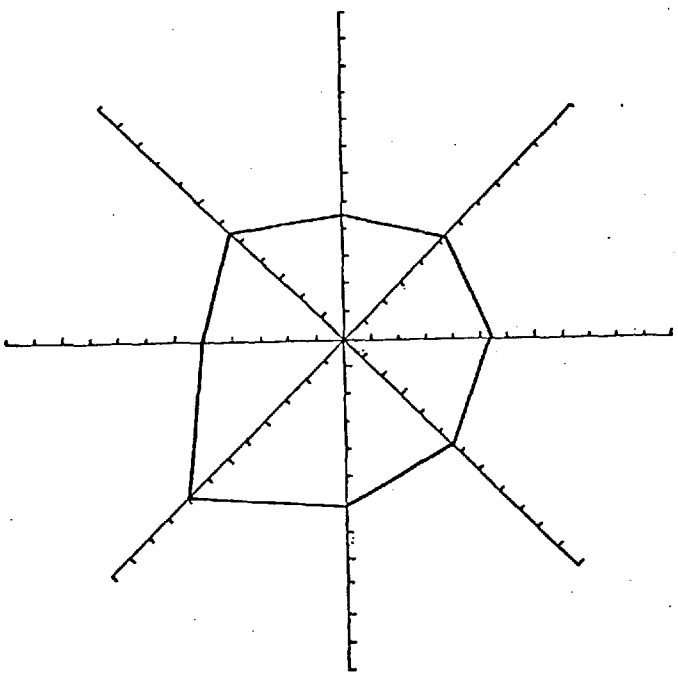
Figure 6.25



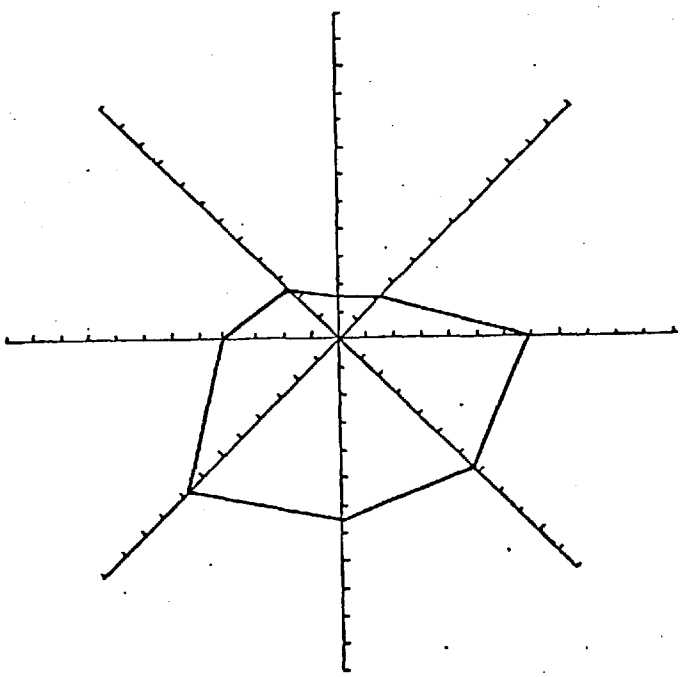
Phosphorus level - 2 p.p.m.



Phosphorus level - 4 p.p.m.



Phosphorus level - 8 p.p.m.



Phosphorus level - 16 p.p.m.

Salicornia ramosissima

Figure 6.26

the annual forms of *Salicornia* at least as far as the experimental material tested here. This is in agreement with the previous conclusions that nitrogen appears to be the limiting growth factor for certain species on the salt marsh, (Tyler 1967, Pigott 1969, Stewart, et al., 1972, 1973, Valiela and Teal 1974, Patrick and Delaune 1976). Ryther and Dunsta (1971) and Gray and Bunce (1972) also referred to phosphorus being available in the salt marsh habitat in amounts adequate for plant growth. It seems that this, may in part, explain why natural selection has not produced a low phosphorus tolerant genotypes in the annual forms of *Salicornia*. In contrast, due to the serious fall in the availability of nitrogen in the *Salicornia* zone (the actual concentrations of inorganic nitrogen and phosphorus in *Salicornia* zone will be discussed in the field studies, Chapter VII), natural selection has let to the development of low nitrogen tolerant genotypes. The biological consequences of this is that the annual forms of *Salicornia* can flower and set seeds, and so can survive, even at very low nitrogen levels.

6.3 The effect of different levels of sodium chloride on the morphology of *Salicornia*:-

As pointed earlier in this thesis (Chapter I), salinity levels vary considerably over the salt marsh habitat, seasonally as well as regionally, from one place to another and in particular between the upper marsh and the lower marsh. Therefore one can expect that such variations in salinity level may have a direct or indirect effect on the morphology of the plants under investigation.

There have been several studies on the effect of salinity on *Salicornia* spp. For example, as early as 1876, Batalin correlated the succulence of the plant with the presence of sodium chloride in

the soil. In addition, others such as Halket 1915, Keller 1925, Van Eijk 1939, Webb 1966, Flower 1972, Frenz-Arnol 1974, Mert and Varder 1976 have explored the effect of sodium chloride on *Salicornia* spp., particularly from the physiological point of view. Little attention was paid to overall development and comparative morphology.

In the present experiment an attempt was made to investigate the effect of different strengths of sodium chloride on the morphology of *Salicornia* in terms of the same morphological parameters used in the previous experiments, as well as correlating the behaviour of three types of *Salicornia* under such levels of sodium chloride in terms of these parameters.

6.3.1 Experimental procedures:-

The seeds used in this experiment came from the plants numbered 2, 8, 13 which belonged to *Salicornia dolichostachya*, *S. nitens* and *S. ramosissima* respectively. Table A 6.1. in the appendix.

The morphology of these three types of *Salicornia* were investigated in four levels of sodium chloride. These levels were 5% (twice the normal sea water strength), 2.5% (normal sea water strength), 1.3% (half normal sea water strength) and 0.65% (quarter normal sea water strength). Sea water total salinity may range from less than one percent to more than five percent (Metson 1961). However, in the present experiment the 2.5 percent solution of sodium chloride was adopted as "normal sea water strength".

As in the previous experiments, concerned with the effects of nitrogen and phosphorus, for each of the four levels of sodium chloride one culture tank was used. The culture tanks numbered 11, 12, 13 and

14 were used for the present experiment, (photograph 2.1, Chapter III). In addition, each culture tank was partitioned into three equal sections, referred to as A`, B` and C`. Each section was sown with seeds of one of the three types of *Salicornia*, in the following pattern; Section A` with seeds of *S. dolichostachya*, Section B` with seeds of *S. nitens* and Section C` with seeds of *S. ramosissima*.

The nutrient solution used was the complete solution of Hoagland and Arnon (1938), Table 2.1, the proper amount of sodium chloride (Grade Analar) for each treatment being added after germination had commenced, Table 6.9. Sodium chloride was added at intervals over one-two days, to avoid any physiological shock to the plant.

The experiment was started by sowing seeds in the tanks on 30th April, 1976. After germination had commenced and the establishment of the seedlings ensured, the plants in each sub-tank (Section) were thinned down to 13-15 plants of a uniform size.

All the other aspects of growth are the same as mentioned earlier in this Chapter.

Table 6.9 The weights and concentrations of sodium chloride used in the four levels of sodium chloride treatment.

Nacl concentration in the culture solution	Nacl concentration in percentage	gm/L of nutrient solution
¼ sea water	0.65	6.5
½ sea water	1.3	13
1 sea water	2.5	25
2 x sea water	5	50

6.3.2. Results:-

The various growth parameters measured are represented in Tables 6.10 and 6.11, along with Figures 6.27-6.36, and Photograph 6.4, to illustrate the effect of the experimental levels of sodium chloride on these parameters, in the three selected types of *Salicornia*. The data were analysed statistically in the same way as in the previous experiment of nitrogen and phosphorus treatments; (Figures 6.47-6.49) with the minimum, maximum, mean, standard deviation and variance values are presented in the appendix (Tables A 6.8.-A 6.10).

The experimental levels of sodium chloride exert a significant effect on the characters; the plant height, number of sterile segments in the main axis, total number of the primary branches from the main axis, terminal spike length, number of fertile segments in the terminal spike, length of the uppermost branch and length of the lowermost branch from the main axis. In the three types of *Salicornia* these characters demonstrate their maximum growth at 0.65% sodium chloride, and their growth was significantly retarded as the amount of the salt in the growth medium increased. Thus at 5% sodium chloride these characters showed their minimum growth, Figures (6.27, 6.29-6.34).

The angle of branching both of the upper branch and the lower branch with the main axis did not show a significant relation to the salinity variation, Figures 6.35 and 6.36.

Though Figure 6.28 shows that the increased dosage of sodium chloride did not exert a significant effect on the root length, the adventitious root development had been considerably reduced at the higher dosage of sodium chloride (Photograph 6.4). From the photograph it is also obvious that the high dosage of sodium chloride affected the development of the

Table 6.10 Shows the mean values for the vegetative characters for each of the selected types of *Salicornia* in the four levels of sodium chloride.

	Salicornia type and treatments / Vegetative Characters	*S. dolichostachya* (A)				*S. nitens* (B)				*S. ramosissima* (C)			
		0.65%	1.3%	2.5%	5%	0.65%	1.3%	2.5%	5%	0.65%	1.3%	2.5%	5%
1.	Shoot length	35.10	29.28	24.98	23.05	36.23	30.48	25.47	19.17	39.87	31.33	26.67	22.66
2.	Root length	10.00	9.63	10.80	9.63	8.70	10.50	9.60	9.17	10.61	9.36	7.54	10.90
3.	Total number of primary branches from the main axis.	47.00	39.33	36.57	34.27	60.86	57.67	50.67	38.83	59.20	49.64	42.53	38.00
4.	Number of sterile segments in the main axis.	23.75	19.83	18.13	17.00	30.86	28.50	25.27	19.50	29.10	24.82	21.40	18.83
5.	Terminal spike length	2.63	1.28	1.13	0.31	2.30	1.80	1.47	0.33	2.41	1.23	0.66	0.23
6.	Number of fertile segments in the terminal spike	11.50	4.33	5.00	1.36	11.29	8.83	7.87	1.67	1.31	7.55	3.93	1.33
7.	Length of the lowermost branch from the main axis.	15.46	10.28	9.17	6.48	11.07	13.76	9.17	5.23	22.51	12.82	11.89	8.00
8.	Length of the uppermost branch from the main axis.	1.98	1.53	1.05	0.67	2.09	1.88	1.13	0.64	1.53	0.85	0.59	0.35
9.	Angle of the uppermost branch with the main axis.	37.08	29.50	25.67	34.33	31.43	30.83	32.22	30.85	33.50	30.00	31.00	31.67
10.	Angle of the lowermost branch with the main axis.	38.33	30.42	26.67	31.00	34.89	40.00	42.78	45.83	38.00	29.55	21.33	39.17

Figures 6.27 - 6.36 Effect of the four levels of sodium chloride on shoot length, root length, total number of primary branches from the main axis, total number of sterile segments in the main axis, terminal spike length, number of fertile segments in the terminal spike, length of the uppermost branch from the main axis, length of the lowermost branch from the main axis, angle of the uppermost branch with the main axis and the angle of the lowermost branch with the main axis, in the three types of *Salicornia*, with 95% confidence limits to show the sensitivity differences between the types at each level of sodium chloride (See note on page 175.).

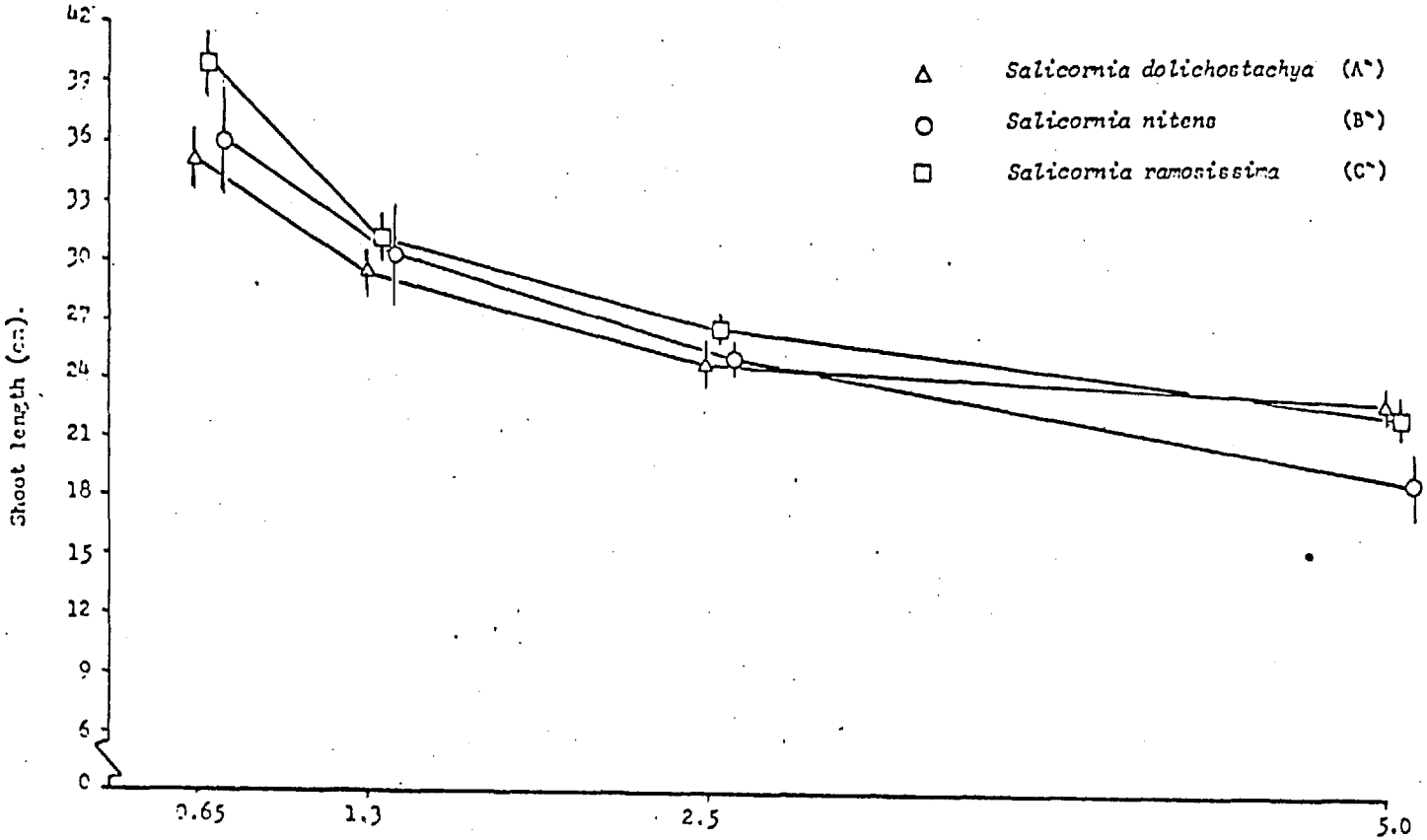

Shoot length (cm).
42
39
36
33
30
27
24
21
18
15
12
9
6
0
0.65
1.3
2.5
5.0
Experimental levels of Sodium chloride treatment (%)
Salicornia dolichostachya (A)
Salicornia nitens (B)
Salicornia ramosissima (C)

Figure 6.27

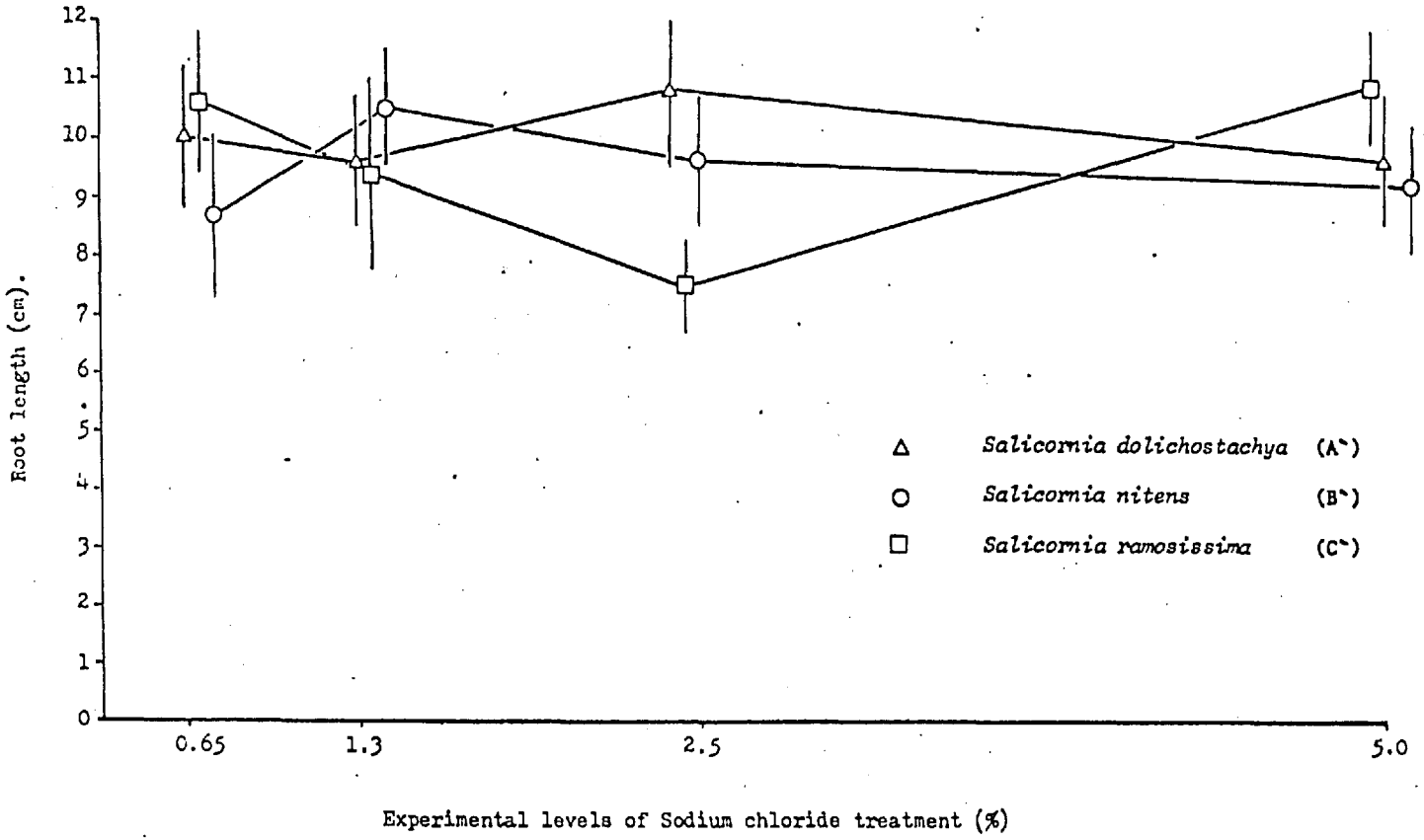

Root length (cm).
12
11
10
9
8
7
6
5
4
3
2
1
0
0.65
1.3
2.5
5.0
Salicornia dolichostachya (A˜)
Salicornia nitens (B˜)
Salicornia ramosissima (C˜)
Experimental levels of Sodium chloride treatment (%)

Figure 6.28

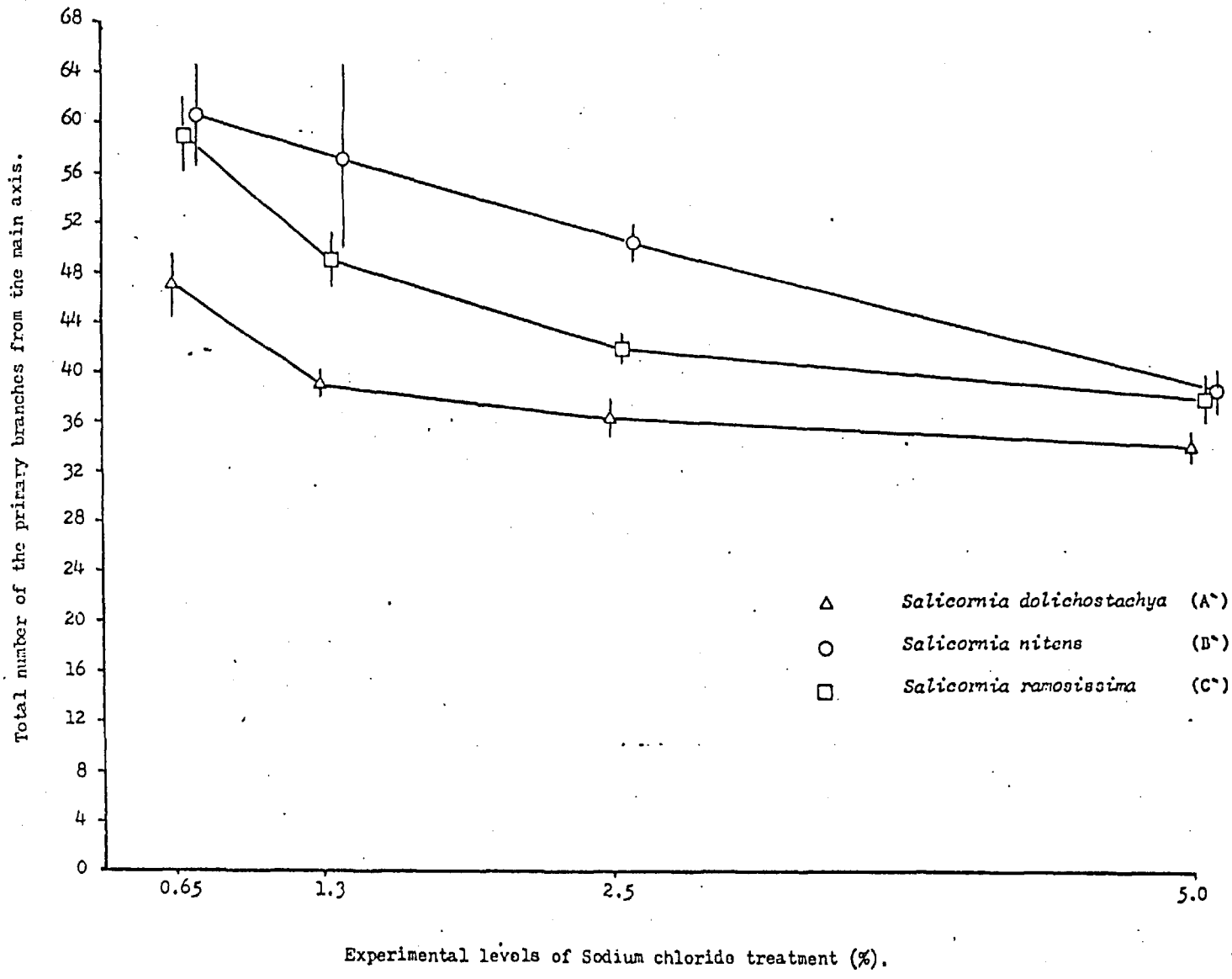

Total number of the prirary branches from the main axis.
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
0.65
1.3
2.5
5.0
Experimental levels of Sodium chloride treatment (%).
Salicornia dolichostachya (A`)
Salicornia nitens (B`)
Salicornia ramosissima (C`)

Figure 6.29

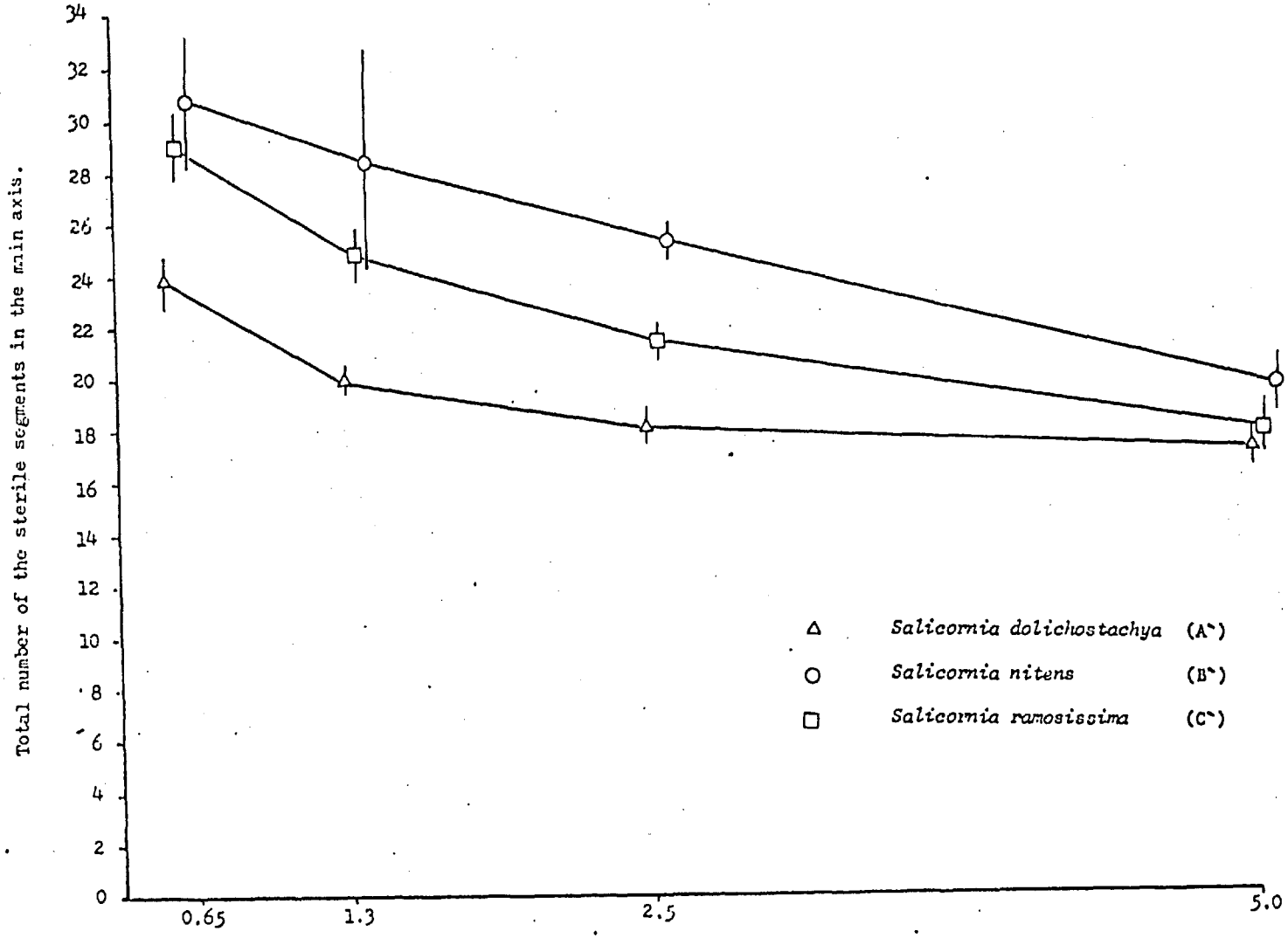

Total number of the sterile segments in the main axis.
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0.65
1.3
2.5
5.0
Experimental levels of Sodium chloride treatment (%).
Salicornia dolichostachya (A`)
Salicornia nitens (B`)
Salicornia ramosissima (C`)

Figure 6.30

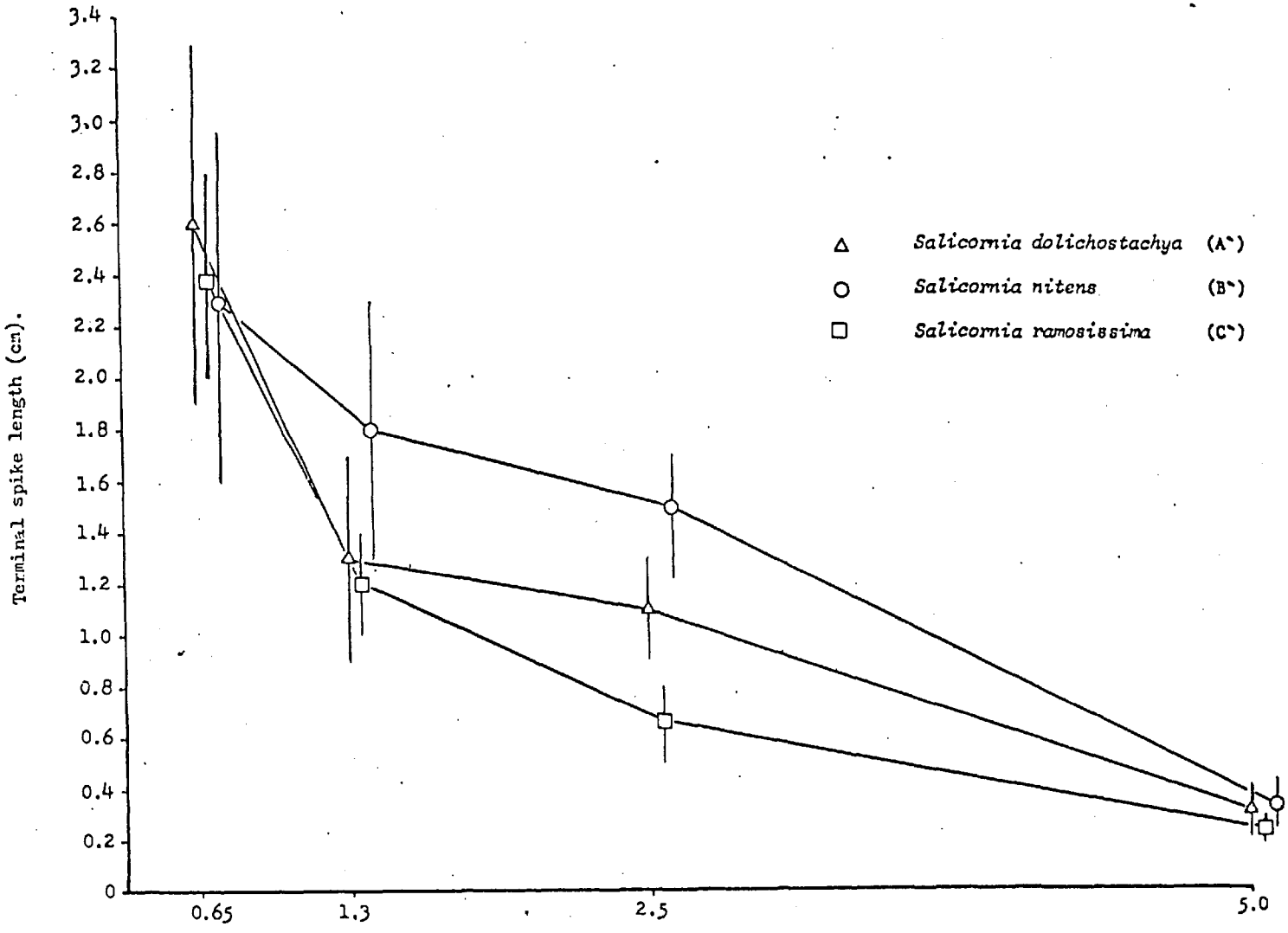

Terminal spike length (cm).
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0.65
1.3
2.5
5.0
Salicornia dolichostachya (A`)
Salicornia nitens (B`)
Salicornia ramosissima (C`)
Experimental levels of Sodium chloride treatment (%).

Figure 6. 31

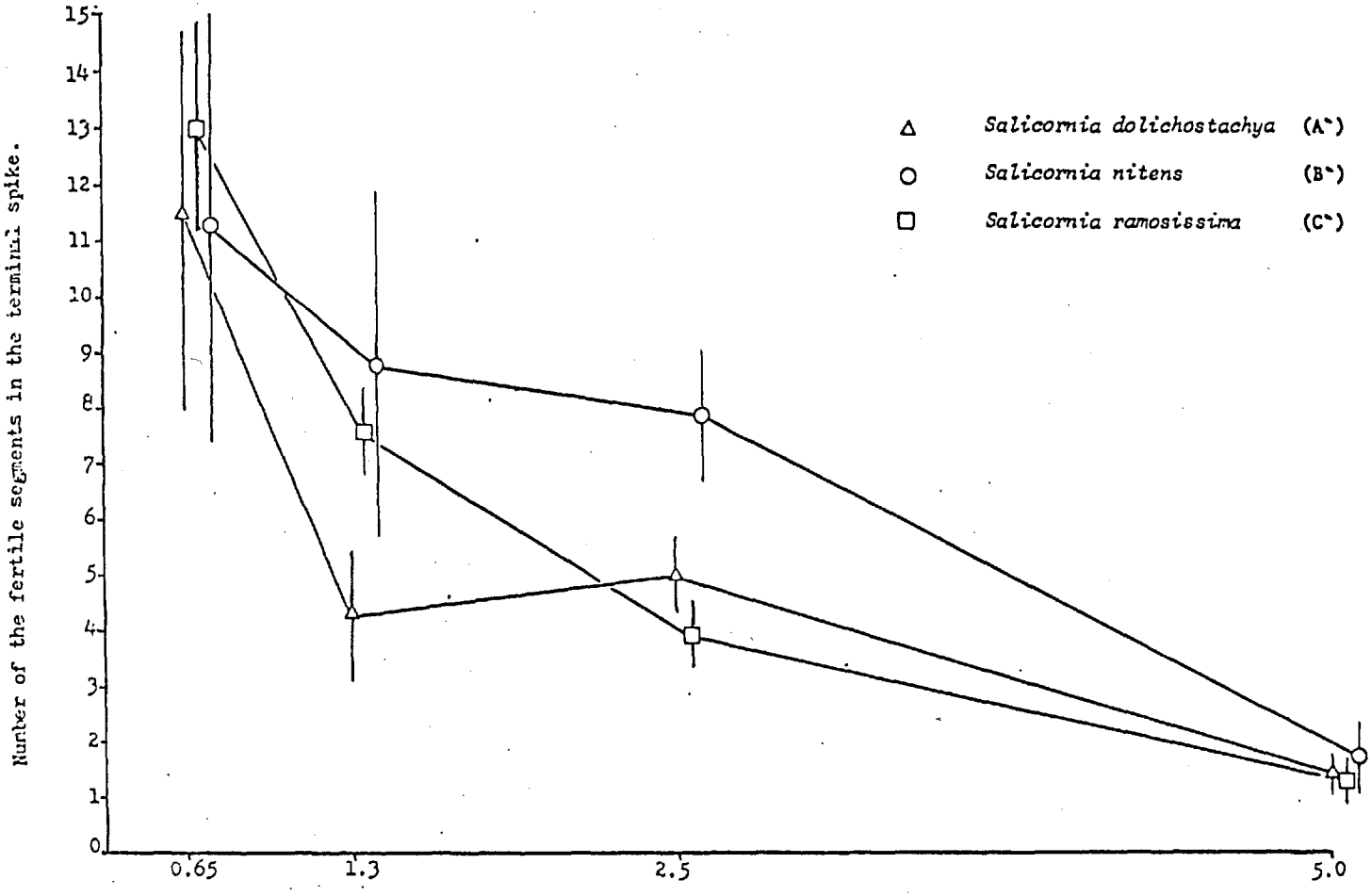

Number of the fertile segments in the terminal spike.
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0.65
1.3
2.5
5.0
Salicornia dolichostachya (A`)
Salicornia nitens (B`)
Salicornia ramosissima (C`)
Experimental levels of Sodium chloride treatment (%).

Figure 6.32

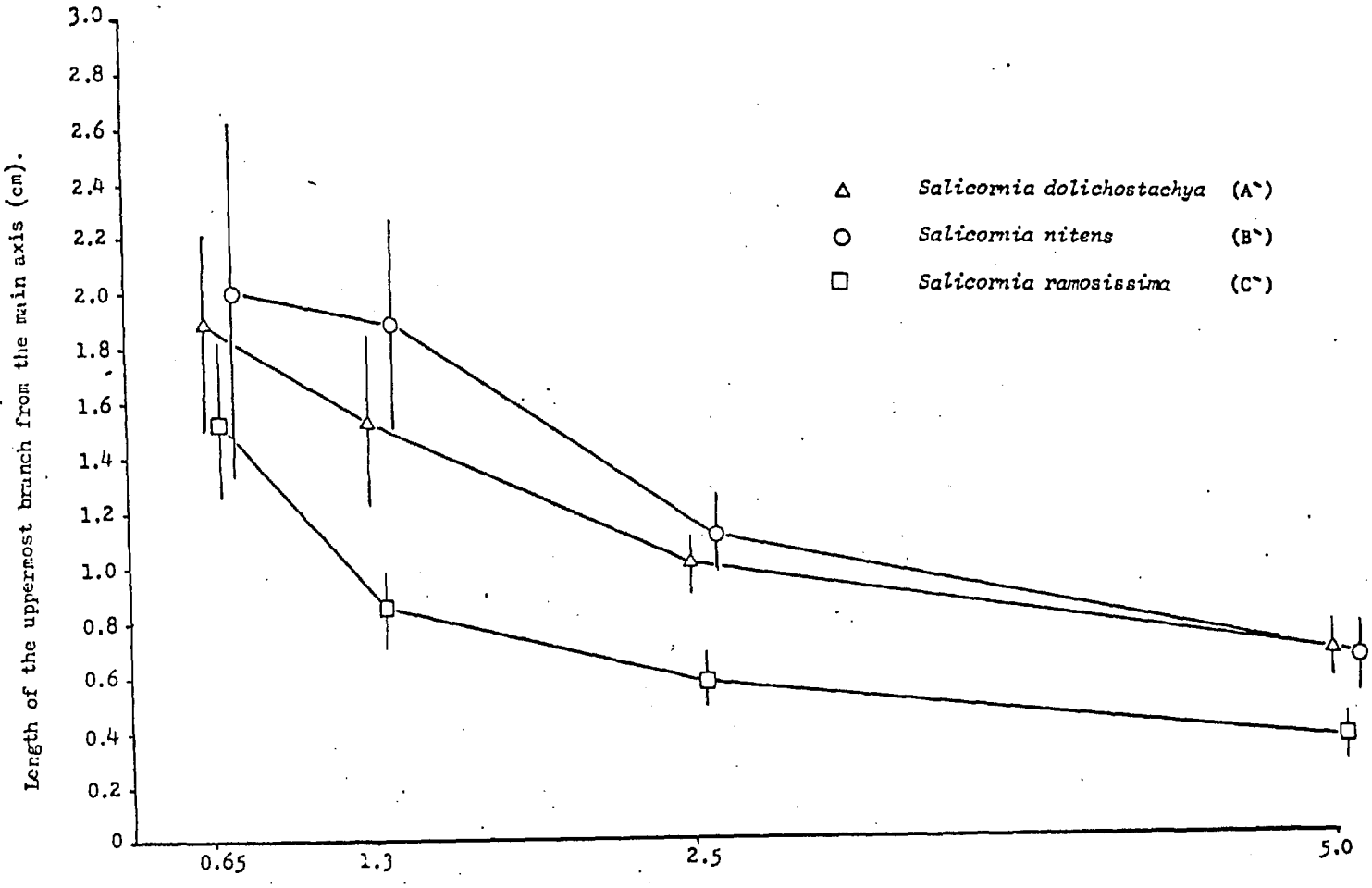

Length of the uppermost branch from the main axis (cm).
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0.65
1.3
2.5
5.0
Salicornia dolichostachya (A`)
Salicornia nitens (B`)
Salicornia ramosissima (C`)
Experimental levels of Sodium chloride treatment (%).

Figure 6.33

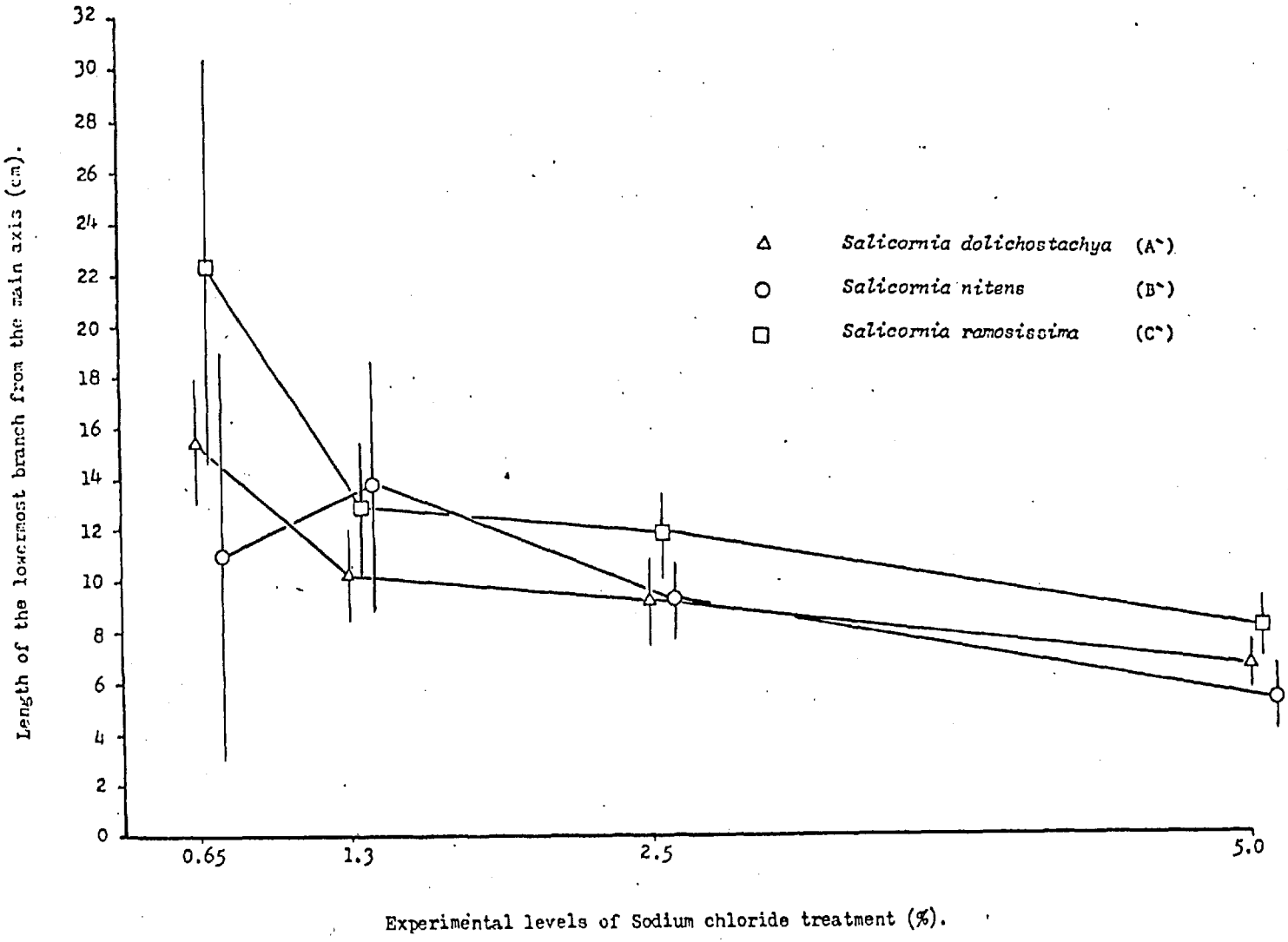

Length of the lowermost branch from the main axis (cm).
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0.65
1.3
2.5
5.0
Salicornia dolichostachya (A')
Salicornia nitens (B')
Salicornia ramosissima (C')
Experimental levels of Sodium chloride treatment (%).

Figure 6.34

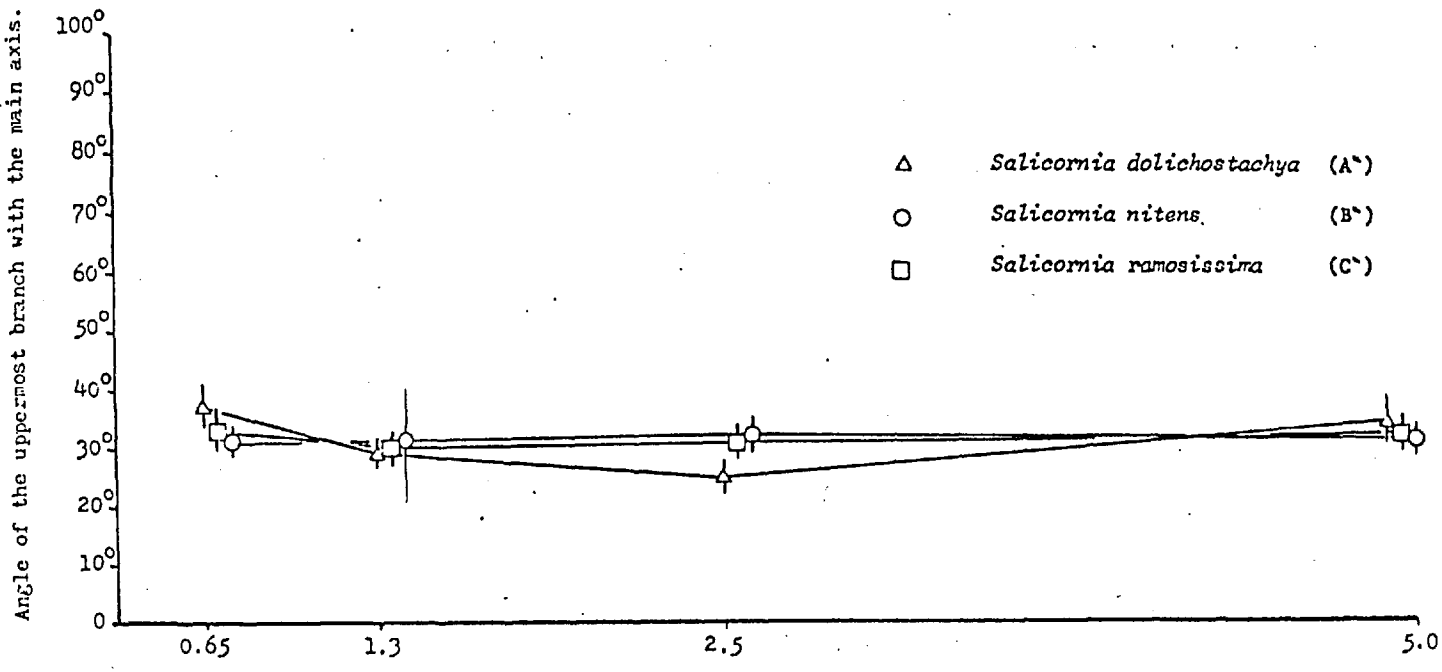

Angle of the uppermost branch with the main axis.
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0
0.65
1.3
2.5
5.0
Salicornia dolichostachya (A`)
Salicornia nitens (B`)
Salicornia ramosissima (C`)
Experimental levels of Sodium chloride treatment (%).

Figure 6.35

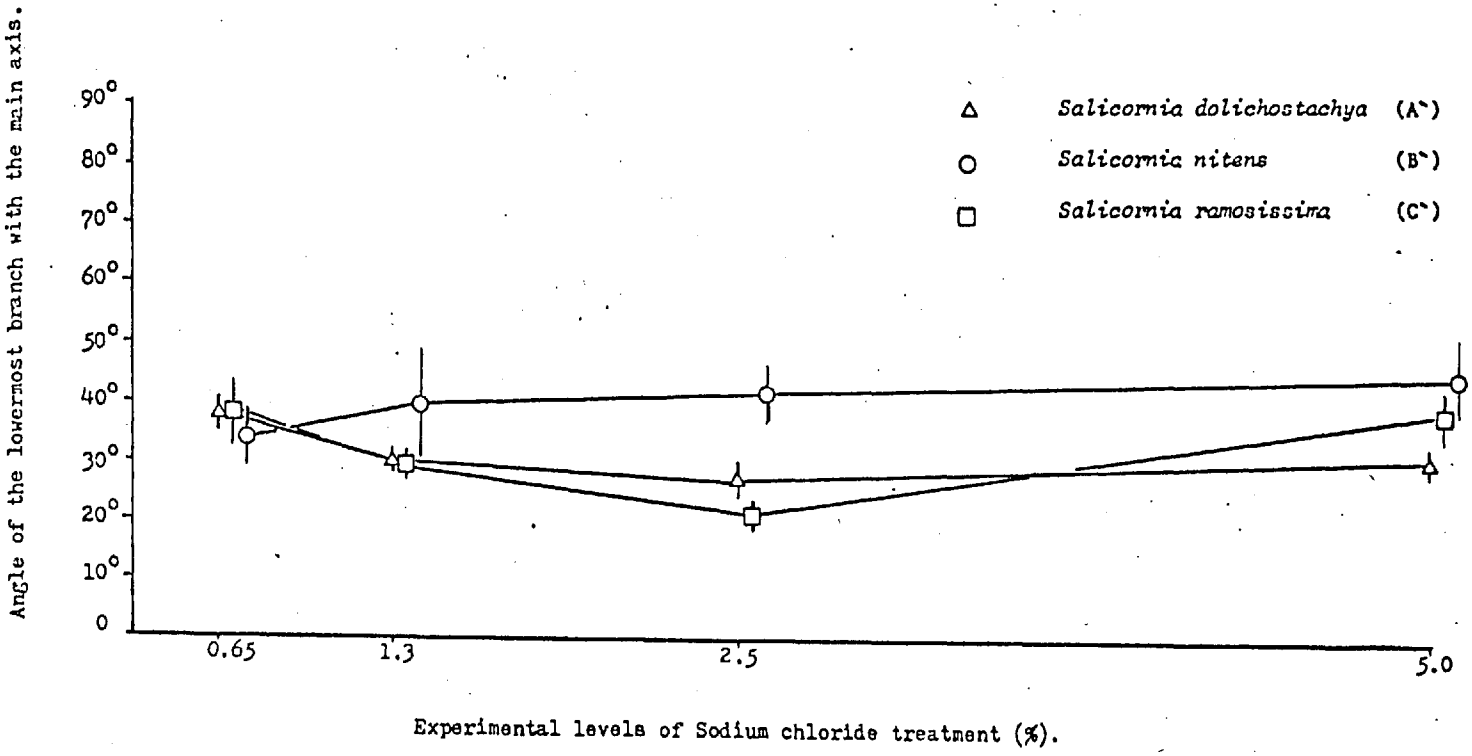

Angle of the lowermost branch with the main axis.
90°
80°
70°
60°
50°
40°
30°
20°
10°
0
0.65
1.3
2.5
5.0
Salicornia dolichostachya (A`)
Salicornia nitens (B`)
Salicornia ramosissima (C`)
Experimental levels of Sodium chloride treatment (%).

Figure 6.36

Photograph 6.4 : Shows *Salicornia nitens* plants grown in 5% Nacl (11B), in 1.3% Nacl (12B) and in 0.65% Nacl (13B).

secondary branches from the primary branches. As it can be seen in the plants grown in 5 percent sodium chloride, the secondary branches consists of a short terminal spike, which usually consists of one-three fertile segments terminating one or two short sterile segments. Sometimes the terminal spike is sessile on the primary branch.

Comparison of Figures 6.27-6.34 and Photograph 6.4 reveals that the increased dosage of sodium chloride produced a stunting effect on growth. It can be noticed that the length of the terminal spike, the number of the fertile segments in terminal spike, and the length of the uppermost branch are the most suppressed by increasing the salinity level in comparison with the other vegetative characters. For example in *S. dolichostachya* type, the terminal spike length was reduced from 2.6 cm in the 0.65 percent sodium chloride solution to 0.3 cm in the 5 percent solution, and the number of fertile segments in the terminal spike had been reduced from ≈ 12 to one fertile segment respectively, and in some, even one fertile segment did not develop well. Similarly in *S. ramosissima* the length of the uppermost branch had been reduced from 1.53 cm. in the 0.65 percent solution to 0.4 cm. in the 5 percent solution.

On the other hand, the number of sterile segments in the main axis and the total number of primary branches appeared to be less sensitive to the increased levels of sodium chloride in comparison with the other vegetative characters.

In contrast to the nitrogen and phosphorus treatments the sodium chloride treatments exerted a considerable effect on the morphology of the fertile segment components in all three types of *Salicornia*,

Table 6.11. In common with the vegetative characters, the increased levels of sodium chloride, particularly the 5 percent treatment, brought about a general reduction in all the fertile segment components. It seems that the most sensitive component of the fertile segment, to the increased levels of sodium chloride, are the maximum widths of the segments (A and B in Figure 3.14), Table 6.11, as these two parts are probably strongly related to the succulency of the plant tissue. However, the experimental levels of sodium chloride did not bring a significant change to the usual flowering period of the types of *Salicornia* grown and as usual the plants of *S. dolichostachya* flowered earlier than the other two types, by 10 - 15 days, in all the four levels of sodium chloride.

6.3.3 Discussion:-

In general the effect of the experimental levels of sodium chloride on the vegetative characters shows that the growth of the apical characters, i.e. terminal spike length, number of fertile segments in the terminal spike, and the length of the uppermost branch from the main axis, are the most suppressed by the increased levels of salinity. The development of the sterile segments in the main axis and the number of the primary branches from the main axis are less affected by the increased levels of sodium chloride.

Comparison of the Figures 6.27-6.34 also reveals that all the three types of *Salicornia* showed a similar growth pattern towards the adopted levels of salinity. But, nevertheless, they showed significant differences in their sensitivity towards sodium chloride, particularly at the 1.3 percent and 2.5 percent levels in terms of the measured characters (Figures 6.27-6.34). From the 95% confidence limits it can be seen that most of the vegetative characters measured demonstrate their lowest

Table 6.11 Shows the means($\bar{x}$) and standard deviation(S.D.) values for the fertile segment components of the three types of *Salicornia* in the four levels of sodium chloride.(Measurements expressed as mm).

S. dolichostachya (A˜)								
Fertile Segment Components *	0.65%		1.3%		2.5%		5%	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
A	4.33	±.38	3.8	±.39	3.45	±.10	3.52	±.24
B	4.24	±.41	3.44	±.33	3.28	±.20	3.06	±.09
C	3.23	±.27	2.74	±.39	2.23	±.18	2.74	±.29
D	2.33	±.19	2.40	±.25	2.06	±.14	2.12	±.15
E	2.49	±.20	2.73	±.34	2.53	±.15	2.26	±.09
F	2.13	±.16	2.33	±.21	2.04	±.15	1.88	±.05
G	1.27	±.25	1.25	±.23	1.01	±.17	1.30	±.10
E-F	.36	±.13	.40	±.28	.49	±.14	.38	±.13
D-F	0.20	±.26	.07	±.09	.03	±.09	.24	±.18

S. nitens (B˜)								
Fertile Segment Components *	0.65%		1.3%		2.5%		5%	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
A	3.08	±.23	3.38	±.43	3.60	±.16	2.97	±.19
B	3.02	±.10	3.10	±.20	2.98	±.05	2.63	±.18
C	2.50	±0.0	2.48	±.35	2.45	±0.10	2.18	±.19
D	2.10	±.12	1.68	±.40	1.48	±.36	1.73	±0.26
E	2.22	±0.18	1.90	±.37	1.83	±.33	1.63	±.21
F	1.82	±0.20	1.48	±0.38	1.28	±.15	1.23	±.19
G	1.02	±.05	.83	±.23	.73	±.24	.74	±.17
E-F	.40	±.16	.42	±.13	.30	±.12	.4	±.16
D-F	.28	±.26	.20	±.29	0.2	±.17	.54	±.32

Table 6.11 (Continued)

S. ramosissima (C`)								
Fertile Segment Components*	0.65%		1.3%		2.5%		5%	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
A	3.51	±.33	3.08	±.26	2.97	±.32	2.76	±.16
B	3.26	±.32	2.77	±.25	2.33	±.55	2.58	±.20
C	2.44	±.23	2.31	±.23	1.86	±.39	2.12	±.08
D	1.63	±.18	1.65	±.26	1.32	±.21	1.44	±0.20
E	2.2	±.17	2.06	±.18	1.90	±.18	1.80	±.14
F	1.40	±.20	1.59	±.23	1.15	±.20	1.22	±.26
G	.70	±.09	.66	±.17	.57	±.15	.58	±.10
E-F	.80	±.19	.47	±.22	.75	±.25	.58	±.22
D-F	.23	±.15	.06	±.13	.17	±.12	.22	±.08

* See Figure 3.14

overlapping between the three types of *Salicornia* at the 1.3 percent and 2.5 percent levels of sodium chloride, whilst at the levels 0.65 percent and 5 percent sodium chloride most of the measured vegetative character show their maximum overlapping between the three types of *Salicornia* i.e. differences were generally none significant. For example at these two levels, the terminal spike length and the number of the fertile segments in the terminal spike did not show significant differences between those plants of *S. dolichostachya* and those of *S. ramosissima* (Figures 6.31 and 6.32).

The presence of such significant differences in the growth ability between the three types of *Salicornia*, in terms of the measured vegetative characters, within the range of 1.3 - 2.5 percent sodium chloride under the standard growth conditions employed could indicate that these types of *Salicornia* have evolved different physiological adaptations to function effectively under a salinity regime similar to that present in habitat of the parent plant. This could be in agreement with Gifford and Nelson (1965) who showed that there is a definite genetic differentiation in the power of the plant to absorb sodium, as is the case for other nutrients. On the other hand, the levels of 0.65 and 5 percent sodium chloride at which most of the measured vegetative characters illustrate a high degree of overlapping between the three types of *Salicornia* i.e. differences are not significant, could indicate that such salinity levels are not similar to those in which the parent plant grew in the field. Though at this point it is difficult to derive such a conclusion without having sufficient evidence from the field, the results of the soil analysis (Chapter VII) showed that the majority of the analysed salt marsh samples possess a range of 1-2 percent sodium.

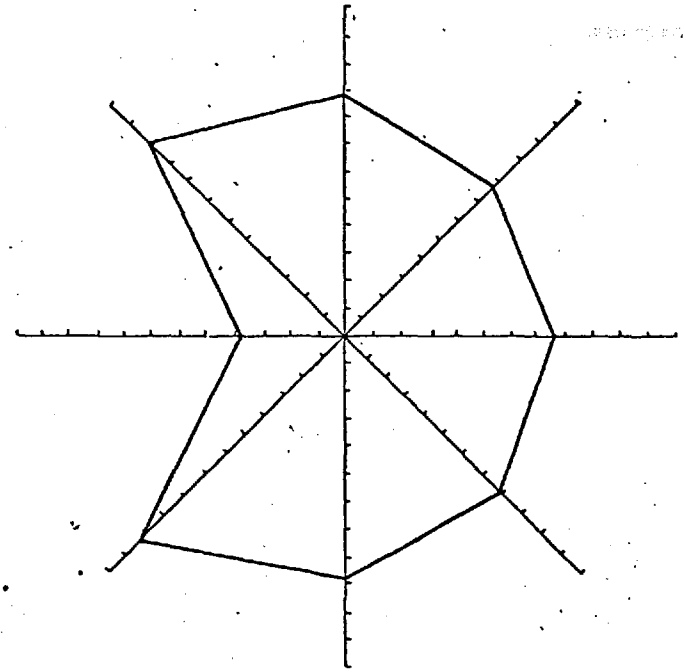
From the observed effect of the experimental levels of sodium

chloride on the general morphology of *Salicornia*, and in particular on the apical characters, it may be concluded that variation in salinity could have an important role in the taxonomical confusion at present experienced in the genus. A plant belonging to the one genotype may behave differently, morphologically, under different regimes of salinity. At the same time plants belonging to different genotypes, but, under extreme conditions of salinity, may look the same, so that it may be very difficult to differentiate between them. The polygonal graphs for each of the three types of *Salicornia* in the four levels of sodium chloride illustrate such phenomena quite clearly (Figures 6.37-6.39).

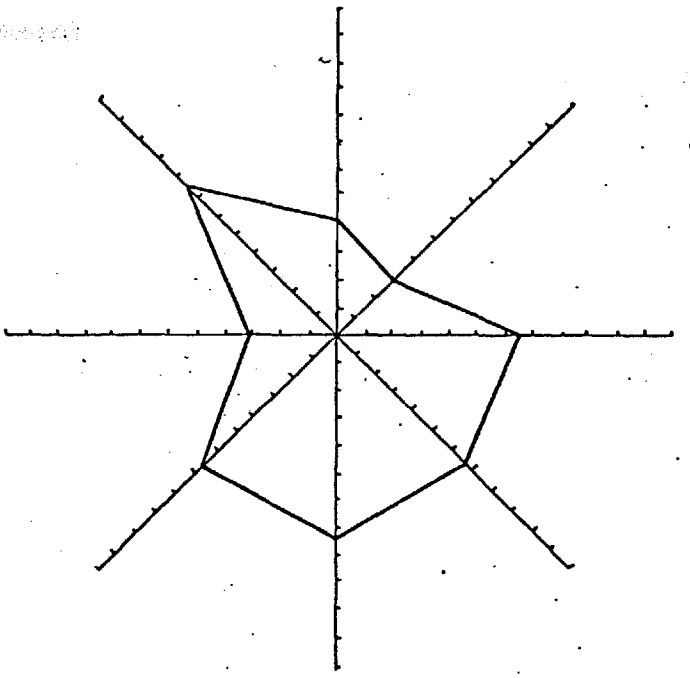
In general the results of the present experiment agree with the general belief that *Salicornia* spp. and other halophytes are salt tolerating rather than salt demanding. Similar observations were recorded by Ganong (1903) when he described the salt marsh plants of the Bay of Fundy Marshes. He said of *Salicornia herbacea* L., that the plants varied in size inversely with the saltiness of the habitat. Halket (1915) also showed that plants of *Salicornia* flourished best in the presence of a certain amount of salt, though the growth was decreased if the amount of salt present increased beyond certain limits.

The general reduction of the plant size as the amount of sodium chloride increases in the growth medium could be in part due to the effect of the salt on the general metabolic processes of the plant, as it was found that the enzymes involved in photosynthesis to be salt sensitive (Greenway and Osmand 1972, Austenfeld 1974). Similarly the enzymatic analysis of *Salicornia* spp. has shown that they are as sensitive to salt as enzymes from salt sensitive plants (Weimberge 1967, Hason-porath and Poljakof-Mayber 1969, Flower 1972, Greenway and Osmond 1972, Heimer

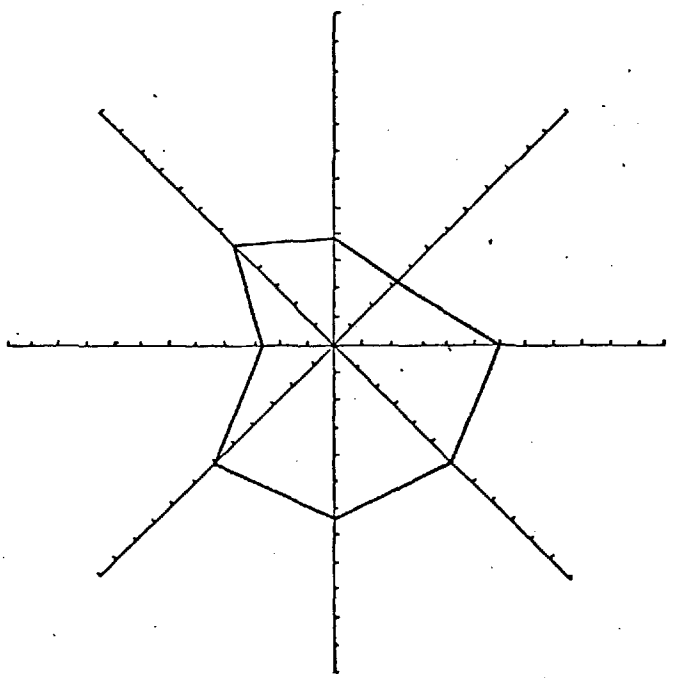
Figures 6.37-6.39 Polygonal graphs of eight morphological characters *Salicornia dolichostachya, S. nitens and S. ramosissima* respectively, grown in the four levels of sodium chloride. (see note on page 207).



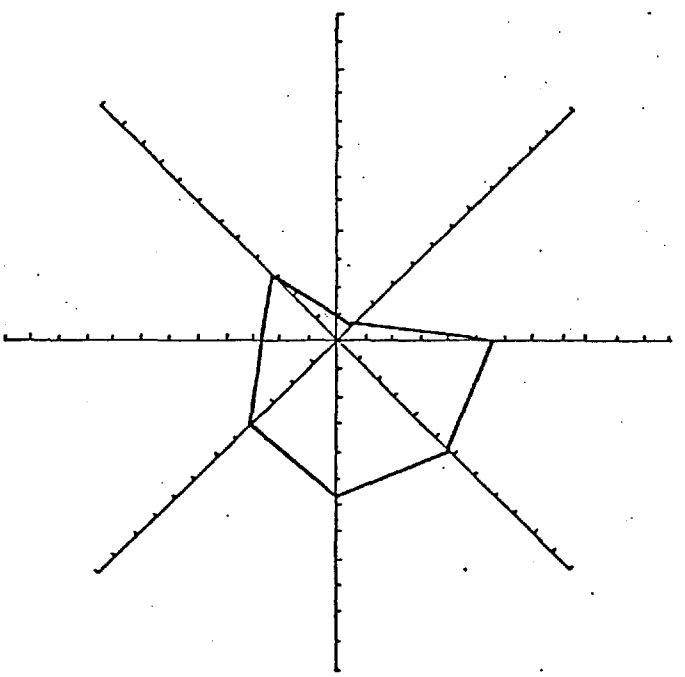
Sodium chloride level - 0.65%



Sodium chloride level - 1.3%



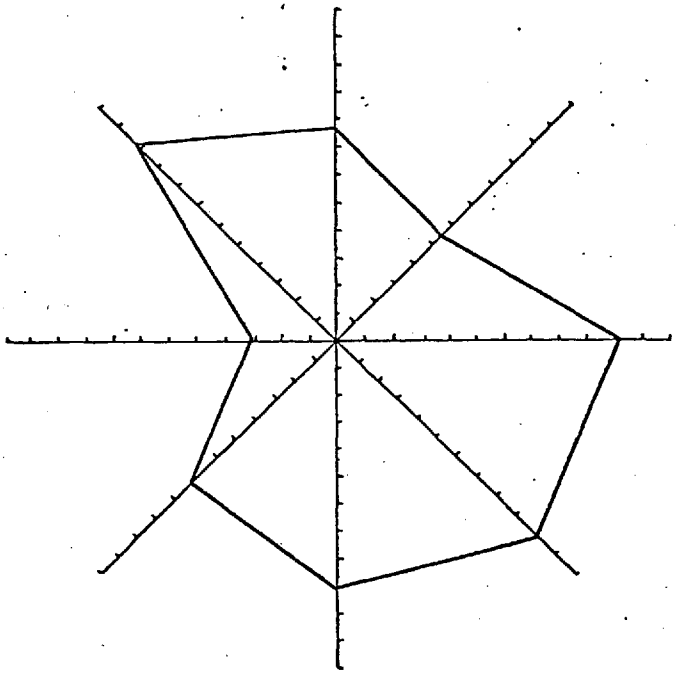
Sodium chloride level - 2.5%



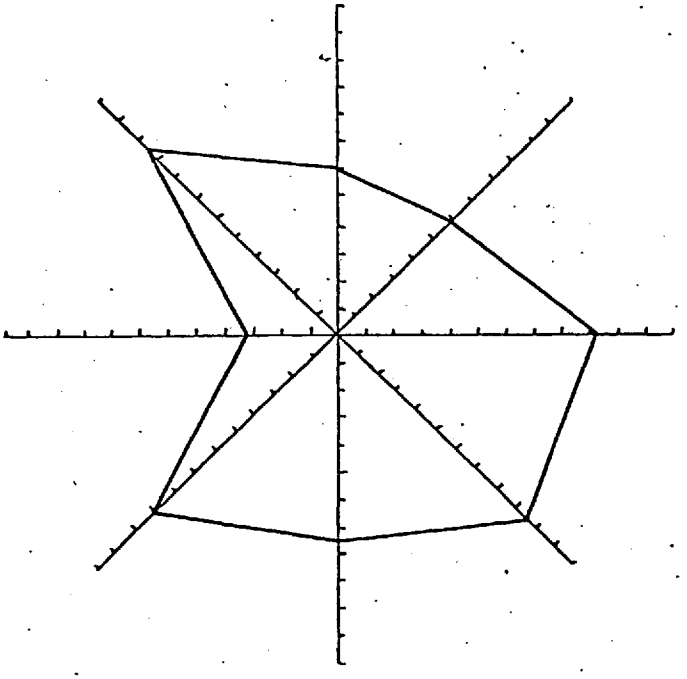
Sodium chloride level - 5%

Salicornia dolichostachya

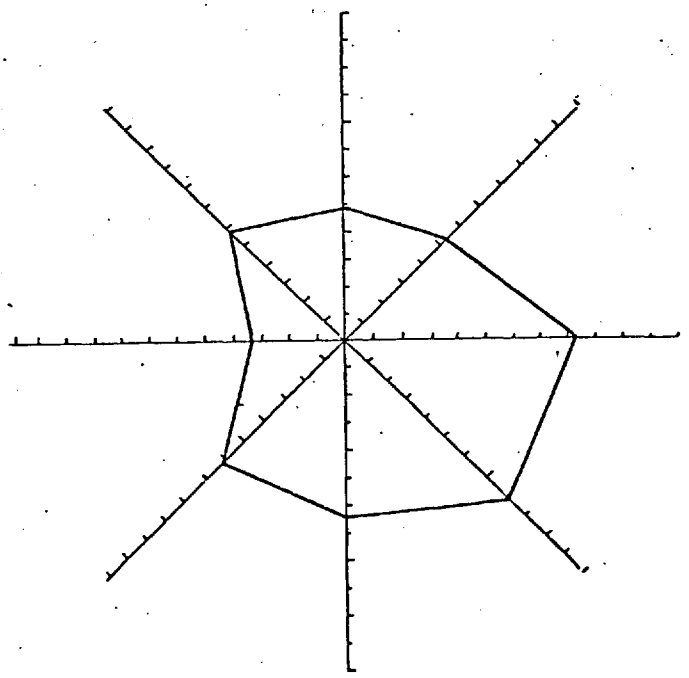
Figure 6.37



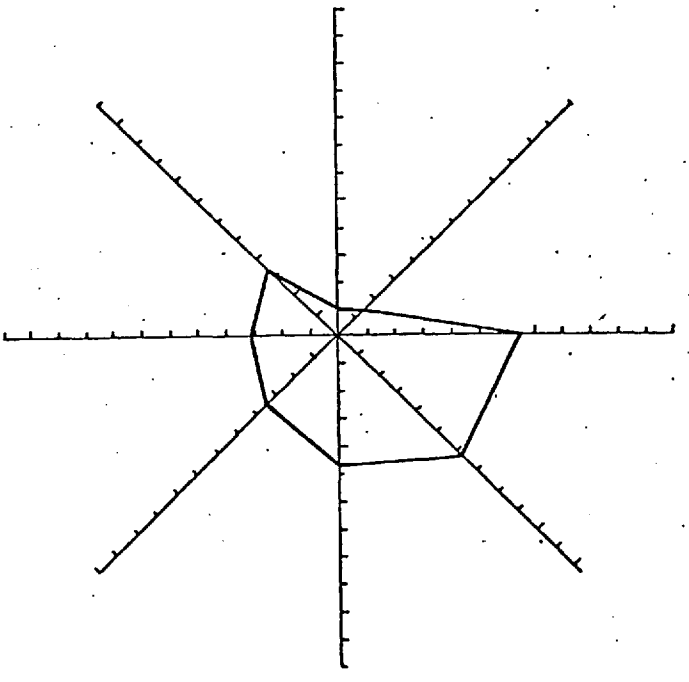
Sodium chloride level-0.65%



Sodium chloride level-1.3%



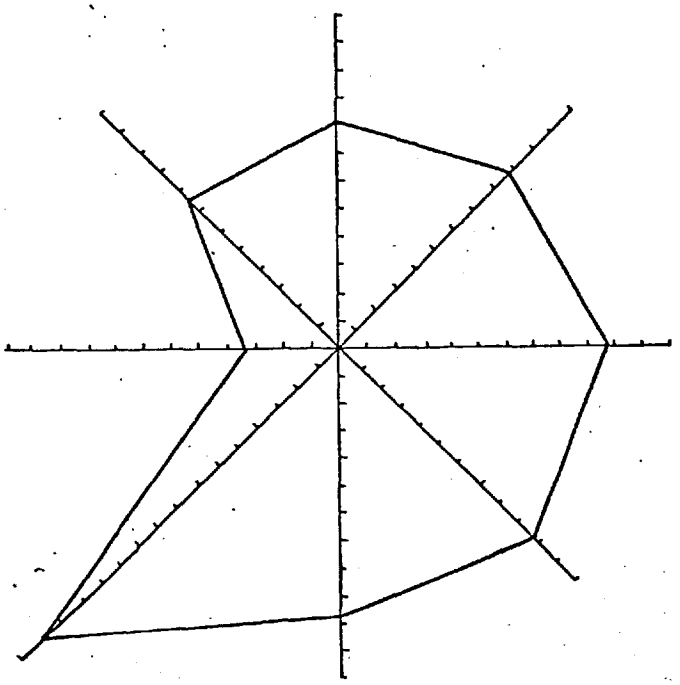
Sodium chloride level-2.5%



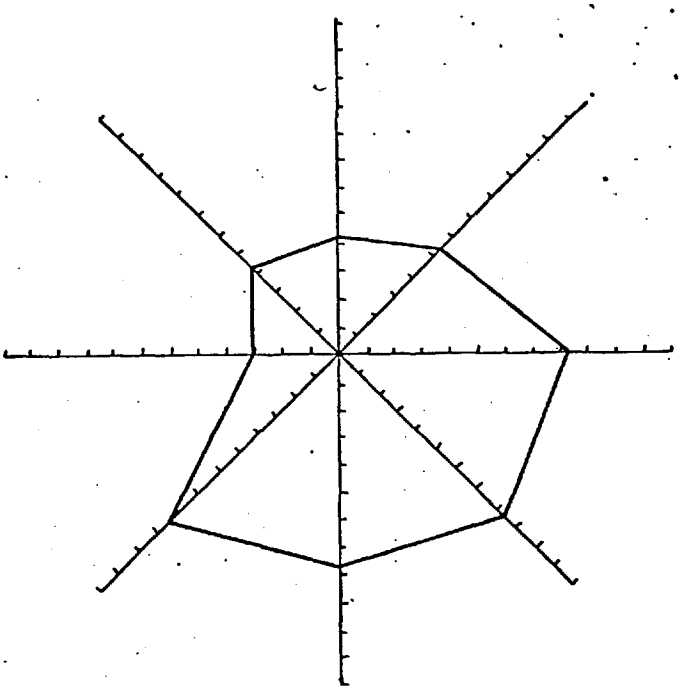
Sodium chloride level-5%

Salicornia nitens

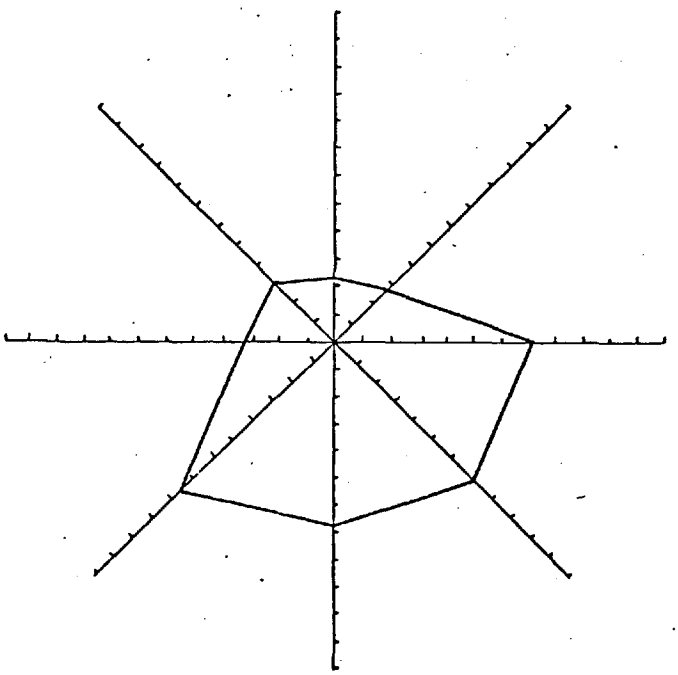
Figure 6..38



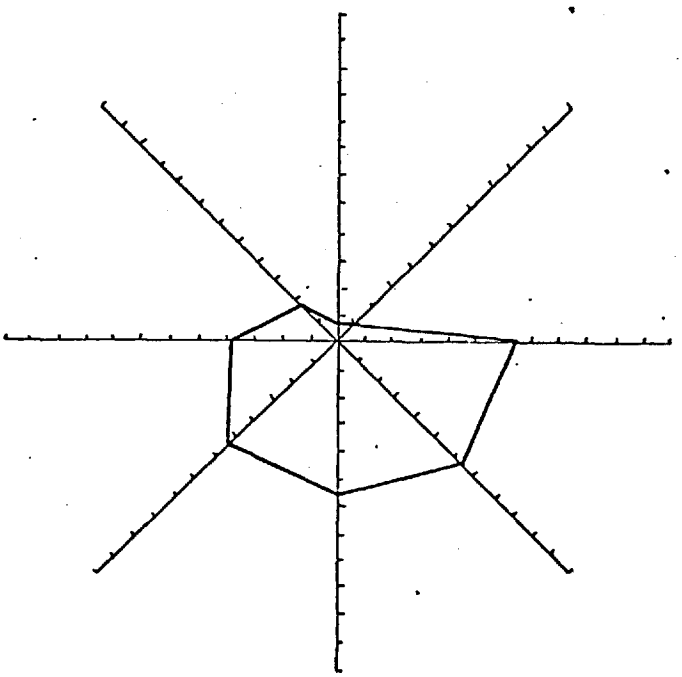
Sodium chloride level - 0.65%



Sodium chloride level - 1.3%



Sodium chloride level - 2.5%



Sodium chloride level - 5%

Salicornia ramosissima

Figure 6.39

1973). In addition, other fundamental metabolic process in halophytes such as protein synthesis are inhibited by salt (Hall and Flower 1973). Protein synthesis and related processes could occur in the palisade cells illustrating the need for lower salt concentrations in the palisade cells. Austenfeld (1974) found that nitrate reductase (the key enzyme of nitrate metabolism) was inhibited by higher concentration of sodium chloride (250mm), both in vivo and in vitro. Albert (1975), pointed out that due to constant salt intake in *Salicornia*, the water content drops continuously until the plants die. This in part may explain the reduction of the two measured maximum widths of the fertile segment (A and B in Figure 3.14).

Webber et al. (1977) found *Salicornia pacifica* able to stand high concentrations of salt, due to its cells ability to pigeon hole the salt into the central membrane bound vacoule, thus protecting the salt sensitive organelles. He added that when the vacuolar salt concentration rises until it becomes intolerable and the surrounding tissues, no longer able to contain it, collapses and dies, it leaves only the lifeless conducting tissue to maintain the plant's continuity.

Generally from the above discussion probably it can be concluded that the ability of *Salicornia* spp. to tolerate such high concentrations of sodium chloride may be similar to many other halophytes. This is due to the spatial separation of the salt from the enzymes and other salt sensitive organalles, as the elemental analyses of *Salicornia* shoots indicate that the root does not exclude salt or its movements into the shoot tissue (Hansen and Webber 1975).

6.4 Development of betacyanin in *Salicornia*:-

The genus *Salicornia*, being a member of the Centrospermae, produces

red violet pigments called betacyanins, formerly known as nitrogenous anthocyanins (see Mabry et al, 1962 and Shichi 1975). The betacyanins and the betaxanthins occur in the cell sap (of the vacuoles) and thus belong to chymochromes (Dreiding 1961). Schichi (1975) concluded that the principal structure of the violet coloured pigment in his *Salicornia herbacea* was betanidins - 5 - O - [2 - O - (β - D glucopyranosyl uronic acid)] - β - D - glucopyranoside.

Salicornia spp. usually develop this red violet pigment at the end of their flowering periods and it increases in quantity as the seeds mature. Quite often some plants become completely red at the end of their life cycle. Its actual distribution within the plant varies, it could be found in the perianth or it may be present as pink purple spots, in a mosaic, along the terminal spike. On the other hand it may be seen as a flush over the entire terminal spike or on the plant as a whole, or it may be confined to the apical parts of the plant only. This variation in red colouring between the different groups of the genus, in which we are concerned, has been used as an additional taxonomic character. For example Oliver (1907) in differentiating between his *S. herbacea* and *S. radicans* referred to them as a red and a green form respectively. Similarly it has been used by most workers on the taxonomy of this genus, e.g. Willmott (1939), Tutin (1953), Hambler (1954), Ball and Tutin (1959), Butcher (1961), Scott (1977). Dalby (1962) related the presence and absence of this pigment in various European species of *Salicornia* with the chromosome number of the species. He found that betacyanin was almost restricted to the diploids, though it does occur in tetraploids to a more limited extent.

The results of the present observations on the development of

Table 6.12 Shows the development of betacyanin in the three types of *Salicornia* in the nitrogen, phosphorus and sodium chloride treatments.

1. Nitrogen treatment:-

	4n*				4n				2n			
Salicornia type/ nitrogen levels Colour grade	*S. dolichostachya* (A)				*S. nitens* (B)				*S. ramosissima* (C)			
	5ppm	15ppm	45ppm	135ppm	5ppm	15ppm	45ppm	135ppm	5ppm	15ppm	45ppm	135ppm
-	100%	100%	100%	100%	0.0	0.0	0.0	33.3%	0	0	0	0
- - +	0	0	0	0	0.0	0.0	0.0	0	0	0	0	0
- +	0	0	0	0	0.0	0.0	100%	66.7%	0	0	26.7%	100%
+	0	0	0	0	100%	100%	0	0	0	0	73.3%	0
+ +	0	0	0	0	0	0	0	0	0	100%	0	0
+ + +	0	0	0	0	0	0	0	0	100%	0	0	0

2. Phosphorus treatment:-

Salicornia type/ phosphorus levels Colour grade	*S. dolichostachya* (A)				*S. nitens* (B)				*S. ramosissima* (C)			
	2ppm	4ppm	8ppm	16ppm	2ppm	4ppm	8ppm	16ppm	2ppm	4ppm	8ppm	16ppm
-	100%	100%	100%	100%	83%	33.33%	100%	0	0	0	0	0
- - +	0	0	0	0	0	66.7%	0	10	0	0	0	0
- +	0	0	0	0	16.7%	0	0	90	6.7%	10%	0	0
+	0	0	0	0	0	0	0	0	93.3%	90%	100	100
+ +	0	0	0	0	0	0	0	0	0	0	0	0
+ + +	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.12 (Continued)

3. Sodium chloride treatment

Salicornia type/ Sodium chloride levels Colour grade	4n *S. dolichostachya* (A`)				4n *S. nitens* (B`)				2n *S. ramosissima* (C`)			
	0.65%	1.3%	2.5%	5%	0.65%	1.3%	2.5%	5%	0.65%	1.3%	2.5%	5%
-	100%	100%	100%	100%	100	100	0	0	80%	100	90	0
- - +	0	0	0	0	0	0	100	100	0	0	10	0
- +	0	0	0	0	0	0	0	0	20%	0	0	0
+	0	0	0	0	0	0	0	0	0	0	0	100
+ +	0	0	0	0	0	0	0	0	0	0	0	0
+ + +	0	0	0	0	0	0	0	0	0	0	0	0

Key of the colour grade for the distribution of betacyanin in the superficial tissues of *Salicornia* plants.

- \- = Observed betacyanin absent.
- \- - + = Betacyanin observed as a small spot diffused in the perianth of few fertile segments.
- \- + = Observed betacyanin cover most of the perianth and in most of the fertile segments.
- \+ = Betacyanin can be found in different parts of the fertile segment.
- \+ + = Betacyanin observed in most of the fertile segments of the terminal spike.
- \+ + + = Betacyanin can be observed in all the fertile segments of the terminal spike and other parts of the plant.

* The chromosome number were determined from the root tips of germinated seeds using the technique described in chapter III.

betacyanin in the plants of the three types of *Salicornia (S. dolichostachya, S. nitens,* and *S. ramosissima)* are presented in Table 6.12. These are in the forms of percentages for each of the adopted scale (Table 6.12) for the visual distribution of betacyanin in the superficial tissues of the plants grown under the different treatments of nitrogen, phosphorus, and sodium chloride.

As pointed out earlier in this chapter, in the 1976 culture experiments the betacyanin coloration had developed very clearly in the plants belonging to *S. ramosissima* type and *S. nitens* type, (Table 6.12). The maximum coloration was developed in 5 p.p.m. nitrogen level. The colour concentration decreased as the dosage of nitrogen increased. At 135 p.p.m. nitrogen if any red colour developed, it was in a form of small pink spots diffused in the perianth. Though *S. nitens* developed red coloration it was not as intense as in the case of *S. ramosissima*. However, in plants of *S. dolichostachya* no red coloration was observed under any of the experimental growth conditions, (Table 6.12). From the Table it seems also that phosphorus deficiency and high concentrations of sodium chloride may stimulate the development of the red coloration in the superficial tissue of the plant, but this coloration is not well developed, as in the case with nitrogen deficiency.

Betacyanin has not been observed in any of the *Salicornia* plants grown in full nutrient solution. Similarly in the 1974 culture experiments (Chapter III) none of the cultured group developed the red coloration, even in the progeny of plants whose parents had developed the colour in the field. In such progeny the pink coloration was observed only in some of the plants as a small pink purple spot in the perianth. However, this is in agreement with Dalby's (1965) observation that in culture there is a tendency for the coloration to be reduced in quantity

and perhaps even to be absent, though present in the parent. In addition, in the progeny of *S. ramosissima* grown in full nutrient solution and under an increased light intensity (Chapter V), the development of the red coloration was not observed.

From the above discussion, it may be concluded that the development of betacyanin in *Salicornia* can be stimulated by nutrient deficiency and in particular by nitrogen deficiency. It seems this in part, may explain the red coloration of most of *Salicornia* spp. found in the upper marsh, which is usually under nitrogen stress. In addition, the results of this experiment clearly show that the three selected types of *Salicornia* differ in their ability to synthesis or to develop betacyanin under the conditions which favours its developments. It seems that this is in agreement with Dalby's observations (1962), that betacyanin are more frequent in the diploids than in the tetraploids.

6.5 Assessment of value of certain taxonomic characters:-

In the present study an attempt was made to express the limit and the variability within and between the different types of *Salicornia* in quantitative terms. Only the quantitative characters were considered suitable for further statistical analysis. These characters were considered to give, after analysis, desirable and taxonomically meaningful statistics. This approach is as objective as possible and simple in application. It is important that the characters chosen are not merely different expressions of the same gene, but show some independent variation. Because *Salicornia* is so specialised morphologically, students of the genus are forced to employ a mixture of purely vegetative characters, and reproductive characters of the much reduced terminal inflorescence. Vegetative characters, however, are generally believed

to be plastic in response to environmental change. This was tested by the application of the particular kind of analysis of variance described by Goodman and Paterniani (1969).

Goodman and Paterniani's analysis of variance is essentially the ratio of variance due to genotype : variance due to environmental variation + an error component. In the present study, environmental factors were changed one at a time (nitrogen, phosphorus, sodium chloride), and an analysis of variance carried out for each of a selected range of characters. Small values of the ratio may indicate a lack of stability of character expression relative to the actual sizes of the observable differences among races. It is necessary to point out that whilst the environmental factors are varied one by one as experimental treatments, in nature they may vary simultaneously and may well interact on the final phenotype.

The characters analysed can be placed in three groups:-

1.- Vegetative morphological characters.

2.- External measurements of the fertile segment components in the terminal spike.

3.- The fertile segment ratios, derived from B. These ratios are measurements of shape and are often believed to be more reliable taxonomically than linear dimensions. The ratios are all expressed as 100. x/y, where x and y are means of linear measurements referred to in B. An Arcsine transformation was applied to the ratio indices before the statistical tests were carried out.

6.5.1 Results:-

The results of the analysis of variance are summarised in

Tables 6.13-6.15, with the full numerical data being presented in the appendix (Tables A6.12-A6.14). All the calculations are based upon the growth experiment of 1976.

6.5.1.1. Vegetative morphological characters:-

The results of the analysis of variance in Table 6.13 show that the morphological characters shoot length, root length, total number of primary branches from the main axis, number of sterile segments in the main axis, length of the lowermost branch from the main axis, and the terminal spike length show a significant response to both the nitrogen levels and the genotypes. However, the characters, the angle of branching both of the uppermost branch and the lowermost branch from the main axis, and perhaps the number of the fertile segments in the terminal spike are not affected by either of these factors. The length of the uppermost branch from the main axis is not influenced by the nitrogen levels, but it responds significantly to the genotype. According to the variance ratio values, the measured vegetative characters under the nitrogen treatment can be ranked as follows, (the numbers are the variance ratio values):- root length, 5.92 > length of the uppermost branch, 1.38 > shoot length, 0.97 > total number of the primary branches from the main axis, 0.88 > number of sterile segments in the main axis, 0.86 > terminal spike length, 0.65 > angle of the lowermost branch with main axis, 0.63 > length of the lowermost branch, 0.49 > angle of the uppermost branch with the main axis, 0.05 > number of fertile segments in the terminal spike. 0.02.

In contrast, all the measured vegetative characters are not influenced by the phosphorus levels. Shoot length, root length, total number of the primary branches from the main axis, number of the sterile segments in the main axis, length of the uppermost branch, and terminal spike length, show significant differences due to *Salicornia* type. However, according to the variane ratio values the morphological

Table 6.13 Result of analysis of variance of vegetative morphological characters in nitrogen, phosphorus and sodium chloride treatments.

	Nitrogen treatment	Phosphorus treatment	Sodium chloride treatment
1. Shoot length			
Treatment	***	NS	***
Race	***	**	NS
2. Root length			
Treatment	**	NS	NS
Race	***	**	NS
3. Total number of primary branches from the main axis.			
Treatment	***	NS	**
Race	***	**	**
4. Number of sterile segments in the main axis.			
Treatment	***	NS	**
Race	***	**	**
5. Terminal spike length.			
Treatment	**	NS	***
Race	**	**	NS
6. Number of the fertile segments in the terminal spike.			
Treatment	*	NS	***
Race	NS	NS	NS

Table 6.13 (Continued)

	Nitrogen treatment	Phosphorus treatment	Sodium chloride treatment
7. Length of the lowermost branch from the main axis.			
Treatment	**	NS	*
Race	**	NS	NS
8. Length of the uppermost branch from the main axis.			
Treatment	NS	NS	***
Race	**	*	**
9. Angle of the uppermost branch with the main axis.			
Treatment	NS	NS	NS
Race	NS	NS	NS
10. Angle of the lowermost branch with the main axis.			
Treatment	NS	NS	NS
Race	NS	NS	NS

NS P > .05 (not significant)

* P 0.05 to :01

** P 0.01 to 0.001

*** P < .001

characters under phosphorus treatment can be ranked as follows:- shoot length, 2.94 > root length, 2.34 > terminal spike length, 2.24 > total number of primary branches, 1.18 > number of sterile segments in the main axis, 1.18 > angle of the upper branch with the main axis, 1.08 > the uppermost branch length, 0.87 > the lowermost branch length 0.56 > number of fertile segments in the terminal spike, 0.27 > angle of the lowermost branch with the main axis, -.03

In the sodium chloride treatment, Table 6.13 shows that, the vegetative characters shoot length, total number of the primary branches, number of the sterile segments in the main axis, terminal spike length, number of fertile segments in the terminal spike, and the length of the lowermost branch and the uppermost branch from the main axis prove to be strongly affected by the levels of sodium chloride. Furthermore the characters total number of the primary branches, number of sterile segments in the main axis, and the length of the uppermost branch are strongly discriminative among the selected types of *Salicornia* (i.e. races). However, the characters root length, the angle of branching of the uppermost branch and the lowermost branch with the main axis are not affected either by the salinity levels or by the genotype. The morphological characters in the sodium chloride treatment can be arranged as follows in relation to their variance ratio values:- number of sterile segments in the main axis, 0.55 > total number of the primary branches from the main axis 0.55 > angle of the lowermost branch with the main axis, 0.44 > length of the uppermost branch from the main axis 0.28 > terminal spike length, 0.17 > length of the lowermost branch from the main axis, 0.13 > shoot length, 0.02 > number of fertile segments in terminal spike, 0.01 > angle of the uppermost branch with the main axis, -0.08 > root length, -0.28.

6.5.1.2. External measurements of the fertile segments:-

Table 6.14, shows that the majority of the fertile segment characters; A, B, C, D, E, F and D-F (see Figure 3.14) are not affected either by

Table 6.14 Result of analysis of variance of fertile segment components in nitrogen, phosphorus and sodium chloride treatments.

	Nitrogen treatment	Phosphorus treatment	Sodium chloride treatment
1. Maximum width of the 2nd segment from the base (A)			
Treatment	NS	NS	NS
Race	NS	NS	*
2. Maximum width of the 4th segment from the base. (B)			
Treatment	NS	NS	*
Race	NS	NS	**
3. Minimum width of the 3rd segment (C)			
Treatment	NS	NS	NS
Race	NS	NS	*
4. Length of the segment (D)			
Treatment	NS	NS	*
Race	NS	NS	***
5. Total length of the central flower. (E)			
Treatment	NS	NS	*
Race	NS	NS	***

Table 6.14 (Continued)

	Nitrogen treatment	Phosphorus treatment	Sodium chloride treatment
6. Observed length of the central flower. (F)			
Treatment	NS	NS	NS
Race	NS	NS	***
7. Observed length of the lateral flower. (G)			
Treatment	*	NS	NS
Race	NS	NS	***
8. Covered part of the central flower (E-F)			
Treatment	*	NS	NS
Race	*	NS	**
9. Distance between the apex of the central flower and the segment top (D-F)			
Treatment	NS	NS	NS
Race	NS	NS	NS

NS P > .05 (not significant)

* P .05 to .01

** P .01 to .001

*** P < .001

the nitrogen levels or by the race. Character G is affected by the nitrogen level but not by the genotype. However, the character E-F is influenced by the nitrogen variation and by the genotype just above the non-significant level. According to the variance ratio values under the nitrogen treatment the fertile segment characters can be ranked as:- E-F, 0.60 > A, 0.14 > B, 0.10 > E, 0.02 > C, -0.005 > G, -0.03 > F, -0.04 > D-F, -0.04 > D, -0.05.

With the phosphorus treatment all the fertile segment components do not show significant differences either in relation to the phosphorus levels or to the differences between the genotypes. According to the variance ratio values these can be arranged as:- B, 0.65 > A, 0.54 > E, 0.48 > C, 0.36 > E-F, 0.28 > F, 0.04 > D, -0.03 > D-F, -0.03 > G, -0.16.

Table 6.14 shows that, with the sodium chloride treatment, most of the fertile segment characters are not affected by the salinity level, however, the characters B, D, and E show an effect just above the significance level. All the fertile segment characters, apart from D-F, are discriminative in response to *Salicornia* types. In relation to their variance ratio values, these characters can be ranked as:- B, 6.41 > F, 3.40 > D, 2.93 > E, 2.40 > E-F, 1.93 > A, 0.94 > B, 0.93 > C, 0.78 > D-F, -0.19.

6.5.1.3- Fertile Segment indices:-

From Table 6.15 it appears that all the calculated fertile segment indices, are not affected by the nitrogen level. However, the indices $\frac{E}{D}$ and $\frac{E-F}{E+D-F}$ show a slight response to nitrogen factor. All the listed fertile segment indices are not discriminative in response to the genotype. According to the variance ratio values, these indices under

Table 6.15 Result of analysis of variance of fertile segment indices in nitrogen, phosphorus and sodium chloride treatments.

	Nitrogen treatment	Phosphorus treatment	Sodium chloride treatment
1. The minimum width of the segment/Maximum width of the segment. $(\frac{C}{B})$			
Treatment	NS	NS	NS
Race	NS	NS	NS
2. Length of the segment/ Maximum width of the segment. $(\frac{D}{B})$			
Treatment	NS	NS	NS
Race	NS	NS	NS
3. Observed length of the lateral flower/Observed length of the central flower. $(\frac{G}{F})$			
Treatment	NS	NS	NS
Race	NS	NS	*
4. Total length of the central flower/length of the segment. $(\frac{E}{D})$			
Treatment	*	NS	**
Race	NS	NS	**
5. Observed length of the lateral flower/length of the segment. $(\frac{G}{D})$			
Treatment	NS	NS	NS
Race	NS	NS	**

Table 6.15 (Continued)

	Nitrogen treatment	Phosphorus treatment	Sodium chloride treatment
6. Observed length of the central flower/length of the segment. $(\frac{F}{D})$			
Treatment	NS	NS	NS
Race	NS	NS	*
7. Distance between the apex of the central flower and the segment top/total length of the central flower + distance between the apex of the central flower and the segment top. $(\frac{D-F}{E+D-F})$			
Treatment	NS	NS	**
Race	NS	NS	**
8. Covered part of the central flower/total length of the central flower + distance between the apex of the central flower and the segment top. $(\frac{E-F}{E+D-F})$			
Treatment	*	NS	NS
Race	NS	NS	***
9. Minimum width of the segment + length of the segment/ 2 x maximum width of the segment. $(\frac{C+D}{2B})$			
Treatment	NS	NS	NS
Race	NS	NS	NS

Table 6.15 (Continued)

	Nitrogen treatment	Phosphorus treatment	Sodium chloride treatment
10. Maximum width of the 2nd segment from the base + maximum width of the 4th segment from the base/ 2 x minimum width of the 3rd segment from the base. $(\frac{A+B}{2C})$			
Treatment	NS	NS	NS
Race	NS	NS	NS
11. Total length of the central flower/total length of the central flower - distance between the apex of the central flower and the segment top. $(\frac{E}{E-F})$			
Treatment	NS	NS	NS
Race	NS	NS	**

NS P > .05 (not significant)

* P .05 to .01

** P .01 to 0.001

*** P < .001

nitrogen treatment may be arranged as:- $\frac{E-F}{E+D-F}$, 0.33 > $\frac{E}{D}$, 0.10 > $\frac{A+B}{2C}$ 0.5 > $\frac{F}{D}$, 0.03 > $\frac{G}{D}$, 0.04 > $\frac{C}{B}$, -0.04 > $\frac{G}{F}$, -0.06 > $\frac{C+D}{2B}$, -0.07 > $\frac{E}{E-F}$, 0.07 > $\frac{D}{B}$ -0.09 > $\frac{D-F}{E+(D-F)}$, -0.13.

With the phosphorus treatment none of the fertile segment indices show significant variation, either in response to the phosphorus treatment, or to the *Salicornia* type. However, according to their variance ratio values, those characters can be ranked as follows:- $\frac{E}{D}$, 0.95 > $\frac{A+B}{2C}$, 0.59 > $\frac{F}{D}$, 0.58 > $\frac{C}{B}$, 0.38 > $\frac{G}{D}$, 0.31 > $\frac{C+D}{2B}$, 0.30 > $\frac{G}{F}$, 0.26 > $\frac{D}{B}$, 0.23 > $\frac{E-F}{E+D-F}$, -0.02 > $\frac{E}{E-F}$, -0.20 > $\frac{D-F}{E+(D-F)}$, -0.62.

Table 6.15 shows that all the fertile segment indices, apart from the ratios $\frac{E}{D}$ and $\frac{D-F}{E+D-F}$, are not affected by the salinity levels. However, the indices $\frac{G}{F}$, $\frac{E}{D}$, $\frac{G}{D}$, $\frac{F}{D}$, $\frac{D-F}{E+D-F}$, $\frac{E-F}{E+D-F}$ and $\frac{E}{E-F}$ appear to be influenced by the genotype. According to the variance ratio values, the fertile segment indices under sodium chloride may be arranged as:- $\frac{G}{D}$, 3.04 > $\frac{E-F}{E+D-F}$, 2.59> $\frac{E}{E-F}$, 2.12 > $\frac{E}{D}$, 1.46 > $\frac{G}{F}$, 1.19 > $\frac{D-F}{E+(D-F)}$, 0.70 > $\frac{F}{D}$, 0.62 > $\frac{A+B}{2C}$, -0.02 > $\frac{C}{B}$, -0.07 > $\frac{C+D}{2B}$, -0.16 > $\frac{D}{B}$, -0.19.

6.5.2 General conclusions:-

Experimental nitrogen levels have a highly significant effect on most of the vegetative characters, and similarly the selected genotypes responded significantly differently. The phosphorus levels effect on these characters is just above the non-significant point, but the selected genotypes again responded differently. Whilst sodium chloride shows more variation and generally exerts a significant effect on the morphology, most of the vegetative characters show no response between the genotypes. However, from the presented data, the vegetative characters, total number of the primary branches from the main axis, number of sterile segments in the main axis, and the length of

the uppermost branch from the main axis showed a significant response due to the genotypes under the experimental levels of nitrogen, phosphorus and sodium chloride. While the angle of the uppermost branch and the lowermost branch with the main axis and perhaps the number of fertile segments in the terminal spike appear to be less influenced by such factors.

The fertile segment components generally showed no effect to the experimental treatments, and in particular to nitrogen and phosphorus levels. Almost all the fertile segment characters show no-significant response due to the genotype under the nitrogen and phosphorus treatment. However, under sodium chloride treatments the characters B, D, E, F, and G show a significant difference between the genotypes.

Fertile segment ratios also appear not to be affected by the experimental levels of nitrogen, phosphorus and sodium chloride. Furthermore these indices also do not show a significant response to the differences between the genotype under nitrogen and phosphorus treatments whilst under the sodium chloride treatment only the ratios $\frac{E}{D}$, $\frac{G}{D}$, $\frac{D-F}{E+D-F}$ and $\frac{E-F}{E+D-F}$ show a significant response between genotypes.

6.6. Taxametric studies:-

For this purpose the selfed progeny of eight *Salicornia* plants belonging to *S. dolichostachya* group (3 plants), *S. nitens* (2 plants) and *S. ramosissima* (3 plants) were selected (Table 6.16). The progeny were cultured in the complete nutrient solution in conjunction with the nutrient experiment of 1976 at a sodium chloride concentration of 2.5 percent.

Table 6.16 The *Salicornia* types and the mean values for the variables used in the taxametric study.

Salicornia groups / Characters	*S. dolichostachya*			*S. nitens*		*S. ramosissima*		
	decumbant	erect	erect	erect	erect	strict	more spreading	still more spreading
I. Vegetative Characters								
1. Shoot length	26.95	24.98	18.29	25.47	29.16	26.67	25.100	30.69
2. Root length	7.92	10.80	7.80	9.60	10.50	7.54	8.52	8.68
3. Total number of the primary branches from the main axis.	38.40	36.57	35.60	50.67	46.73	43.53	44.33	44.53
4. Number of sterile segments in the main axis.	19.20	18.13	17.67	25.27	23.09	21.40	22.25	22.33
5. Length of the lowermost branch from the main axis.	7.30	9.17	8.01	9.17	12.58	11.89	9.93	8.93
6. Length of the uppermost branch from the main axis.	1.09	1.05	0.78	1.13	0.87	0.59	0.50	0.60
7. Terminal spike length	1.55	1.13	1.16	1.47	1.16	0.66	0.43	0.85
8. Number of fertile segments in the terminal spike.	5.87	5.00	4.60	7.87	5.36	3.93	2.18	5.13

Table 6.16 (Continued)

Salicornia groups. / Characters	*S. dolichostachya*			*S. nitens*		*S. ramosissima*		
	decumbant	erect	erect	erect	erect	strict	more spreading	still more spreading
9. Angle of the uppermost branch with the main axis.	52.00°	25.67°	36.67°	32.22°	49.55°	31.00°	34.58°	61.43°
10. Angle of the lowermost branch with the main axis.	40.00°	26.67°	32.00°	42.78°	55.46°	21.33°	30.00°	46.15°
II Fertile segment components								
1. Maximum width of the 2nd segment from the base (A).	3.81	3.45	3.52	3.60	3.53	2.97	2.99	3.02
2. Maximum width of the 4th segment from the base (B).	3.49	3.28	3.36	2.98	3.46	2.33	2.60	2.83
3. Minimum width of the 3rd segment (C).	2.75	2.23	2.56	2.45	2.46	1.86	1.99	2.11
4. Length of the segment (D).	2.27	2.06	2.22	1.48	1.56	1.15	1.40	1.62
5. Total length of the central flower (E).	2.30	2.53	2.26	1.83	2.11	1.90	2.00	2.11
6. Observed length of the central flower (F)	1.99	2.04	1.86	1.53	1.47	1.15	1.30	1.43

Table 6.16 (Continued)

Characters / *Salicornia* groups	*S. dolichostachya*			*S. nitens*		*S. ramosissima*		
	decumbant	erect	erect	erect	erect	strict	more spreading	still more spreading
7. Observed length of the lateral flower (G).	1.11	1.01	1.34	0.73	0.65	0.57	0.80	0.93
8. Covered part of the central flower (E-F).	0.31	0.49	0.40	0.29	0.64	0.75	0.70	0.68
9. Distance between the apex of the central flower and the segment top (D-F)	0.28	0.03	0.36	-0.58	0.90	0.00	0.10	0.19
III Fertile Segment indices								
1. The minimum width of the segment/ maximum width of the segment $(\frac{C}{B})$	79.0	72.0	76.	82.0	71.0	79.0	77.0	75.0
2. Length of the segment/maximum width of the segment $(\frac{D}{B})$	65.0	64.0	66.0	49.0	45.0	56.0	54.0	57.0
3. Observed length of the lateral flower/Observed length of the central flower $(\frac{G}{F})$	56.0	50.3	72.0	48.0	44.0	49.0	62.0	65.0
4. Total length of the central flower/ Length of the segment $(\frac{E}{D})$.	101.0	120.9	102.0	124.0	135.0	144.0	143.0	130.0
5. Observed length of the lateral flower/Length of the segment $(\frac{G}{D})$	49.0	49.0	60.0	49.0	42.0	43.0	57.0	57.0

Table 6.16 (Continued)

Characters	*Salicornia* groups	*S. dolichostachya*		*S. nitens*			*S. ramosissima*	
		decumbant	erect	erect	erect	erect	strict	more spreading	still more spreading
6.	Observed length of the central flower/Length of the segment $(\frac{F}{D})$	88.3	96.4	84.0	104.	94	87.3	93.	88.3
7.	Distance between the apex of the central flower and the segment top/ total length of the central flower + distance between the apex of the central flower and the segment top $(\frac{D-F}{E+D-F})$	10.8	2.89	13.7	-	4.0	-	5.0	8.3
8.	Covered part of the central flower /total length of the central flower + distance between the apex of the central flower and the segment top. $(\frac{E-F}{E+D-F})$	12.0	19.7	15.0	17.0	29.0	39.0	33.0	29.0
9.	Minimum width of the segment + length of the segment/ 2 x maximum width of the segment $\frac{C+D}{2B}$	72.0	65.8	71.0	66.0	58.0	65.0	65.0	66.0
10.	Maximum width of the 2nd segment from the base + maximum width of the 4th segment from the base/ 2 x minimum width of the 3rd segment from the base $(\frac{A+B}{2C})$	133.0	143.0	134.0	134.0	142.0	142.0	140.0	139.0

Table 6.16 (Continued)

Characters — *Salicornia* groups	*S. dolichostachya*			*S. nitens*		*S. ramosissima*		
	decumbant	erect	erect	erect	erect	strict	more spreading	still more spreading
11. Total length of the central flower /total length of the central flower - distance between the apex of the central flower and the segment top. $(\frac{E}{E-F})$	740.0	493.0	565.0	625.0	329.0	250.0	286.0	310.0

In the previous section (6.5), the majority of the characters tested i.e. vegetative, fertile segment components and fertile segment ratios responded significantly in conjunction with the genotypes (i.e. races) under the nitrogen and sodium chloride treatments. In the present investigation 15 mature plants were measured for each progeny line, each plant being scored for the 30 variables examined in the nutrient studies. These characters are listed with their mean values, for each of the selected types in Table 6.15.

Then these variables for the eight progeny lines were ordinated by principal components analysis (see Chapter IV, 4.7). As pointed out earlier such a technique is useful in evaluating the relationships between closely related groups of plants or animals. Although it is true that the technique of principal components analysis is not free from criticism and is known to introduce some distortion in the display of relationships, the method has proved valuable in many studies in revealing major groupings and general trends.

The present analysis was applied to detect how far these progeny lines or types remain distinct in terms of these variables under uniform growth conditions.

The result of the analysis is given in Figure 6.40. Viewed as a whole the eight progeny lines form three well separated groups. Axis one separates *S. ramosissima* group from *S. dolichostachya* group. This separation is probably due to the following characters; total number of primary branches from the main axis, number of sterile segments in the main axis, length of the uppermost branch from the main axis, the terminal spike length, the fertile segment components: A, B, C, E, F,

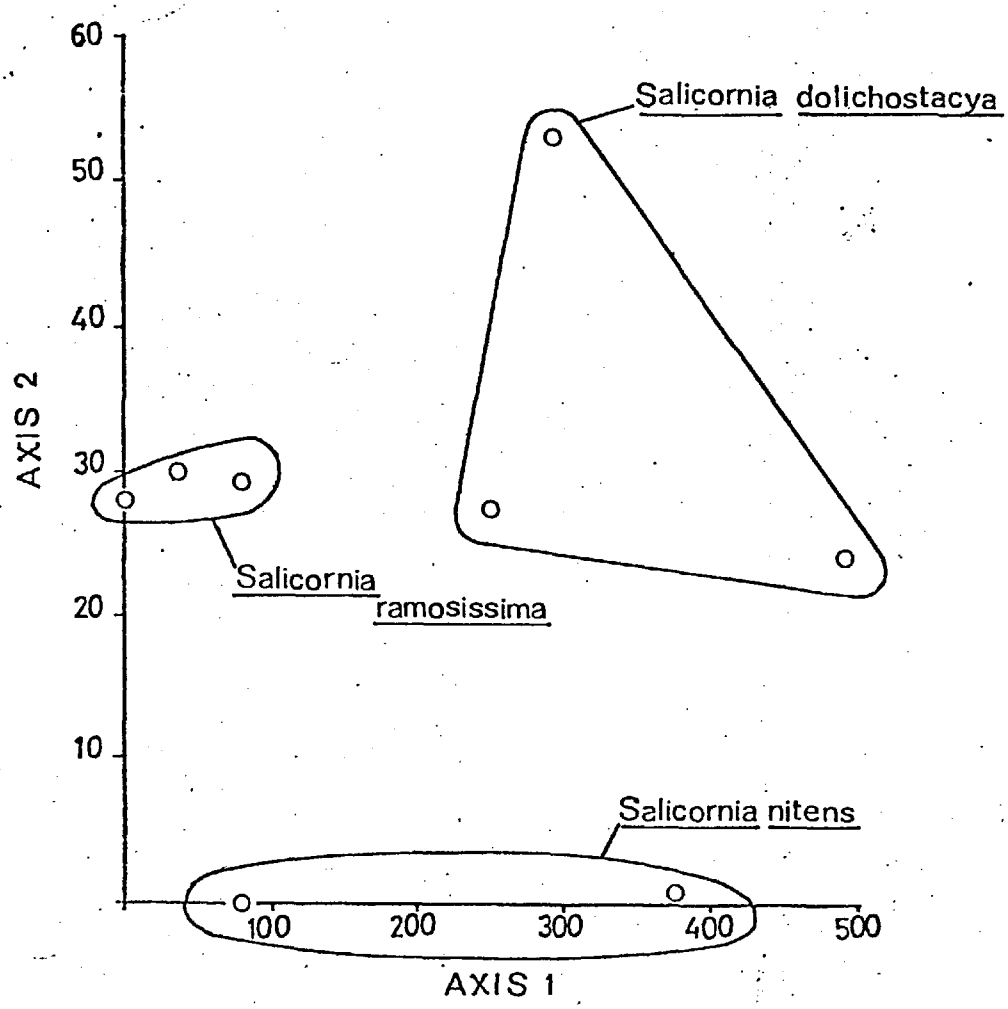


Figure 6.40 : Diagram shows the scatter plots of the 8 types of *Salicornia* analysed by Pricipal Component Analysis(Based on their morphological characters). The continuous line encloses the same named species.

E-F, and the fertile segment ratios $\frac{D}{B}$, $\frac{E-F}{E+(D-F)}$, $\frac{E}{E-F}$, as the mean values of these variables show marked differences between the types of each group (Table 6.16). The *Salicornia nitens* group shows an overlap between the *S. ramosissima* group and *S. dolichostachya* group on axis one. However, this is to be expected since for most of the above characters *S. nitens* comes between *S. ramosissima* and *S. dolichostachya* (Table 6.16). Axis 2 separates the *S. nitens* group from both the *S. ramosissima* and the *S. dolichostachya* groups. It seems this is mainly due to the following characters, total number of primary branches from the main axis, number of fertile segments in the terminal spike, the fertile segment component D-F and the fertile segment ratios $\frac{D}{B}$, $\frac{G}{F}$.

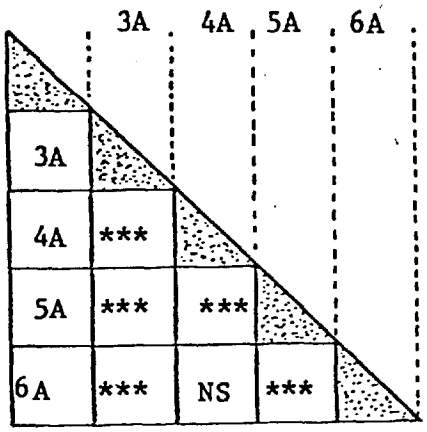
The figure shows also that within each group (or cluster on the ordination diagram), there is considerable scatter particularly for *S. dolichostachya* and *S. nitens*. However, this is probably due to the angle of branching between the uppermost branch with the main axis, and the lowermost branch with the main axis. Though probably not of great taxonomic significance, these characters nevertheless show great numerical variation.

Though such analyses were carried out on a limited number of *Salicornia* types, due to the high uniformity of the growth conditions, the evidence supports these three groups of *Salicornia* being regarded as distinct, at least statistically. However, the characters, number of sterile segments in the main axis, total number of primary branches from the main axis, length of the uppermost branch from the main axis and, probably, the terminal spike length, played an important role in the separation of these groups.

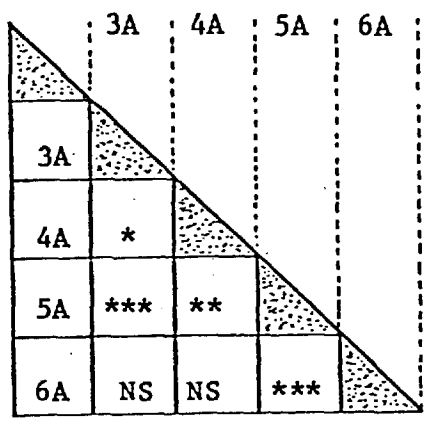
Figure 6.41 Shows the level of significance (t-test), between the four nitrogen levels for the measured vegetative characters of *Salicornia dolichostachya* (A).

NS	P >	.05	(not significant)
*	P	.05 to .01	
**	P	.01 to .001	
***	P <	.001	

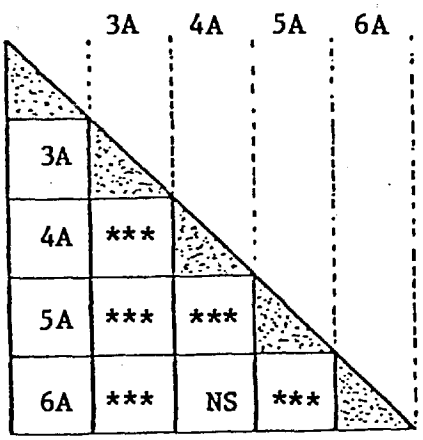
TANK NO.	:	Nitrogen level
3A	:	5 p.p.m.
4A	:	15 p.p.m.
5A	:	45 p.p.m.
6A	:	135 p.p.m.



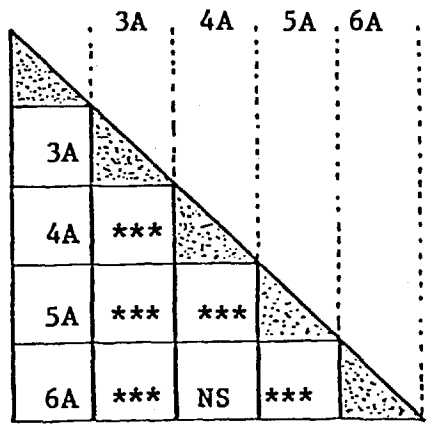
1. Shoot length



2. Root length

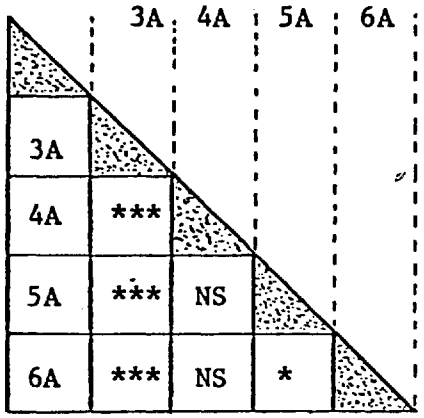


3. Total number of primary branches from the main axis.

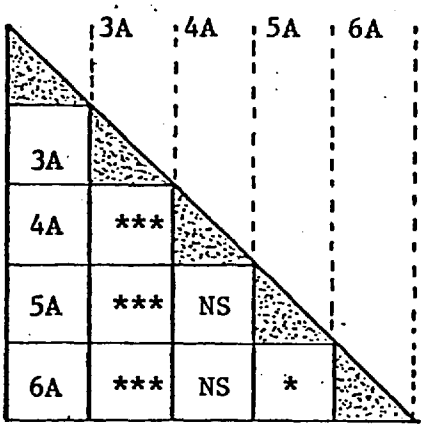


4. Number of sterile segments in the main axis.

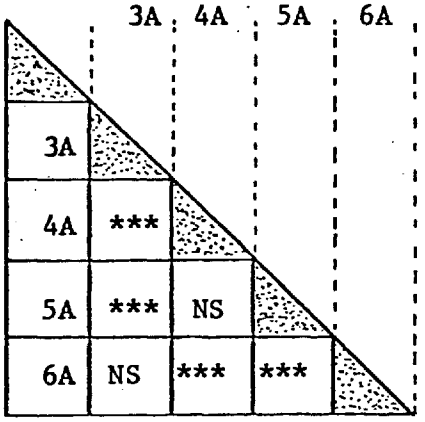
Figure 6.41 (Continued)



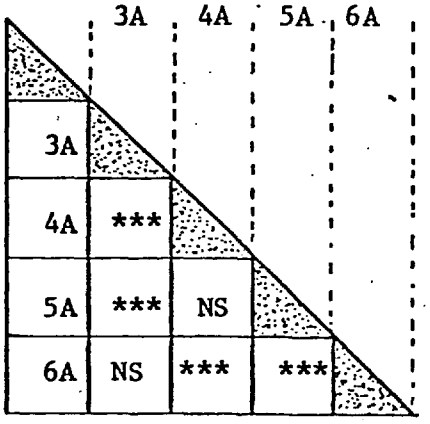
5. Length of lowermost branch from the main axis.



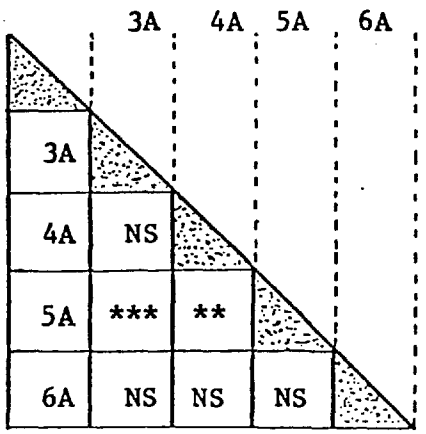
6. Length of uppermost branch from the main axis.



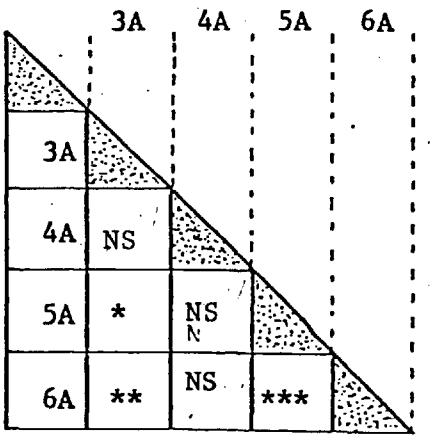
7. Terminal spike length.



8. Number of fertile segments in the terminal spike.



9. Angle of the uppermost branch with the main axis.

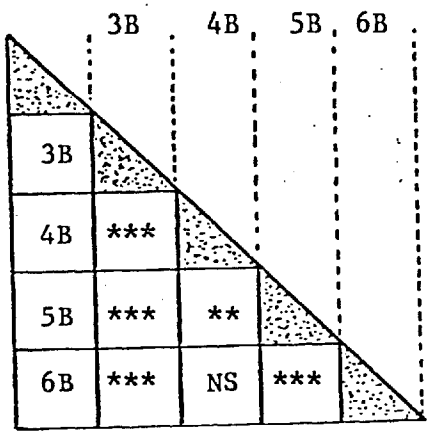


10. Angle of the lowermost branch with the main axis.

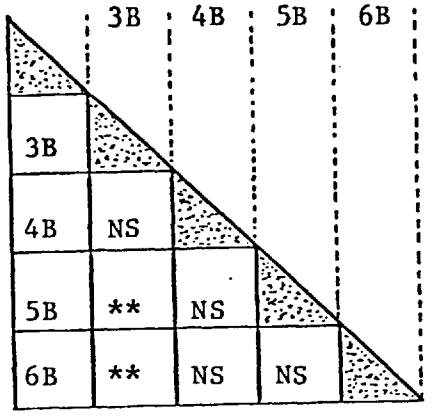
Figure 6.42 Shows the level of significance (t-test), between the four nitrogen levels for the measured vegetative characters of *Salicornia nitens* (B).

NS	P > .05	(not significant)
*	P	.05 to .01
**	P	.01 to .001
***	P <	.001

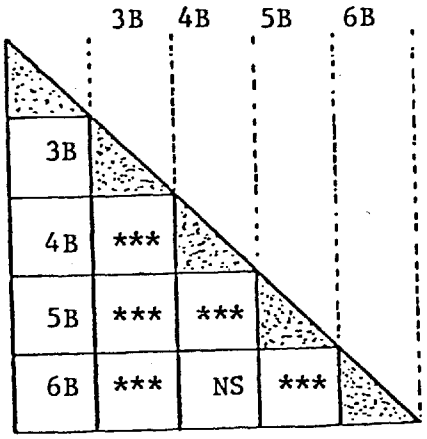
TANK NO.	:	Nitrogen level
3B	:	5 p.p.m.
4B	:	15 p.p.m.
5B	:	45 p.p.m.
6B	:	135 p.p.m.



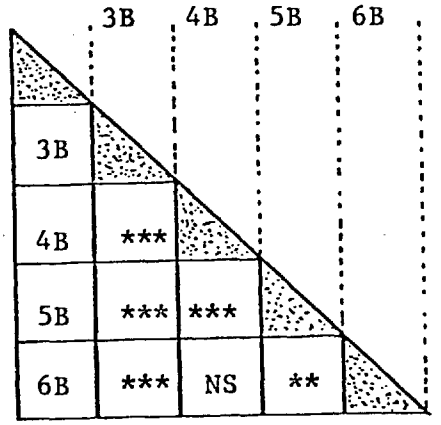
1. Shoot length



2. Root length.

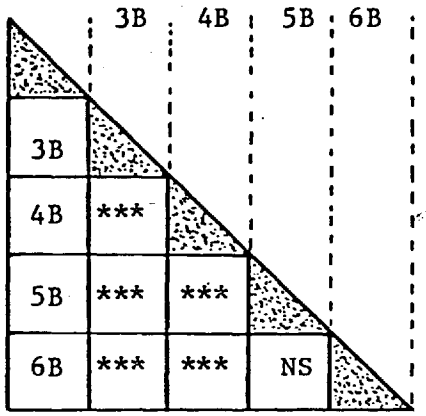


3. Total number of primary branches from the main axis.

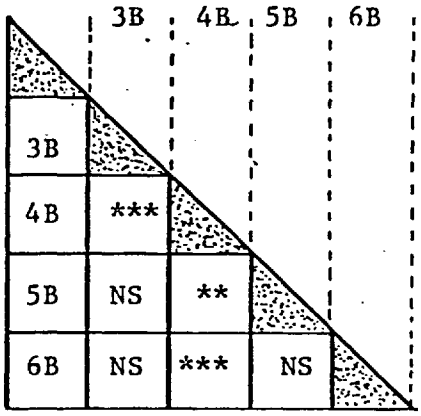


4. Number of sterile segments in the main axis.

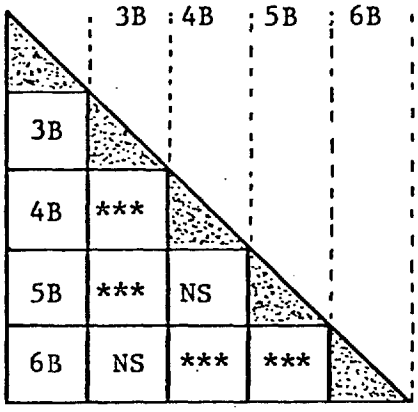
Figure 6.42 (Continued)



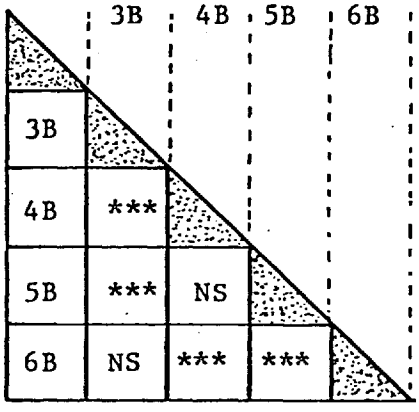
5. Length of lowermost branch from the main axis.



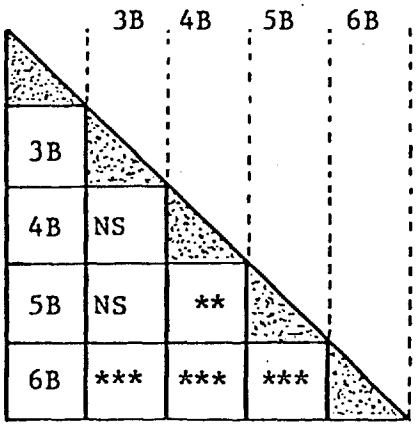
6. Length of uppermost branch from the main axis.



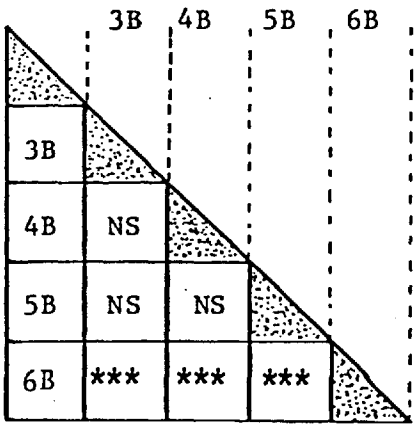
7. Terminal spike length.



8. Number of fertile segments in terminal spike.



9. Angle of the uppermost branch with the main axis.

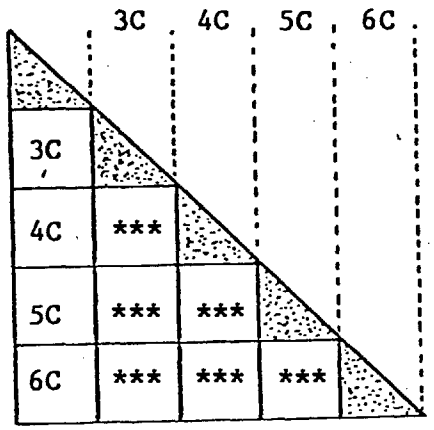


10. Angle of the lowermost branch with the main axis.

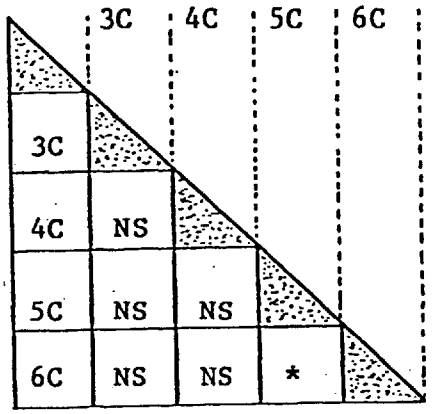
Figure 6.43 Shows the level of significance (t-test), between the four nitrogen levels for the measured vegetative characters of *Salicornia ramosissima* (C).

NS	P >	.05	(not significant)
*	P	.05 to .01	
**	P	.01 to .001	
***	P <	.001	

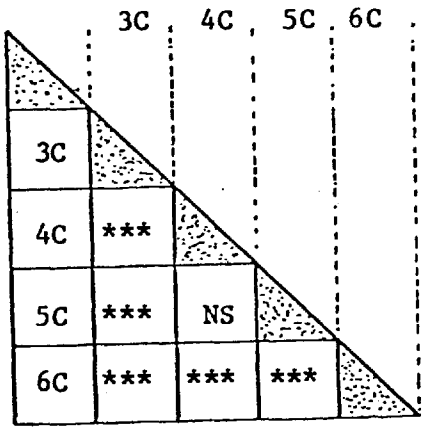
TANK NO.	:	Nitrogen level
3C	:	5 p.p.m.
4C	:	15 p.p.m.
5C	:	45 p.p.m.
6C	:	135 p.p.m.



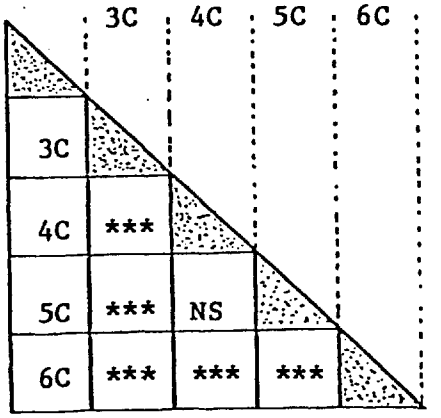
1. Shoot length



2. Root length.

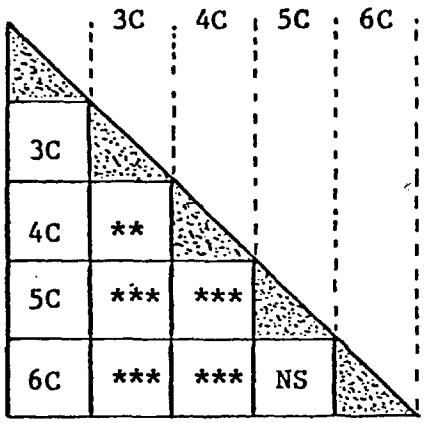


3. Total number of primary branches from the main axis.

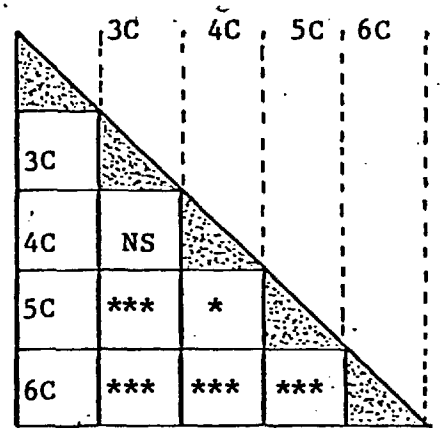


4. Number of sterile segments in the main axis.

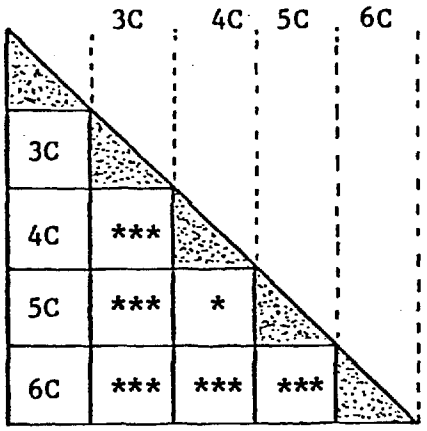
Figure 6.43 (Continued)



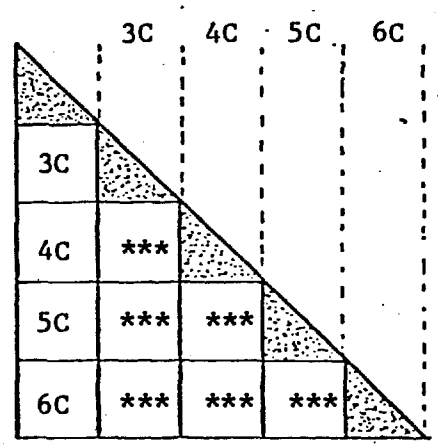
5. Length of the lowermost branch from the main axis.



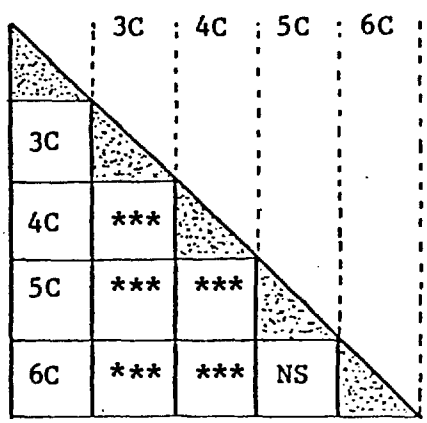
6. Length of the uppermost branch from the main axis.



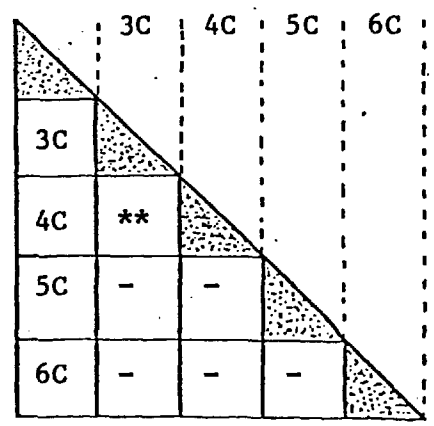
7. Terminal spike length.



8. Number of fertile segments in the terminal spike.



9. Angle of uppermost branch with the main axis.

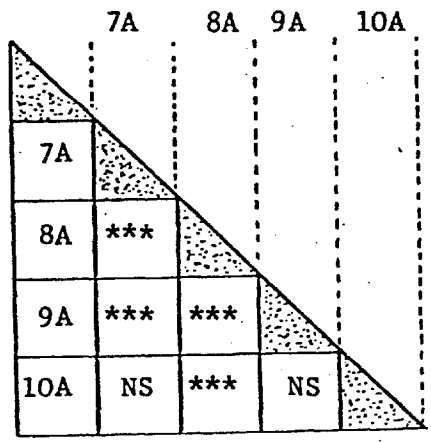


10. Angle of lowermost branch with the main axis.

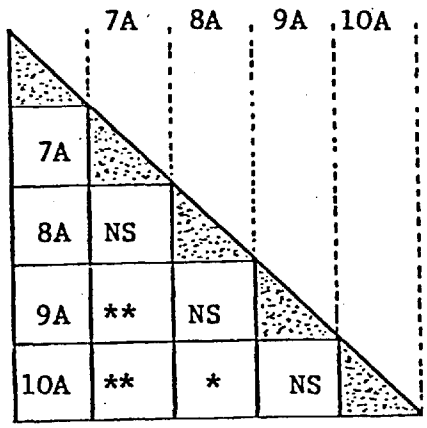
Figure 6.44 Shows the level of significance (t-test) between the four phosphorus levels for the measured vegetative characters of *Salicornia dolichostachya* (A).

NS	P > .05	(not significant)	
*	P	.05 to .01	
**	P	.01 to .001	
***	P <	0.001	

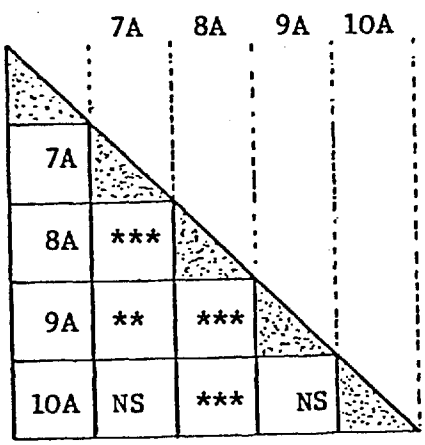
TANK NO.	:	Phosphorus level
7A	:	2 p.p.m.
8A	:	4 p.p.m.
9A	:	8 p.p.m.
10A	:	16 p.p.m.



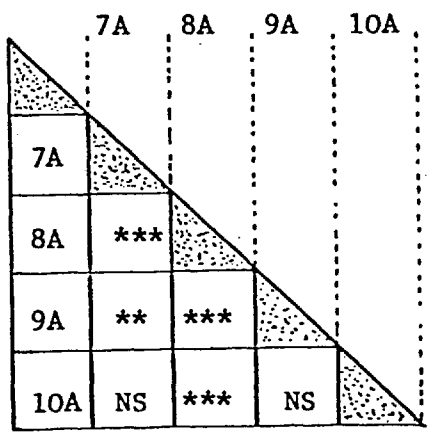
1. Shoot length.



2. Root length.

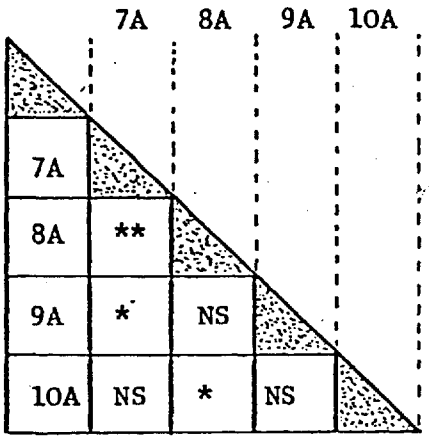


3. Total number of primary branches from the main axis.

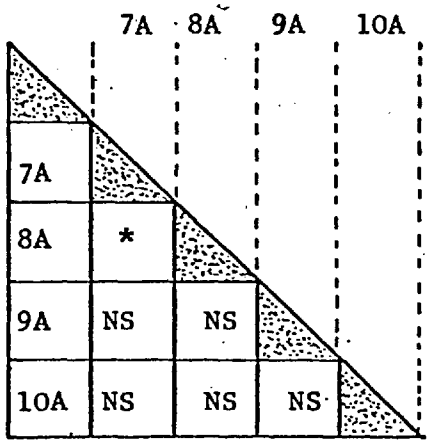


4. Total number of sterile segments in the main axis.

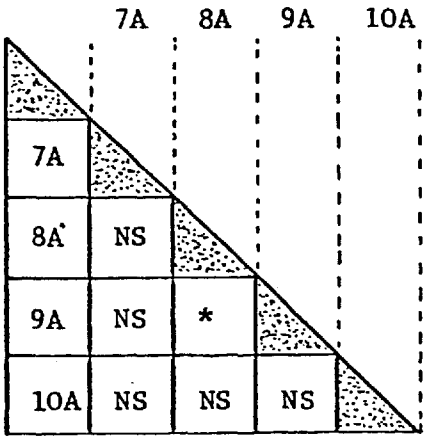
Figure 6.44 (Continued)



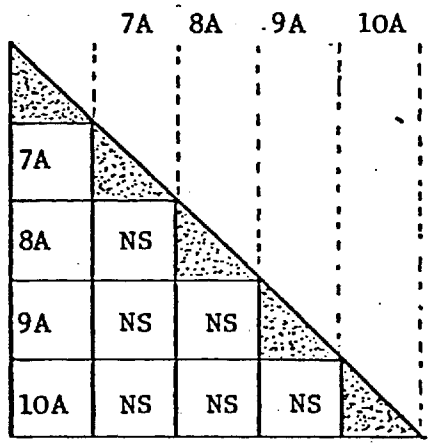
5. Length of the lowermost branch from the main axis.



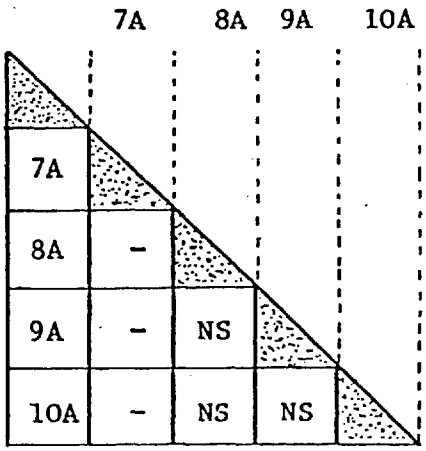
6. Length of the uppermost branch from the main axis.



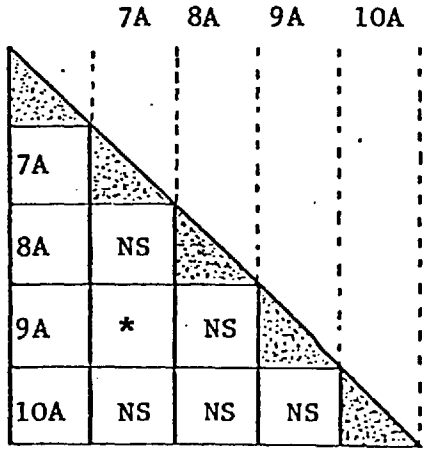
7. Terminal spike length.



8. Number of fertile segments in the terminal spike.



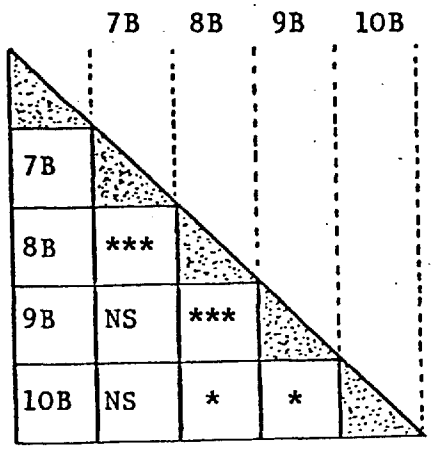
9. Angle of uppermost branch with the main axis.



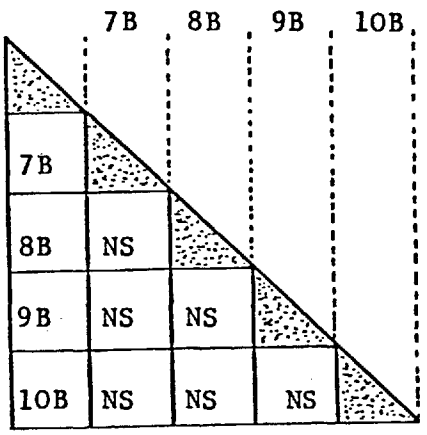
10. Angle of lowermost branch with the main axis.

Figure 6.45 Shows the level of significance (t-test), between the four phosphorus levels for the measured vegetative morphological characters of *Salicornia nitens* (B).

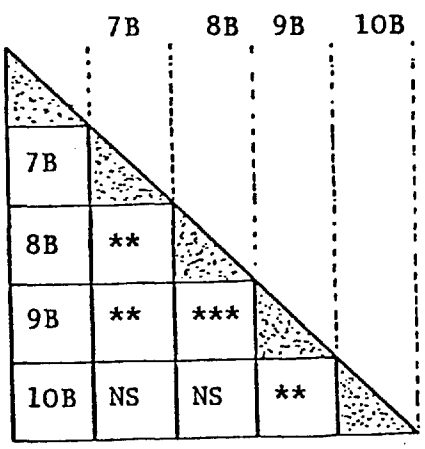
NS	P > .05 (not significant)	TANK NO. : Phosphorus level
*	P .05 to .01	7B : 2 p.p.m.
**	P .01 to .001	8B : 4 p.p.m.
***	P < 0.001	9B : 8 p.p.m.
		10B : 16 p.p.m.



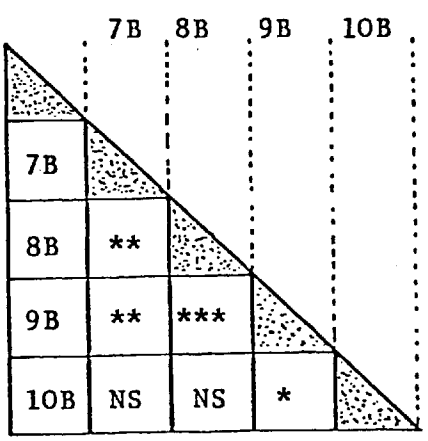
1. Shoot length



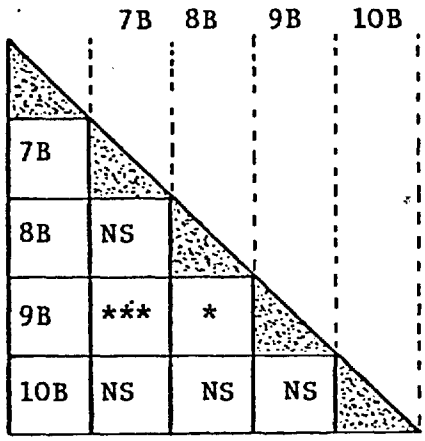
2. Root length



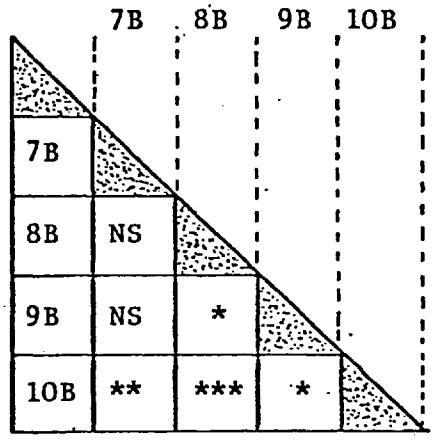
3. Total number of primary branches from the main axis.



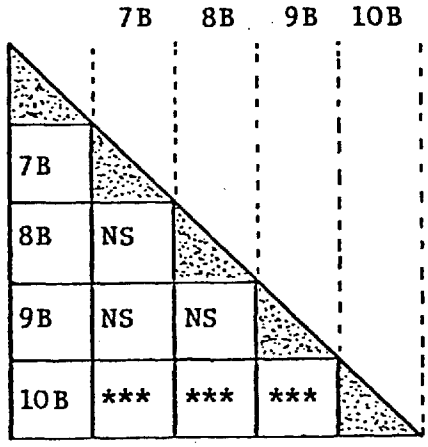
4. Number of sterile segments in the main axis.



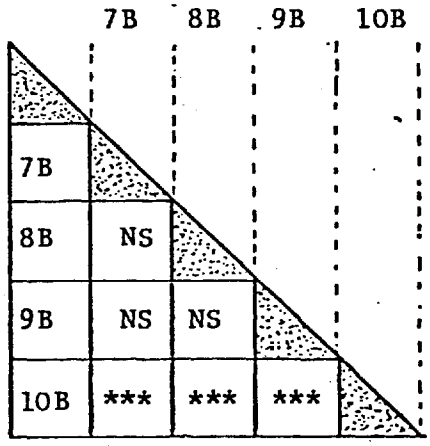
5. Length of the lowermost branch from the main axis.



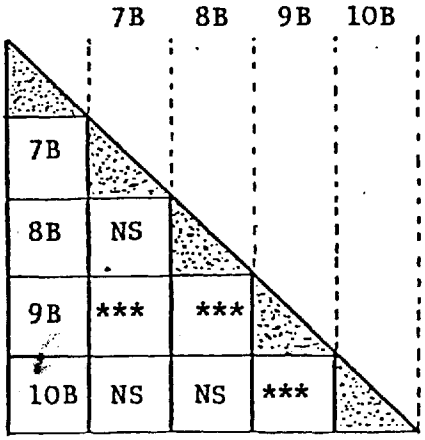
6. Length of the uppermost branch from the main axis.



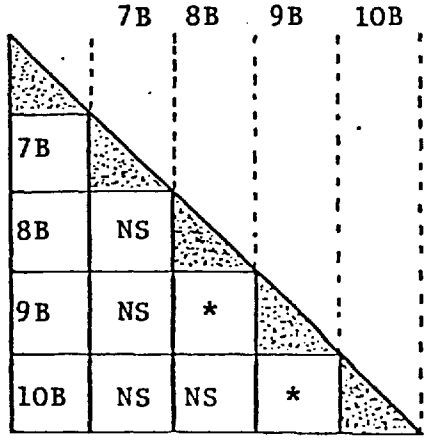
7. Terminal spike length



8. Number of fertile segments in the terminal spike.



9. Angle of uppermost branch with the main axis.

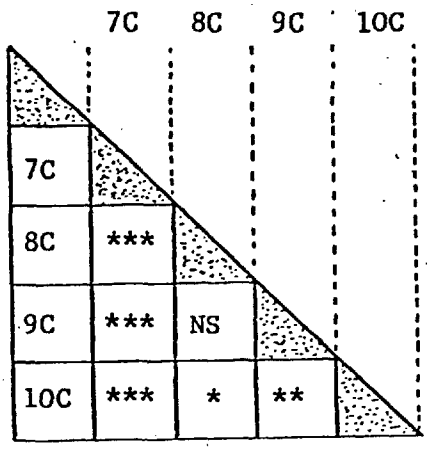


10. Angle of lowermost branch with the main axis.

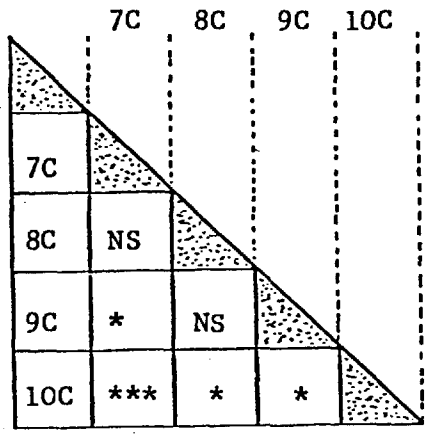
Figure 6. 46 Shows the level of significance (t-test), between the four phosphorus levels for the measured vegetative characters of *Salicornia ramosissima* (C).

NS	P	> .05 (not significant)
*	P	.05 to .01
**	P	.01 to .001
***	P	< 0.001

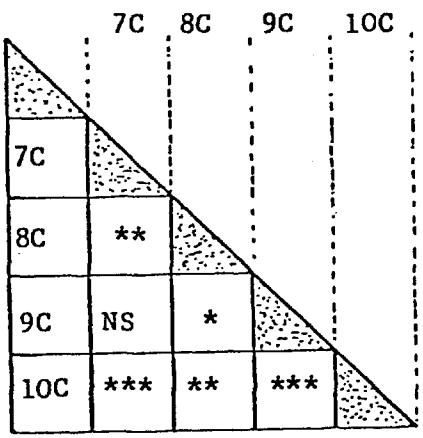
TANK NO.	:	Phosphorus level
7C	:	2.p.p.m.
8C	:	4 p.p.m.
9C	:	8 p.p.m.
10C	:	16 p.p.m.



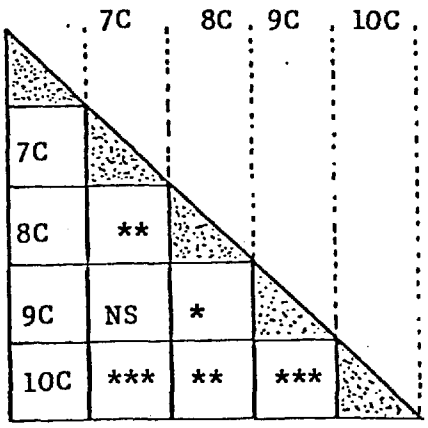
1. Shoot length.



2. Root length.

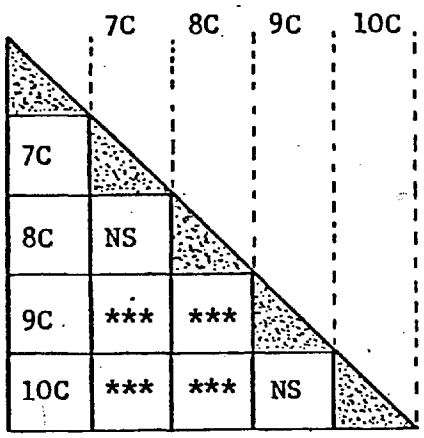


3. Total number of primary branches from the main axis.

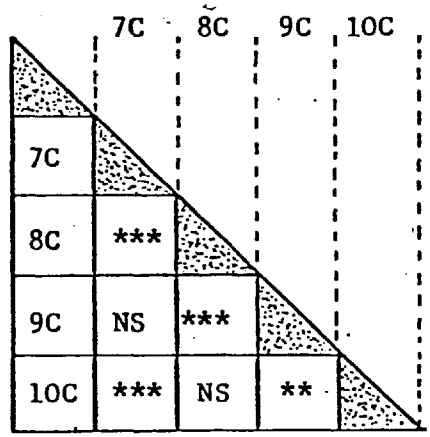


4. Number of sterile segments in the main axis.

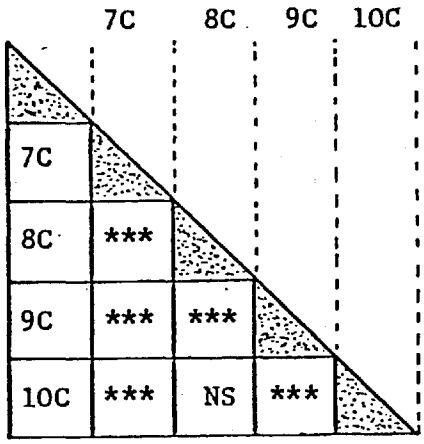
Figure 6.46 (Continued)



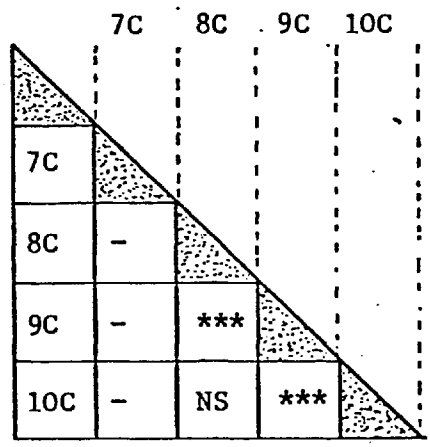
5. Length of lowermost branch from the main axis.



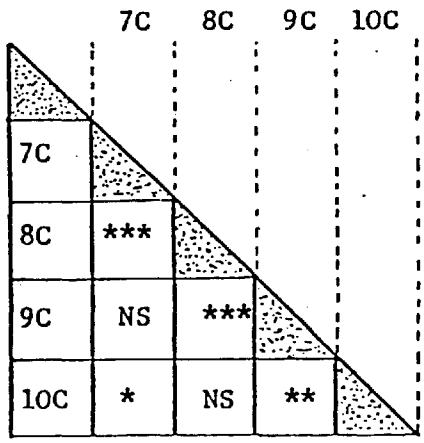
6. Length of uppermost branch from the main axis.



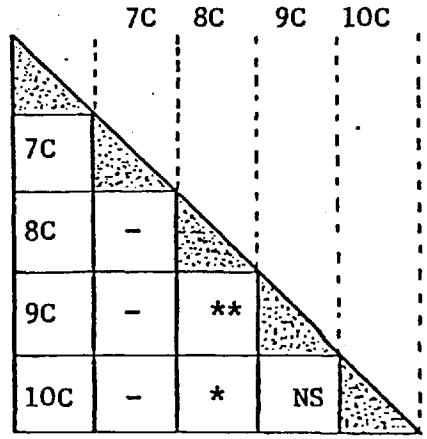
7. Terminal spike length.



8. Number of fertile segments in the terminal spike.



9. Angle of uppermost branch with the main axis.

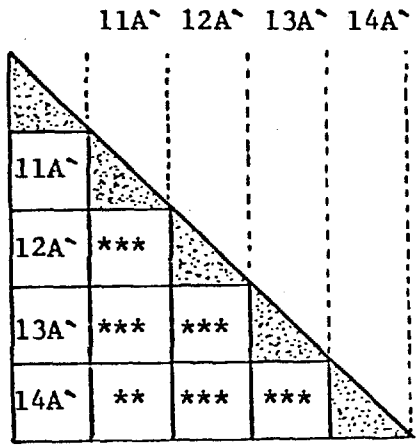


10. Angle of lowermost branch with the main axis.

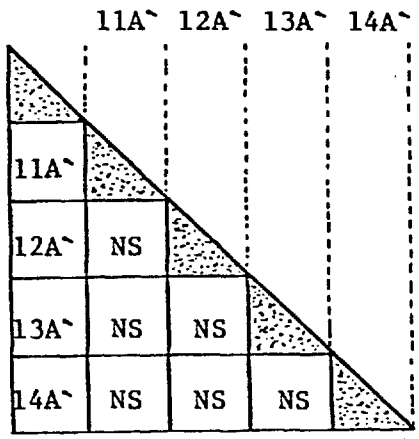
Figure 6.47 Shows the level of significance (t-test), between the four sodium chloride levels for the measured vegetative characters of *Salicornia dolichostachya* (A)

NS	P > .05	(not significant)
*	P	.05 to .01
**	P	.01 to .001
***	P <	.001

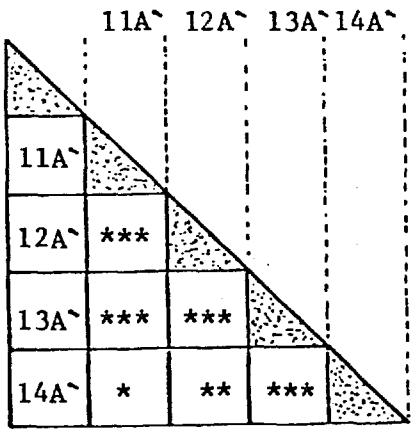
TANK NO.	: Nacl level
11A`	: 5%
12A`	: 1.3%
13A`	: 0.65%
14A`	: 2.5%



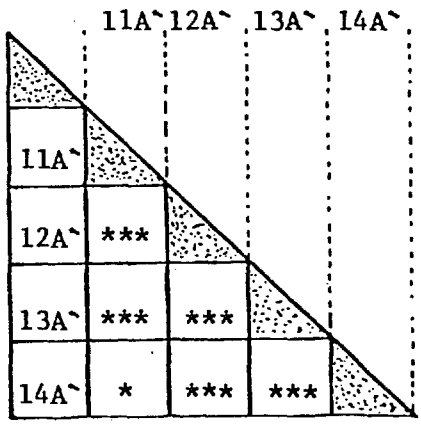
1. Shoot length



2. Root length

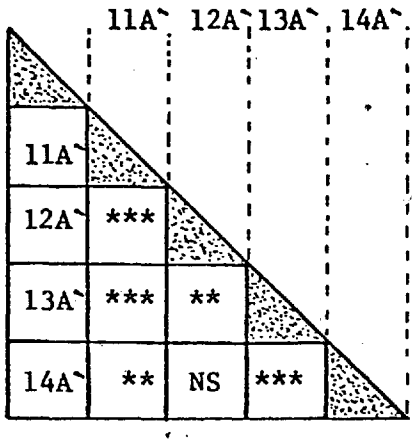


3. Total number of primary branches from the main axis.

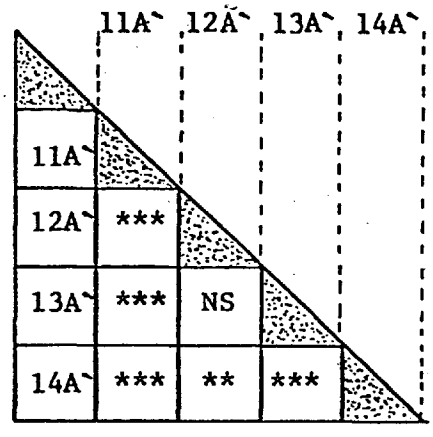


4. Total number of sterile segments in the main axis.

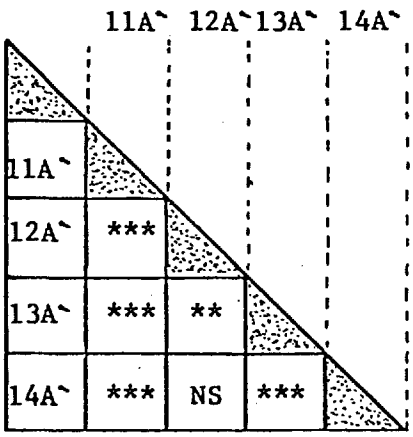
Figure 6.47 (Continued)



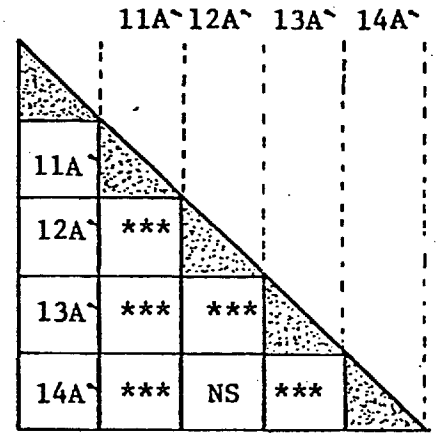
5. Length of the lowermost branch from the main axis.



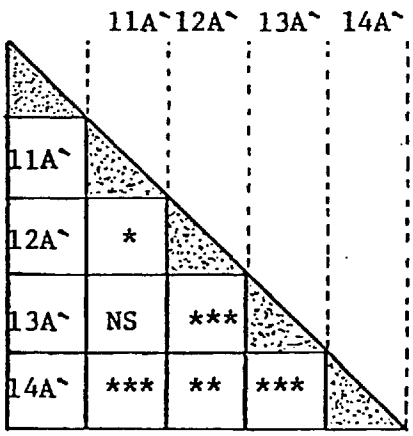
6. Length of the uppermost branch from the main axis.



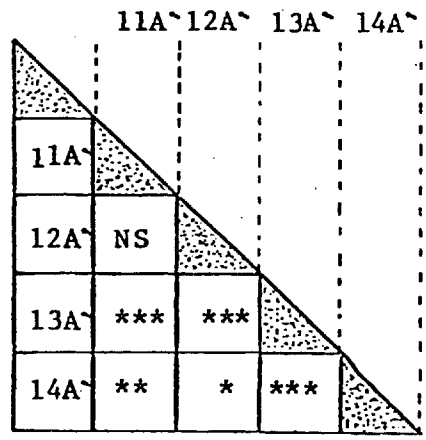
7. Terminal spike length.



8. Fertile segment number in the terminal spike.



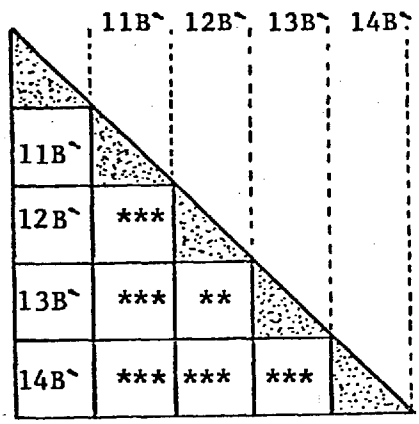
9. Angle of uppermost branch with the main axis.



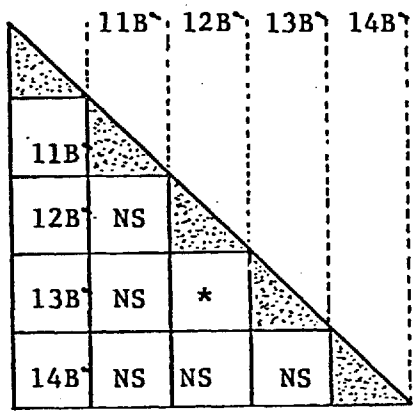
10. Angle of lowermost branch with the main axis.

Figure 6.48 Shows the level of significance (t-test), between the four sodium chloride levels for the measured vegetative characters of *Salicornia nitens* (B`)

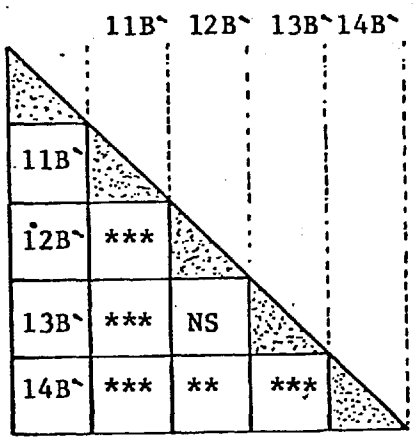
NS	P > .05 (not significant)	TANK NO.	: Nacl level
*	P .05 to .01	11B`	: 5%
**	P .01 to .001	12B`	: 1.3%
***	P < .001	13B`	: 0.65%
		14B`	: 2.5%



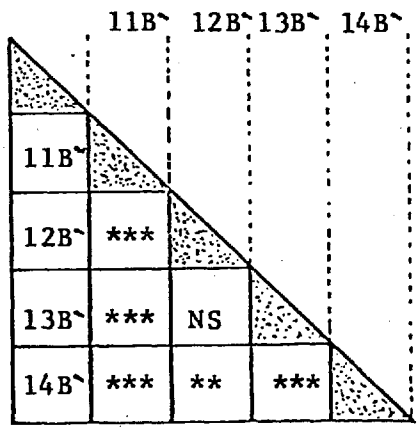
1. Shoot length



2. Root length

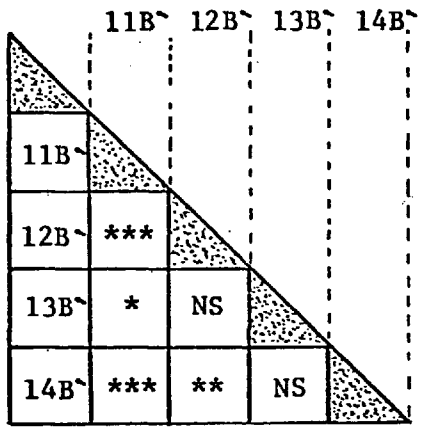


3. Total number of primary branches from the main axis.

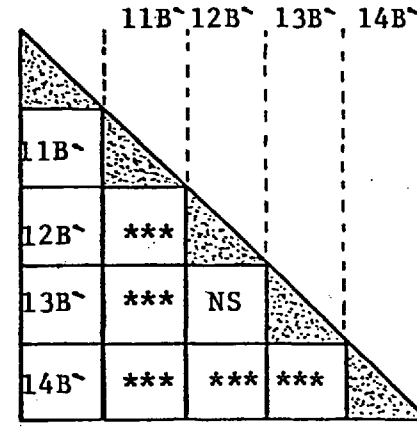


4. Total number of sterile segments in the main axis.

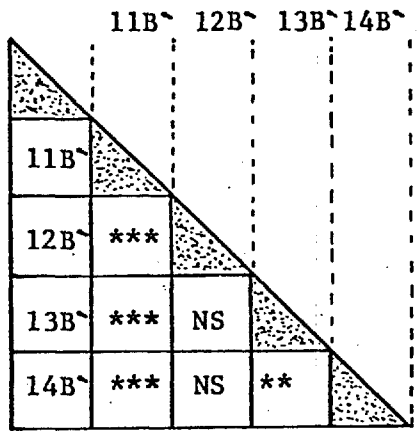
Figure 6.48 (Continued)



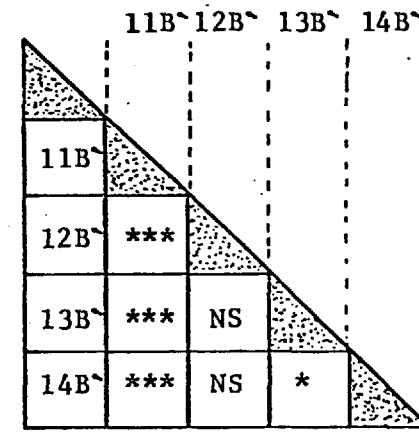
5. Length of the lowermost branch from the main axis.



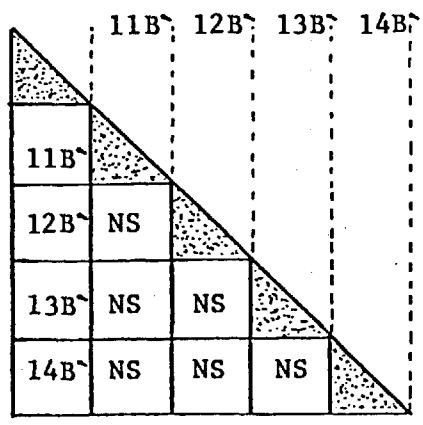
6. Length of the uppermost branch from the main axis.



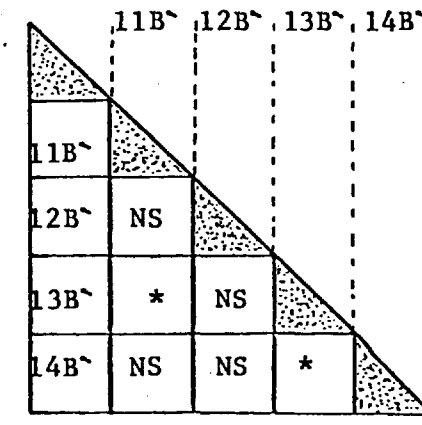
7. Terminal spike length



8. Fertile segment number in the terminal spike.



9. Angle of uppermost branch with the main axis.

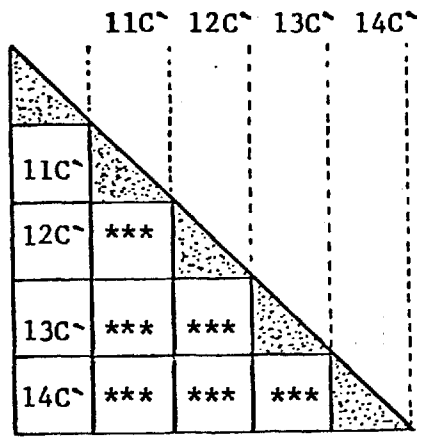


10. Angle of the lowermost branch with the main axis.

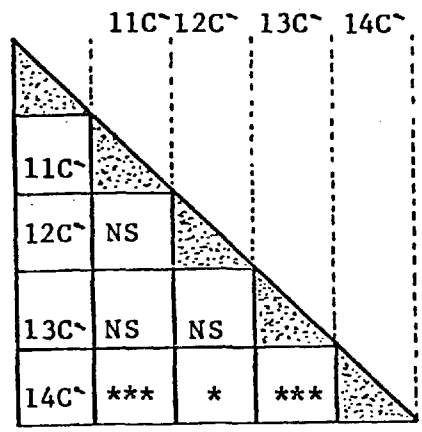
Figure 6.49 Shows the level of significance (t-test), between the four sodium chloride levels for the measured vegetative characters of *Salicornia ramosissima* (C).

NS	P	>	.05	(not significant)
*	P		.05 to .01	
**	P		.01 to .001	
***	P	<	.001	

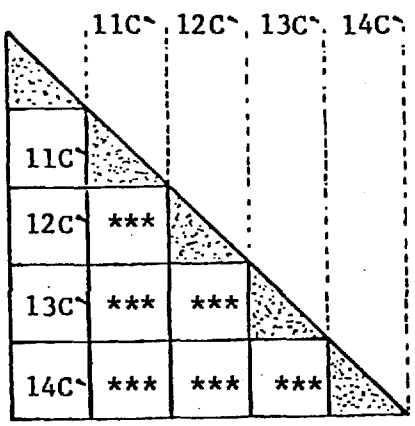
TANK NO.	:	Nacl level
11C	:	5%
12C	:	1.3%
13C	:	0.65%
14C	:	2.5%



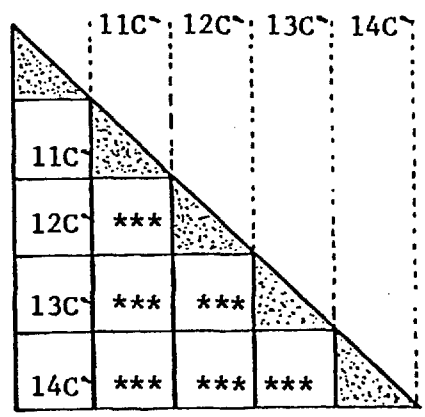
1. Shoot length



2. Root length

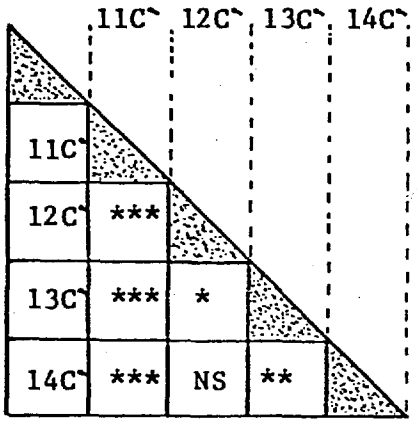


3. Total number of primary branches from the main axis.

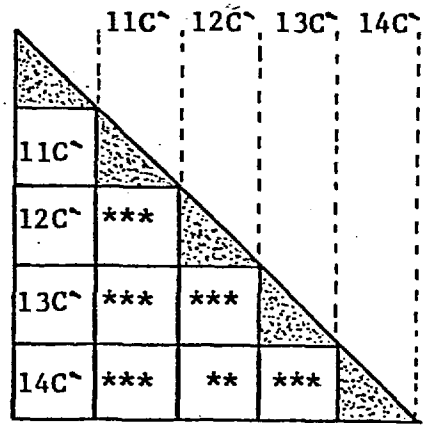


4. Total number of sterile segments in the main axis.

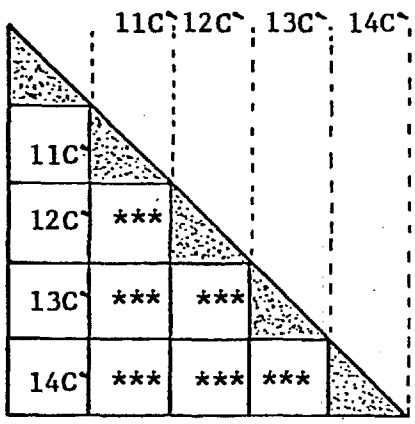
Figure 6.49 (Continued)



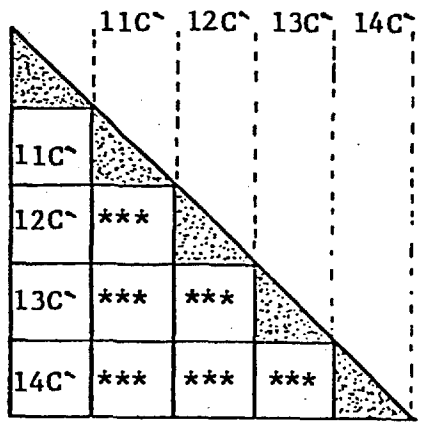
5. Length of the lowermost branch from the main axis



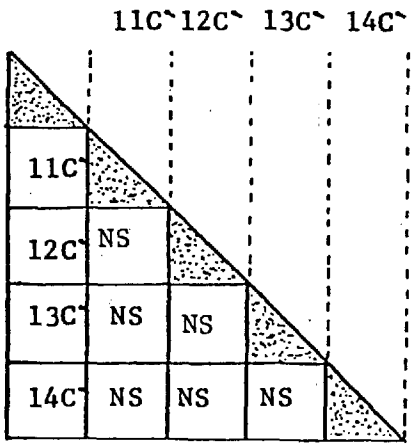
6. Length of the uppermost branch from the main axis.



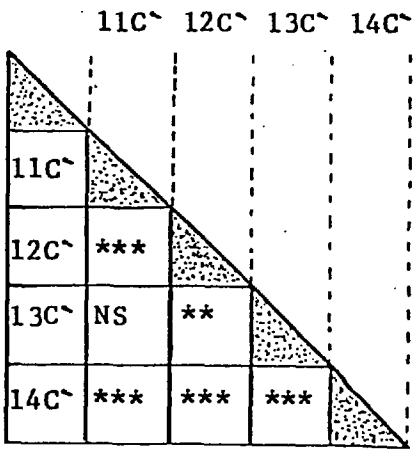
7. Terminal spike length.



8. Fertile segment number in the terminal spike.



9. Angle of uppermost branch with the main axis.



10. Angle of the lowermost branch with the main axis.

CHAPTER VII

FIELD STUDIES

7.1 Soil analysis of *Salicornia* populations:-

In the present study the greenhouse experiment illustrated that *Salicornia* showed a wide range of variation in morphological response to levels of nitrogen and sodium chloride, and a narrow range of variation to levels of phosphorus (Chapter V and VI). In the study of field responses a knowledge of the actual concentrations of nutrients in the field must be related to the scale of variation induced by modifying the culture nutrient levels. This approach should go some way to helping in the separation of the phenotypic components involved in the morphological variation encountered in nature.

7.1.1. Collection of the soil samples:-

All the soil samples used were collected during the summer (August - September) of 1976. The soil samples were collected from three different salt marshes on the British coast; these were Shingle Street, Suffolk (TM 374 445), Warham, Well - next to the sea, Norfolk (942 44-45) and Northney, Hayling Island, Hampshire (725039). The soil samples were collected from areas where a number of *Salicornia* plants had been observed along a transect through the *Salicornia* zone in each marsh. The transect usually started from the neap tide zone area (lower marsh) and continued upto the upper limit of the *Salicornia* populations. Soil samples were also collected from several populations which occupied similar habitats, and which might belong to similar types of *Salicornia*. This was relatively easy to achieve on the Shingle Street marsh as it seems that most of the populations are physiographically distinct (Figure 7.1,

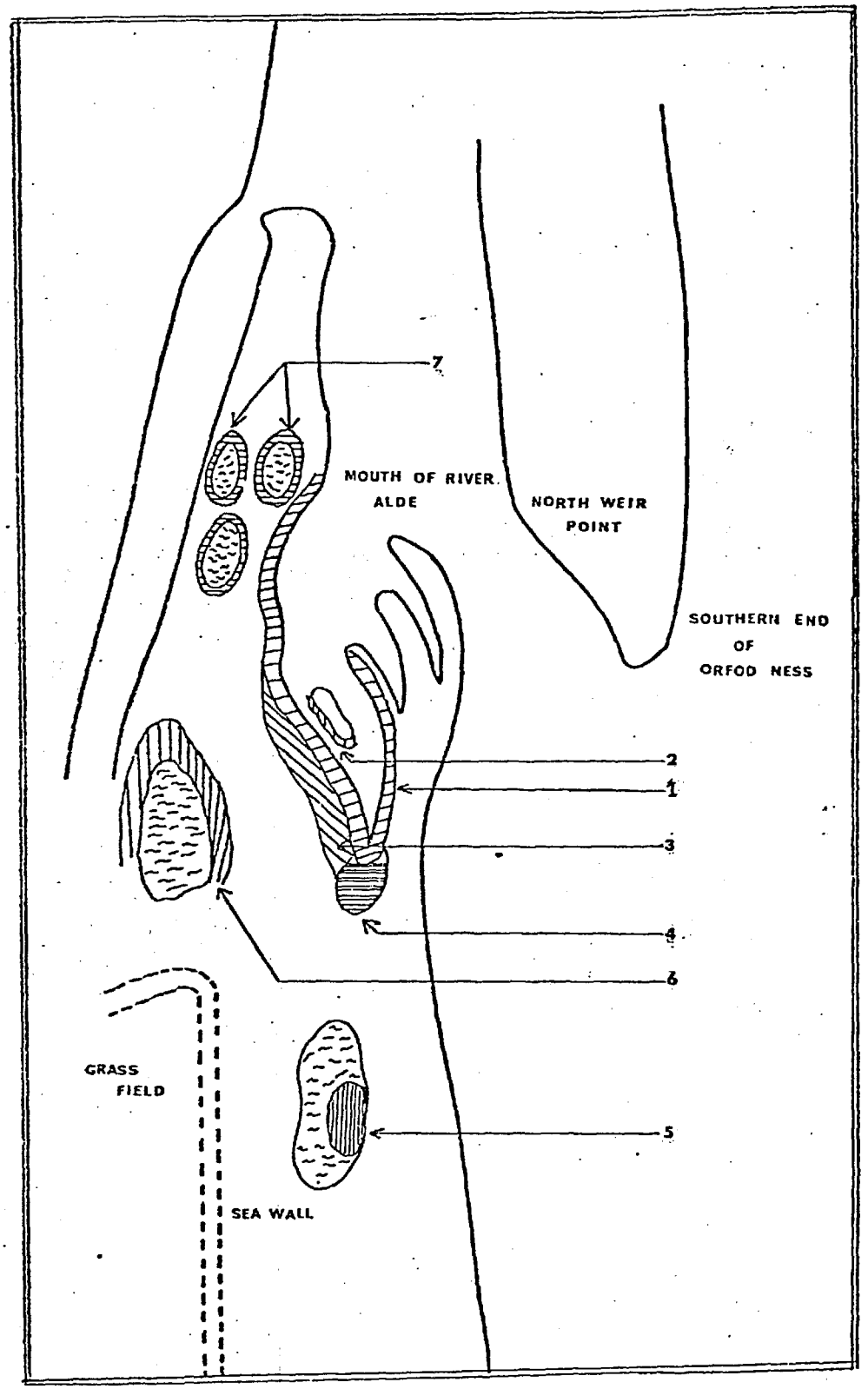


Figure 7.1 : Diagrammatic map showing the locations of the soil sample collection sites at Shingle Street, Suffolk.

Table 7.1), but in the case of the Warham marsh the *Salicornia* populations or aggregations form a mosaic pattern.

From each population five soil samples were taken. Each sample was about 7.0 cm. in diameter and 15 cm. in depth. This depth was chosen on the basis of being approximately the standard root length of annual *Salicornia* spp. Since the marsh soil is wet, the extraction was made in one cut with the help of a trowel. The field samples were put directly into clean polythene bags and brought to the laboratory as soon as possible. Then the soil samples were cut into small pieces and spread over a newspaper in the greenhouse and allowed to dry completely at normal air temperature. The air-dried soil samples were ground gently in a mortar and sieved through 2.00mm sieve, and stored in dry clean polythene bags and kept in the dark before the analysis.

7.1.2 The method adopted for the soil analysis:-

The soils were analysed for their total nitrogen, total phosphorus and sodium. The analyses were carried out according to the method adopted by Stewart et al.(1974). Solutions for the total nitrogen analyses were prepared by Kjeldahl digestion, using one tablet of sodium sulphate (each tablet contained 1gm of Na_2 SO4, supplied by BDH) as the catalyst. Nitrogen was estimated with an auto-analyser using the indophenol blue method. Phosphorus and sodium were extracted by a wet oxidation method utilising nitric acid, hydrochloric acid, 60% perchloric acid mixture (20:5:5 V/V respectively). Phosphorus was then estimated with the auto-analyser using molybdenum chloride as the reducing agent. Sodium was estimated using an SP 90 spectrophotometer (IL151 Atomic Absorbtion spectrophotometer, flame emission). Through all the analyses blank controls (digested with reagents alone) were carried out.

Table 7.1 Shows brief description for the habitat of the collected soil samples collected from Shingle-Street, Suffolk and Northney, Hayling Island.

Equivalent soil sample reference number	Brief description of habitat.
1. Shingle Street, Suffolk	
1.	Lower marsh - plants form almost closed population of *Salicornia* (may be tetraploid), which was usually at the river side (on edge of the creek), which was affected directly by the tide.
2.	Lower marsh - *Salicornia* (tetraploid group *Salicornia dolichostachya*), plants could be found with very rich vegetative growth, the plants somewhat separated from each other.
3.	Lower or middle marsh - Rather similar to soil sample 1, where the soil was a little bit drier than soil number 1, in this habitat *Salicornia* population mixed with other species particularly at the outer edge of the population, *Halimone portulacoides* was a dominant invader.
4.	Lower or middle marsh - similar to soil samples 1 and 2. *Salicornia* plants apparently diploid, but with good vegetative growth.
5.	The soil of this habitat was formed at the edge of pool which was indirectly connected to the sea. *Salicornia* plants occupying this site grew well and were well spaced. Three morphological types appeared to be present.
6.	Upper marsh - Soils collected from a depression where the water accumulated in the form of a pool, *Salicornia* was found in dense patches around the pool - The soil was very moist with a black organic layer below the surface.
7.	Upper marsh - Free from tidal access - soil was very moist, covered with small dense *Salicornia*, pink in colour - There were depressions where water accumulated in the form of small pools. *Salicornia* grew at the edge of these small pools more luxuriantly than in the surrounding areas.

Table 7.1 (Continued)

Equivalent soil sample reference number	Brief description of habitat
II. Hayling Island (Northney), Hampshire.	
1A, 1D, 1E	Lower marsh - Soil samples were collected from the edge of the creeks, *Salicornia* plants of these populations looked very rich in their vegetative growth; they could also be found a little distance away from creeks, but still within the range of the tide.
1B, 1C	Lower marsh - This may be considered as the extreme lower marsh habitat - Plants (*Salicornia dolichostachya*) usually bushy and with very long terminal spikes, and usually found a little separated from each other.
2.	Upper marsh - In this habitat *Salicornia* plants usually with red colour, soil was very moist, and away from the direct range of the tide.

The analytical results for sodium were converted to p.p.m. by means of a standard curve. The results obtained in p.p.m. for nitrogen, phosphorus and sodium (Appendix, Tables A7.1-A7.3) are presented in the form of percentages. The following formula was used for transforming the p.p.m. reading obtained from the graphs and curve in to percentages:-

$$\% = \frac{C \text{ (p.p.m.)} \times \text{solution volume (ml)}}{10^4 \times \text{sample weight (gm)}}.$$

7.1.3 Results:-

The results from the 124 soil samples, from the three salt marshes (for each soil sample three sub samples were analysed), for total nitrogen, phosphorus and sodium are given in Tables 7.2-7.4 in percentages, showing the ranges (minimum - maximum), means and their standard deviations for soil samples from each *Salicornia* population.

7.1.4 Discussion:-

Tables 7.2-7.4 reveal that the total nitrogen content varies considerably over each marsh, and in particular between the soil samples from the lower and the upper marsh. In the three salt marshes the total nitrogen level in the upper marsh soil reached twice the amount of the lower marsh soil samples. Moreover, the range of variation varies considerably from marsh to marsh. For example, the range of variation of the mean values for total nitrogen between the soil samples of lower marsh at Shingle street was 0.05% (0.24% - 0.29%), for Hayling Island, 0.12% (0.28% - 0.40%), and for Warham, 0.17% (0.09% - 0.26%) (Tables 7.2-7.4). For the upper marsh samples, corresponding values were, Shingle Street, 0.12% (0.57% - 0.69%), Hayling Island (0.63% from one population only), and Warham, 0.3% (0.22% - 0.52%) (Tables 7.2,7.3 &7.4). Total nitrogen levels thus seem to be much more variable

Table 7.2 Shows minimum, maximum, mean and standard deviation for total nitrogen, total phosphorus and sodium for the soil samples collected from *Salicornia* populations on Shingle Street, Suffolk.

The elements / Soil sample number and habitat		Total nitrogen (%)				Total phosphorus (%)				Sodium (%)			
		Minimum	Maximum	Mean	S.D.	Minimum	Maximum	Mean	S.D.	Minimum	Maximum	Mean	S.D.
Lower marsh populations	1.	0.24	0.28	0.26	±0.02	0.9	0.11	0.09	±0.009	1.12	1.33	1.22	±0.08
	2.	0.21	0.28	0.24	±0.027	0.08	0.09	0.09	±0.005	0.98	1.09	1.06	±0.04
Lower marsh (or middle marsh) populations	3.	0.23	0.28	0.26	±0.023	0.08	0.09	0.09	±0.004	0.91	1.03	1.02	±0.08
	4.	0.27	0.33	0.29	±0.026	0.09	0.10	0.09	±0.005	0.80	1.01	0.91	±0.08
	5.	0.27	0.29	0.29	±0.009	0.09	0.09	0.09	±0.00	0.92	1.24	1.05	±0.12
Upper marsh populations	6.	0.36	0.70	0.57	±0.13	0.66	0.08	0.07	±0.008	1.09	1.60	1.32	±0.22
	7.	0.60	0.84	0.69	±0.09	0.10	0.12	0.11	±0.008	2.17	2.37	2.28	±0.11

Table 7. 3 Shows minimum, maximum, mean and standard deviation (S.D.) for total nitrogen, total phosphorus and sodium for the soil samples collected from *Salicornia* populations in Northney, Hayling Island.

The elements / Soil sample number and habitat		Total nitrogen (%)				Total phosphorus (%)				Sodium (%)			
		Minimum	Maximum	Mean	S.D.	Minimum	Maximum	Mean	S.D.	Minimum	Maximum	Mean	S.D.
Lower marsh populations	1A	0.26	0.30	0.28	±0.02	0.08	0.08	0.08	±0.00	0.88	0.94	0.90	±0.03
	1B	0.25	0.34	0.29	±0.05	0.07	0.08	0.07	±0.006	0.98	1.07	0.96	±0.13
	1C	0.35	0.40	0.38	±0.03	0.09	0.09	0.09	±0.00	0.87	1.07	1.00	±0.11
	1D	0.35	0.37	0.36	±0.02	0.09	0.09	0.09	±0.00	0.93	1.14	1.03	±0.10
	1E	0.33	0.43	0.39	±0.06	0.08	0.09	0.09	±0.006	1.04	1.2	1.12	±0.08
Upper marsh populations	2	0.56	0.67	0.63	±0.06	- *	-	-	± -	-	-	-	± -

* These values were omitted because most of the samples contents were lost during the digestion due to it's sandy texture.

Table 7.4 Shows minimum, maximum, mean and standard deviation for total nitrogen, total phosphorus and sodium for soil samples collected from *Salicornia* populations in Warham Wells - next to the sea, Norfolk.

The elements / Soil sample number and habitat		Total nitrogen (%)				Total phosphorus (%)				Sodium (%)			
		Minimum	Maximum	Mean	S.D.	Minimum	Maximum	Mean	S.D.	Minimum	Maximum	Mean	S.D.
Lower marsh populations	1A	0.09	0.15	0.09	±0.02	-*	-	-	± -	-	-	-	± -
	1B	0.17	0.23	0.19	±0.03	0.07	0.09	0.08	±0.01	0.64	0.75	0.71	±0.06
	1C	0.04	0.34	0.14	±0.15	0.09	0.10	0.09	±0.003	0.24	1.07	0.66	±0.59
	1D	0.04	0.09	0.06	±0.02	-	-	-	± -	-	-	-	± -
	1E	0.18	0.23	0.20	±0.02	0.06	0.09	0.08	±0.02	0.54	0.89	0.72	±0.18
Lower marsh populations	2A	0.04	0.18	0.09	±0.05	0.04	0.06	0.05	±0.01	0.36	0.52	0.45	±0.08
	2B	0.23	0.32	0.26	±0.03	-	-	-	± -	-	-	-	± -
	2C	0.03	0.12	0.06	±0.04	-	-	-	± -	-	-	-	± -
	2D	0.16	0.24	0.18	±0.03	-	-	-	± -	-	-	-	± -

* See the note to the Table 7.3

Table 7.4 (Continued)

The elements / Soil sample number and habitat		Total nitrogen (%)				Total phosphorus (%)				Sodium (%)			
		Minimum	Maximum	Mean	S.D.	Minimum	Maximum	Mean	S.D.	Minimum	Maximum	Mean	S.D.
Lower marsh (or middle marsh) populations	3A	0.12	0.23	0.17	±0.04	0.06	0.09	0.08	±0.01	0.45	1.20	0.89	±0.32
	3B	0.09	0.15	0.12	±0.05	0.05	0.07	0.06	±0.007	0.56	0.83	0.67	±0.12
	3C	0.14	0.29	0.20	±0.05	0.06	0.06	0.07	±0.01	0.57	1.19	0.92	±0.27
Upper marsh populations	4A	0.33	0.38	0.34	±0.02	0.08	0.10	0.09	±0.009	1.09	1.27	1.20	±0.08
	4B	0.19	0.24	0.22	±0.02	0.07	0.09	0.08	±0.007	0.63	0.74	0.68	±0.05
	4C	0.29	0.47	0.34	±0.07	0.09	0.11	0.10	±0.009	0.89	1.76	1.16	±0.40
	4D	0.18	0.37	0.25	±0.05	0.07	0.10	0.09	±0.009	0.65	1.17	0.86	±0.20
	4E	0.36	0.66	0.52	±0.09	0.09	0.12	0.10	±0.01	1.07	1.98	1.60	±0.35

on the higher marsh, with higher maximum, but rather similar minimum, values.

On the other hand, total phosphorus levels showed much less variation than total nitrogen over a single marsh, and between the studied marshes. The range of phosphorus mean values for the Shingle Street population was 0.06% (0.06% - 0.12%), Hayling Island, 0.02% (0.07% - 0.09%), and Warham populations, 0.08% (0.04% - 0.12%). However, for the majority of the soil samples from the three salt marshes the phosphorus mean values ranged from 0.07% - 0.09%.

The concentration of sodium, expected to correlate strongly with sodium chloride salinity, showed a marked range of variation over the soil samples from a single marsh, particularly between the soil samples of the upper marsh and the lower marsh populations. The presented data also shows that this range of variation varies from one marsh to another. For example, the lower marsh soil from Shingle Street the sodium mean values showed a range of 0.31% (0.91% - 1.22%), Hayling Island, 0.22% (0.9% - 1.12%), and in Warham population, 0.47% (0.45% - 0.92%). For upper marsh samples corresponding values were; Shingle Street 0.96% (1.32% - 2.28%), and Warham, 0.74%(0.86% - 1.60%), (Tables 7.2 - 7.4). From the presented data it seems that the upper marsh soil has a higher sodium value, but this shows a greater range of variation than that for the lower marsh soil.

In general the results of the present analyses for the soil water of the three salt marshes suggest that nitrogen and sodium levels showed marked increase towards the upper marsh. However, there is greater ranges of variation here than for the lower marsh soils. The gradient in phosphorus seems to be in the same direction, but this is not as clear as those for total nitrogen and sodium.

7.2 Comparison of the results of the soil analyses with the growth behaviour of *Salicornia* in the greenhouse and in the field.

The results of the soil analyses from the three salt marshes, that, for total nitrogen a range of 0.06% - 0.69% was obtained. Total nitrogen does not of course tell us much about the availability of the nitrogen to the plants, but it seems that the majority of the salt marsh soils analysed are low in their total nitrogen (At Rothamsted the limit of 0.25 percent of nitrogen were considered for the old pasture on poor soil. While a rich pasture soil may have 0.4 - 0.6 percent of nitrogen, Russell 1967), with a wide range of variation, particularly between the upper and the lower regions of the marsh, and from marsh to marsh. Such results, probably explain, in part, the low amount of nitrogen required by the *Salicornia* plants grown in the greenhouse to achieve their optimum growth, i.e. 15 - 45 p.p.m. nitrogen (Chapter VI). Moreover, the *Salicornia* types grown showed significant differences in their growth ability (in terms of the measured vegetative characters) towards the experimental levels of nitrogen and particularly at the level of their optimum growth (Chapter VI). Indeed, from the results of the soil analyses and the greenhouse experiments (Chapter V and VI) nitrogen appears to be a limiting growth factor of *Salicornia* in the field.

On the other hand, the *Salicornia* types grown in the greenhouse did not show a marked response to the experimental levels of phosphorus (2 - 16 p.p.m.) in terms of the vegetative characters used. Similarly, in the field, a narrow range of variation had been observed from the soil analyses. This range was 0.05% to 0.11%, as a minimum and maximum phosphorus mean value, detected from the soils of the three marshes. However, the majority of the soil samples showed a range of 0.07% - 0.09% phosphorus. From these values and the greenhouse experiments (Chapter V and VI), one can expect the phosphorus levels to be adequate

for the normal growth of *Salicornia*. It would seem, therefore, that phosphorus cannot be considered as a limiting factor for the growth of *Salicornia* in the field.

Concerning the results of the sodium analyses, a wide range of variation had been observed between the soil samples, particularly between the upper and the lower marsh region, and also from marsh to marsh. Generally, the range was 0.45% - 2.28% sodium as the minimum and the maximum values detected from the soils of the three marshes. The morphological behaviour of the *Salicornia* types grown in the greenhouse showed a significant reduction in their growth as the experimental levels of sodium chloride increased, (Chapter VI). In addition, the three types of *Salicornia* grown also demonstrated significantly different sensitivities to the experimental levels of sodium chloride, particularly in the range of 1.3% - 2.5%, in terms of their vegetative characters.

In this study no attempt has been made to determine the total nitrogen, phosphorus and sodium for the *Salicornia* plant tissues collected from the field. However, one might expect from the results of the greenhouse experiments, that sodium and, in particular total nitrogen would have a marked effect on the general morphology of *Salicornia* in the field. But, studies similar to the present one, where only a limited number of environmental factors (total nitrogen, total phosphorus, and sodium) were investigated, the variation in the morphology of *Salicornia* observed must be interpreted with caution in the light of possible interference from any other unknown factors. For such comparisons 10 populations were selected. From each population the vegetative characters of 15 well developed plants were measured (Appendix, Tables A7.4-A7.6) In each marsh the selected populations were chosen so that they occupied

similar habitats on the marsh (e.g., from the creeks or flat areas), and attempts were made to ensure the plants phenotypically belonged to similar type, despite noticeable differences in their shoot size. However, this was found much easier to achieve in the lower part of the marsh. Moreover, the frequent submergence of the lower marsh by the tide, probably reduces the range of variation in many factors, such as salinity and aeration. In addition, the lower marsh populations almost free from the effect of competitor species, as is the case in most of the upper marsh populations, and also can be considered as an important interfering factor. So, from the mentioned factors, it seems more practical to compare populations from the lower marsh than from the upper marsh.

Table 7.5 shows the values for the vegetative characters of *Salicornia* populations 1B and 1D, 2B and 2C (Warham). The Table clearly shows that the increase in their measurements is linked with the total nitrogen content. *Salicornia* plants from populations 1A and 1E (Hayling Island; Table 7.6) show a narrow range of variation in their total nitrogen and also a narrow range of variation is observed in their vegetative characters. *Salicornia* plants from the populations numbered 11, 12, 13, 14 (Shingle Street) show quite similar values for their vegetative characters and their soils have similar amounts of total nitrogen (Table 7.7).

On the other hand, the following ranges of sodium had been detected from the three marshes; 0.45% - 1.22% in the soils of the lower marsh, and 0.63% - 2.88% in the soils of the upper marsh. From a comparison of these values with the effects of the experimental levels of sodium chloride(0.63%, 1.3%, 2.5% and 5%) on the morphology of *Salicornia* grown in the greenhouse, one might expect the sodium range in the field

Table 7.5 Shows the means ($\bar{x}$) and standard deviation (S.D.) values for the morphological characters of *Salicornia* populations occupying soils differing in their total nitrogen content in the lower marsh region of Warham.

Population number / total nitrogen Vegetative characters	1D 0.06%		1B 0.19%		2C 0.06%		2B 0.26%	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
1. Shoot length.	16.39	±2.89	24.06	±2.65	13.64	±2.63	21.33	±2.76
2. Number of sterile segments in the main axis.	12.53	±1.68	14.73	±1.90	10.13	±2.03	13.9	±2.13
3. Total number of primary branches from the main axis.	24.13	±4.03	28.8	±1.90	20.00	±4.00	27.4	±4.53
4. Terminal spike length.	2.39	±0.81	4.33	±1.78	3.3	±1.06	3.59	±0.94
5. Number of fertile segments in the terminal spike.	7.53	±2.75	12.00	±2.75	9.93	±2.81	10.50	±2.76
6. Length of the uppermost branch from the main axis.	1.43	±0.42	2.84	±1.30	2.02	±0.59	2.44	±0.64
7. Length of the lowermost branch from the main axis.	7.73	±2.73	8.66	±3.5	7.55	±1.44	9.63	±3.06
8. Angle of the uppermost branch with the main axis.	40°	±10.0	39.29	±7.30	28.7°	±4.42	31.0°	±3.16

Table 7.6 Shows the mean($\bar{x}$) and standard deviation(S.D.) values for the morphological characters of *Salicornia* populations occupying soils differeing in their total nitrogen content in the lower marsh of Northney, Hayling Island.

Population number – Total nitrogen / Vegetative characters	1A 0.28%		1E 0.39%	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.
1. Shoot length	24.96	±3.63	28.97	±2.73
2. Number of sterile segments in the main axis.	19.00	±2.75	19.2	±1.74
3. Total number of primary branches from the main axis.	27.60	±5.79	38.27	±3.69
4. Terminal spike length.	2.56	±0.56	2.97	±0.49
5. Number of fertile segments in the terminal spike.	8.1	±2.77	10.06	±1.75
6. Length of the uppermost branch from the main axis.	1.58	±0.94	1.77	±0.42
7. Length of the lowermost branch from the main axis.	14.05	±4.16	19.3	±4.64
8. Angle of the uppermost branch with the main axis.	38.89	±6.00	41.43	±6.63

Table 7.7 Shows the means ($\bar{x}$) and standard deviation (S.D.) values for the morphological characters of *Salicornia* populations occupying soils relatively with similar total nitrogen content in the lower marsh of Shingle Street.

Population number/ total nitrogen / Vegetative characters	11 0.28%		12 0.28%		13 0.25%		14 0.26%	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
1. Shoot length	28.69	±2.64	26.03	±4.01	26.53	±2.25	27.62	±4.75
2. Number of sterile segments in the main axis.	16.8	±1.66	16.33	±2.06	16.73	±1.62	16.55	±2.29
3. Total number of primary branches from the main axis.	33.60	±3.56	32.53	±4.17	33.6	±2.41	32.4	±4.88
4. Terminal spike length.	5.24	±0.88	4.05	±0.98	4.75	±0.88	5.18	±1.08
5. Number of fertile segments in the terminal spike.	14.13	±1.85	12.93	±2.02	14.07	±2.49	15.18	±2.99
6. Length of the uppermost branch from the main axis.	3.00	±0.73	2.19	±0.75	2.59	±0.65	3.06	±1.04
7. Length of the lowermost branch from the main axis.	12.46	±4.03	10.52	±3.90	-	± -	14.2	±4.67
8. Angle of the uppermost branch with the main axis.	52°	±5.60	50.67	±2.58	56°	±10.56	50°	±6.32

could result in a marked effect on the general morphology of *Salicornia*. However, it seems difficult with the available data from the field to demonstrate the effect of sodium alone on the morphology. Nevertheless, the field observations show that the shoots of *Salicornia* from lower marsh populations had better (more luxurious) growth than the shoots of *Salicornia* plants from the upper marsh, despite the lower marsh soils containing less nitrogen than those from the upper marsh. Moreover, *Salicornia* plants from the upper marsh populations quite often showed stunted growth and developed the red coloration (betacyanin). These observations could suggest in part, that if *Salicornia* plants in the upper marsh are more subjected to nitrogen deficiency, then this is probably due to several environmental factors which may interfere with the uptake of nitrogen, such as hyper-salinity, due to high evaporation during summer months, and competition. In addition, there are genetic differences, (i.e. different species). Both Levitt (1972 and Waisel (1972) believe that high salinity may reduce the uptake of phosphate and, more particularly, nitrate by *Salicornia*, resulting in a deficiency of chlorophyll and a reddish colour. However, Jefferies (1977) suggested that the upper marsh plants (including *Salicornia* spp.) have slower growth rates as a result of selection to survive the period of nitrogen stress during the summer months when the soil is hypersaline.

From the above discussion it can be concluded that the detected ranges of sodium and in particular, nitrogen over a single marsh and particularly from marsh to marsh could result in a significant effect on the morphology of *Salicornia*, but that phosphorus levels are likely to be adequate for normal growth.

7.3 Chromatographic analysis of natural populations of *Salicornia*

The purpose of this study was to investigate the chromatographic pattern of the phenolic glycosides in field populations of *Salicornia*. It was hoped that the study might cast some light on genetic relationships in the genus, the possible infraspecific variation and the nature of hybridisation. Such work was considered necessary as very little or no work involving such an approach has been reported in the genus under investigation.

7.3.1 Collection of the plant material:-

In the present study about 52 populations of *Salicornia* occuring naturally in the field were sampled during the months of September - October, 1976. The specimens were collected from the following marshes, Shingle Street, Suffolk (TM 374 445), Warham, Wells next to the sea, Norfolk (942 44-45), Northney, Hayling Island, Hampshire (725039), and Pagham harbour, Sussex (875965). From each marsh the plants were collected randomly from the distinctive *Salicornia* populations or aggregations in the upper and lower regions of each marsh. Then from each population or aggregation 10 - 15 well grown plants were collected from the centre of the community to ensure genetic uniformity as far as possible. Then the collected plant put in clean polythene bags and sealed, and brought to the laboratory as soon as possible.

7.3.2. Experimental procedures:-

The cut branches for the analysis were first washed with distilled water and then put in the well ventilated oven at 55° - 60° for 48 hours, and their phenolic glycosides analysed using the same technique mentioned in Chapter IV. From each plant 0.1g. of dried powdered material was used. About 150 µl of the concentrated methanolic extract (total volume approximately one ml.) was spotted on the corner of a square

sheet of chromatographic paper (Whatman No. 1, size 30 x 30cm.). The chromatograms were developed two-dimensionally in BAW as the first solvent and 5% HOAC as the second solvent, and in each case the solvent front was allowed to reach the other end. The chromatograms were developed by the ascending method. Then the developed chromatograms were left overnight in a current of cold air to dry completely and the spots were made visible in ultra-violet light alone and in the presence of ammonia fumes. In the case of the BAW solvent the paper was equilibrated for six hours.

At first 10 individual plants were analysed from a few selected populations. However, since little if any variation was observed in the chromatographic patterns of individuals from the same population, this number was later reduced to 3 - 5 plants from each population.

7.3.3. Results

The results of surveying the 52 populations of *Salicornia*, from the selected salt marshes, for their phenolic glycosides on paper, are presented in form of presence/absence (+/-) scores (Table 7.8). The number of spots for each population is the sum of all the spots which were detected in two or more individuals (Appendix, Table A.7.4). From the chromatographic results presented in Chapter IV it was found that the *Salicornia* annuals showed mainly two chromatographic patterns i.e. those of *Salicornia europaea* group and *Salicornia procumbens* group. Since these two plant groups are often separated ecologically (*S. europaea* group in the upper marsh, and *S. procumbens* group in the lower marsh), in the present representation of the results the field populations were referred to as lower marsh and upper marsh populations only.

A master chromatogram has been drawn to show all the spots detected

Table 7.8 Showing the presence of the phenolic glycosides spots isolated in two-dimensional paper chromatography for the analysed populations of *Salicornia* from Shingle Street - Suffolk; Warham, Wells next to the sea, Norfolk; Pagham harbour, Sussex and Northney, Hayling Island.

Saltmarsh name and population reference / Spots colour in U.V. + NH_3 and number *		O.Y. 1	YG 2	O.Y. 3	O.Y. 4	BL. 5	O.Y. 6	F.YG 7	F.YG 8	BL 9	BL 10	BL 11	BL 12	BL/YG 13	BL/YG 14	BL/F.BL 15	BL 16	YG 17	YG 18	YG 19	YG 20	O.Y. 21	O.Y. 22	BL 23	BL/YG 24	Chlo. 25	F.YG 26	Y 27	BL/YG 28	BL 29	D.O.Y. 30	BL. 31	B.O.Y 32	YG
1. Shingle Street.																																	
Lower marsh populations	III	+	+	−	−	−	+	+	+	−	+	−	−	+	+	+	+	+	+	+	+	−	−	+	+	−	−	−	−	−	−	−	−
	V	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
	VI	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	−	−	−	−
	VII	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
	XC	+	+	+	−	+	−	+	+	−	+	−	−	+	+	+	+	+	+	+	+	−	−	+	+	−	−	−	−	+	−	−	+
	XI	+	+	+	−	+	+	+	+	−	+	+	−	+	+	+	−	+	+	+	+	−	−	+	+	−	−	−	−	−	−	−	+
	XII	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	−	−	+	+	−	−	−	−	−	−	−	−
	XIII	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	+	−	−	−	+	+	−	−	−	−	−	−	−	−
	XIV	+	+	+	−	+	+	+	+	−	+	+	−	+	+	+	+	+	+	+	+	−	−	−	+	−	−	−	−	−	−	−	−
Upper marsh populations	I	+	+	−	−	−	+	+	+	−	+	−	−	+	+	+	−	−	+	+	+	−	−	+	+	−	−	−	−	−	−	−	−
	II	+	+	−	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	−	−	−	−
	IV	+	+	−	−	+	+	+	+	−	+	−	−	+	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	−	−	−	−
	VIII	+	+	−	+	+	−	+	+	−	+	−	−	+	+	+	+	+	+	−	−	−	−	−	+	−	−	−	−	−	−	−	−
	IX	+	+	+	+	+	−	+	+	−	+	+	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	+	−	−	−

* See page 12 1

Table 7.8 (Continued)

Saltmarsh name and population reference	Spots colour in U.V. + NH_3 and number	1 O.Y.	2 YG.	3 O.Y.	4 O.Y.	5 BL.	6 O.Y.	7 F.YG.	8 F.YG.	9 BL.	10 BL.	11 BL.	12 BL.	13 BL/YG	14 BL/YG	15 BL/FBL	16 BL.	17 YG.	18 YG.	19 YG.	20 O.Y.	21 O.Y.	22 BL.	23 BL/YG	24 Chl.	25 FYG	26 Y	27 BL/YG	28 BL.	29 D.O.Y.	30 BL.	31 R.O.Y.	32 YG.
1. Shingle Street																																	
upper marsh populations	XA	+	+	+	+	+	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	+	−	−	−
	XB	+	−	−	−	+	−	+	+	−	−	−	−	+	+	+	−	−	−	−	+	−	−	−	+	−	−	−	−	+	−	−	+
2. Warham																																	
Lower marsh populations	1A	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	+	+	+	+	+	−	+	+	−	+	−	−	+	−	−	−
	1B	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	+	+	+	+	+	−	+	+	−	+	−	−	+	−	−	−
	1C	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	+	−	−	+	−	+	−	−	+	−	−	−
	1D	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	−	−	−	+	+	−	−	+	−	+	−	−	+	−	−	−
	$1E_1$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	+	−	−	+	−	+	−	−	+	−	−	−
	$1E_2$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	−	+	−	+	−	−	+	−	−	−
Lower marsh populations	$2A_1$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	−	+	−	−	−	−	+	−	−	−
	$2A_2$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	+	−	−	−	+	−	+	−	−	+	−	−	−
	2B	+	+	+	+	−	+	+	+	−	−	−	−	+	+	+	−	+	+	−	+	+	−	+	+	−	+	−	−	−	−	−	+
	$2B_2$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+		−	+	−	+	−	−	+	−	−	−
	2C	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	+	+	−	+	−	−	+	+	+	−

Table 7.8 (Continued)

Saltmarsh name and population reference / Spots colour in U.V. + NH_3 and number		1 O.Y.	2 Y.G.	3 O.Y.	4 O.Y.	5 BL.	6 O.Y.	7 F.YG	8 F.YG	9 BL.	10 BL.	11 BL.	12 BL.	13 BL/YG	14 BL/FBL	15 BL/FBL	16 BL.	17 YG.	18 YG.	19 YG.	20 O.Y.	21 O.Y.	22 BL	23 BL/YG	24 Chl.	25 FYG	26 Y	27 BL/YG	28 BL	29 D.O.Y.	30 BL.	31 B.O.Y.	32 Y.G.
2. Warham population																																
Lowermarsh populations	$2C_2$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	+	+	+	−	+	+	−	+	−	−	+	−	+	−
	$2D_1$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	+	−	+	+	−	+	+	−	+	−	−	−
	$2D_2$	+	+	+	+	−	+	+	+	−	−	−	−	+	+	+	−	−	−	−	+	−	−	+	+	−	+	−	−	+	+	−	−
	$2D_3$	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	+	−	−	+	+	−	+	−	−	−	+	−	−
Lowermarsh (middle marsh) populations	3A	+	+	+	+	−	+	+	+	−	+	−	−	+	−	+	−	−	−	−	+	−	−	+	+	−	+	−	−	+	−	−	−
	3B	+	−	+	+	−	+	+	+	−	+	−	−	+	+	+	+	−	−	−	+	+	−	+	+	−	+	−	−	+	−	−	−
	3C	+	+	+	+	−	+	+	+	−	+	+	−	+	+	+	+	−	−	−	+	+	−	+	+	−	+	−	−	−	−	−	−
Upper marsh populations	4A	+	−	−	−	−	+	+	+	−	+	−	−	+	−	+	+	−	−	−	−	−	−	−	+	−	+	−	−	−	−	−	−
	$4B$	+	−	+	+	−	−	+	+	−	+	−	−	+	+	+	+	−	−	−	−	−	−	−	+	−	+	−	−	+	−	−	−
	$4B_2$	+	−	+	−	−	−	+	+	−	+	−	−	+	−	+	+	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−
	$4C_1$	+	−	−	−	−	+	+	+	−	+	−	−	+	−	+	+	−	−	−	−	−	−	−	+	−	+	−	−	−	−	−	−
	$4C_2$	+	−	−	−	−	+	+	−	−	+	−	−	+	−	+	+	−	−	−	+	−	−	−	+	−	−	−	−	−	−	−	−
	4D	+	−	−	+	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	−	−	−	−	+	−	+	−	−	−	−	−	−

Table 7.8 (Continued)

Saltmarsh name and population reference	and number	Spots colour in U.V. + NH_3																														
		O.Y.	Y.G.	O.Y.	O.Y.	BL.	O.Y.	FYG.	FYG.	BL.	BL.	BL.	BL.	BL/YG	BL/FBL	BL/FBL	BL.	YG.	YG.	YG.	O.Y.	O.Y.	BL.	BL/YG	Chl.	F.YG.	Y.	BL/YG	BL.	D.O.Y.	BL.	B.O.Y.	YG.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
3. Pagham harbour																																
Lower marsh	II	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	-	+	+	−	+	−	−	−	−	−
	III	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	−	=	+	+	−	−	−	−	−	−	−
	IV	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	=	+	+	−	−	−	−	+	−	−
Upper marsh	V	+	+	−	−	−	−	+	+	−	+	−	−	+	+	+	−	+	+	+	−	−	−	+	+	−	−	−	−	−	−	−
	VI	+	+	−	−	−	−	+	+	−	+	−	−	+	−	+	−	+	+	+	+	−	−	+	+	−	−	−	−	−	−	+
	VII	+	+	−	−	−	−	+	+	−	+	−	−	+	+	+	−	+	+	+	+	−	−	+	+	−	−	−	−	−	−	+
	VIII	+	+	−	−	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	=	+	+	−	−	−	−	−	−	+
4. Northney, Hayling Island.																																
Lower marsh populations	1A	+	−	+	+	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	−	−	−	−	+	−	−	−	−	+	−	−	−
	1B	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	−	+	−	+	−	−	−	−	−	−
	1D	+	−	+	+	−	−	+	−	−	+	−	−	+	+	+	−	−	−	−	+	−	−	−	+	−	−	−	−	+	−	−	−
	$1E_1$	+	+	+	+	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	−	−	−	−	+	−	−	−	−	+	−	−	+
	$1E_2$	+	−	+	+	−	−	+	−	−	+	−	−	+	+	+	−	+	+	−	−	−	−	−	+	−	−	−	−	+	−	−	−

from these populations, and the spots were given the same number as on the master chromatogram of the cultured *Salicornia* spp. (Figure 4.3., Chapter IV).

7.3.4. Discussion:-

It can be seen that the master chromatogram for the analysed *Salicornia* populations is similar to that for *Salicornia* plants grown in the greenhouse (Figure 7.2).

The chromatographic results from the Shingle Street populations show that spots numbered 1 (orange-yellow in ultra violet with ammonia) 7, 8 (Fluorescent yellowish-green in ultra violet with ammonia), 10, 15 (blue sometimes fluorescent blue in ultra violet with ammonia), 13, 14 (blue sometimes yellowish green in ultra violet with ammonia), 2, 17, 18 (yellowish-green in ultra violet with ammonia) and probably 20 (bright orange yellow in ultra violet with ammonia) were found in almost all the populations analysed. The spots numbered 3 and 6 (orange yellow in ultra violet with ammonia) were more frequent in the chromatograms of the lower marsh populations (Table 7.8).

In the Warham population (Table 7.8) it is found that the spots numbered 1, 7, 8, 10, 15 and 13 are common to almost all the populations analysed. However, spots numbered 2, (yellowish green and blue in ultra violet with ammonia) 3, 4, 6 (orange yellow in ultra violet with ammonia) and 20 and probably 21 (orange-yellow in ultra violet with ammonia) are restricted to the chromatograms of the lower marsh populations, (Table 7.8).

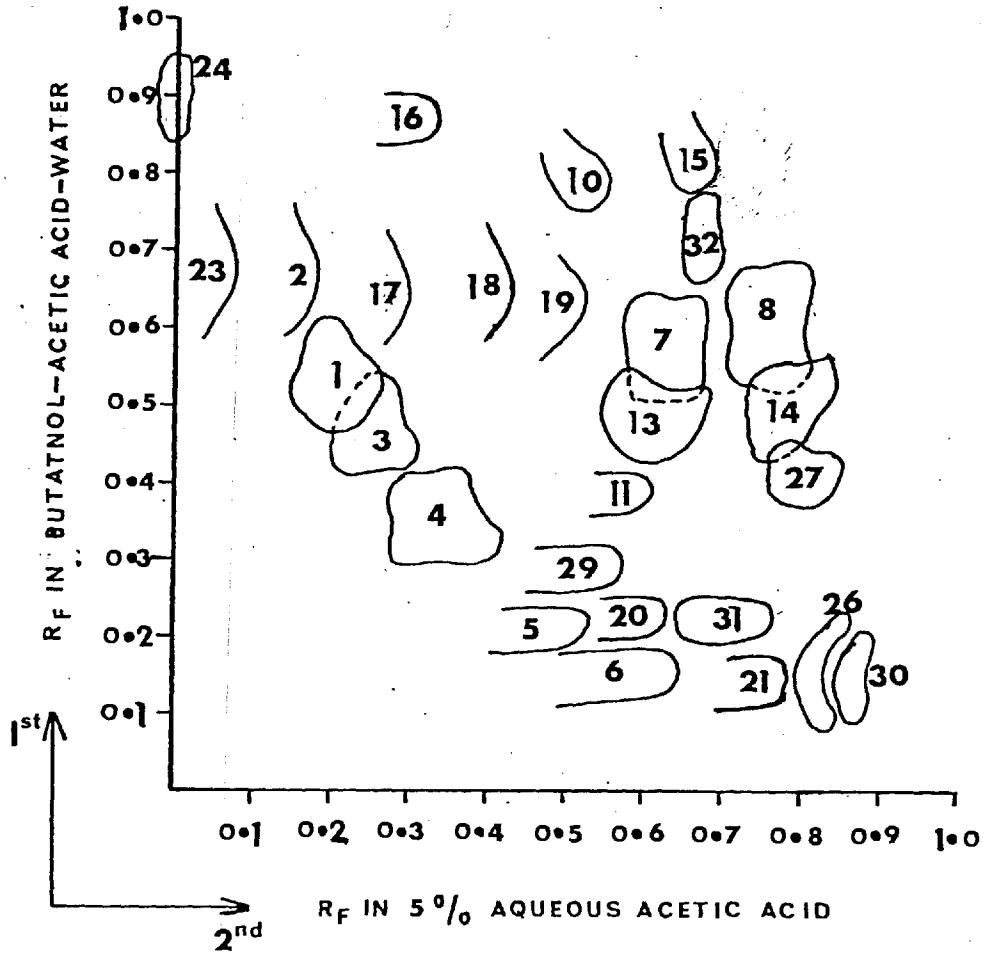


Figure 7.2 Master chromatogram of the phenolic glycsides spots detected from the analysed populations of *Salicornia* spp..

Similarly chromatograms, from populations on Pagham marsh show that the spots numbered 1, 7, 8, 10, 15; 2, 17, 18, 23, 13, 14, and probably 20 are present in the chromatograms of all the population analysed. However, the spots numbered 3, 4, and 6 are found in the lower marsh population chromatograms only, (Table 7.8).

The chromatograms of the lower marsh populations from Hayling Island show that the spots numbered 1, 7, 10, 13, 14, 15, are common to almost all the chromatograms of the populations analysed. In addition, the spots numbered 3, 4 and 29 (dark orange-yellow in ultra violet with ammonia) were detected in the chromatograms of these populations.

From the present study of the chromatographic patterns of the field populations, it is very clear that the spots numbered 1, 7, 8, 10, 13, 15 and probably 14 are common to almost all the populations analysed from the selected salt marshes. Moreover, the chromatographic patterns of the populations in each marsh differed, in general, between those of lower marsh and upper marsh populations. It seems that this difference is mainly due to the presence or absence of the spots numbered 3, 4, and 6 and, in some cases the spots numbered 20, 21, and 29. However, there is a little variation from marsh to marsh in the number of the detected spots which varied between the lower and the upper marsh. The data also showed that the lower populations in each marsh showed a high similarity in their chromatographic patterns, whilst in the chromatograms of the upper marsh populations more variation was observed.

From the chromatographic data, it seems important to point out that a spot or spots can be found frequently in populations from one

marsh, but not in other marsh populations. For example, the spots numbered 21 and 26 (yellow in U.V. + NH_3) were found in most of Warham populations, none of Shingle Street populations showed these two spots, whilst only individuals of one population in both Hayling Island (1B) and Pagham marsh (II) showed these two spots. Similarly spot number 29 is very frequent in chromatograms of the Warham and Hayling Island population (in particular those of the lower marsh), whilst it was found much less frequently in the Shingle Street and Pagham populations. The chromatographic patters of the Shingle Street populations sometimes contain spot number 11 and, in particular, 5 (blue in U.V. + NH_3). However, none of the Warham populations showed spot number 5, and only individuals of one population (3C) showed spot number 11, and none of Hayling Island and Pagham populations showed the presence of these spots. Also it was noticed that individuals from one population or more show the presence of uncorrelated spot or spots which are absent in the chromatograms of the other populations from the marsh. For example, the spots numbered 27, 30 (blue in U.V. + NH_3), 31 (bright orange-yellow in U.V. + NH_3) were found sporadically in the chromatograms of populations 2C, $2C_2$, $2D_1$, $2D_2$ and $2D_3$ from Warham marsh, but none of the other population analysed in this study showed these spots, (Table 7.8).

On the same line, it seems worth while to point out that comparison between the two master chromatograms from the field studies with that from *Salicornia* plants grown in the greenhouse, reveals that the spots numbered 9, 12, 22, 25 and 28 (blue in U.V. + NH_3), found in individuals from the cultured, were not found in the chromatograms for the field populations. On the other hand, spots numbered 30 (R_F values, in BAW 0.1 in 5% HOAC 0.82), 32 (R_F values, in BAW 0.71, in 5% HOAC 0.67), (blue in U.V. +NH_3) and 31 (R_F values, in BAW 0.22, in 5% HOAC 0.69),

(bright orange-yellow in U.V. + NH_3) were found in the chromatograms of some field populations, but not observed in *Salicornia* plants cultured in the greenhouse, (Figure 7.2).

From the above presentation, it seems that the chromatograms of the field populations in form of presence/absence (+/−) scores did not give a very clear picture, but in general, there was a tendency for the upper-marsh and the lower marsh population to show different spot patterns. The chromatographic results of the phenolic glycosides for the 52 field populations were subjected to Principal Component Analysis (R - type) in the hope of clarifying the picture (see Section 4.7).

The result of the field population ordination is given in Figure 7.3. The result of the present analysis were mainly determined by the chromatographic spots which showed variation among the populations analysed, in other words the spots which were either always absent or were always present in Table 7.8 were dropped from the analysis. From the latent vector table (Appendix, Table A,7.8), it seems spots numbered 2, 17, 18, 16 and probably 21, 26 and 27 are the most useful for axis 1, and spots numbered 4, 5, 19, 21, 26, 32 and probably 3 are the most useful for axis 2.

Figure 7.3 shows very clearly that the upper marsh and the lower marsh populations are occupying rather different parts of the plot, forming two main groups. But, as expected, this aggregation does not provide an exact split between the two groups, since some of the lower marsh populations fall within the upper marsh range of the plot, and visa versa. From the previous chromatographic results (Chapter IV), such variation in the chromatographic results seem to follow from

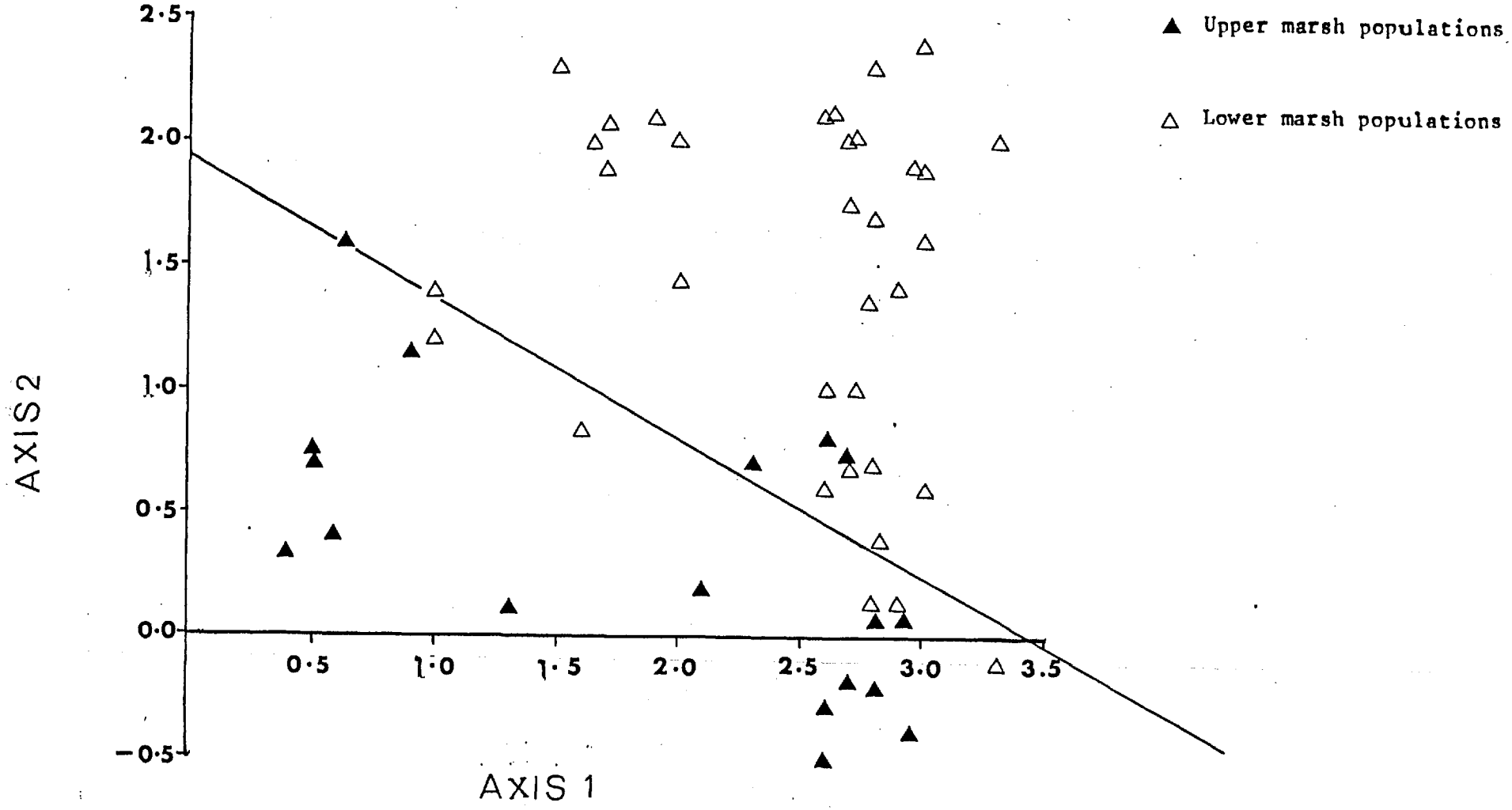


Figure 7.3 : Diagram shows the scatter plots of the 52 *Salicornia* populations analysed by Principal Component Analysis (Based on their phenolic glycosides).

differences in chromosome number and morphology. However, the majority of the lower marsh population chromatograms showed the tetraploid patters, whilst the uppermarsh populations produced mainly the diploid patterns and occasionally the tetraploid patterns.

The separation line between the upper marsh and the lower marsh populations on the plot in the form of a slope suggests that there is a degree of correlation between axes 1 and 2. Though it seems difficult from the provided data to point out exactly which are the correlated chromatographic spots, but nevertheless, previous observations in Chapter IV showed that (apart from *S. pusilla*) the total number of the fluorescent yellowish-green and the blue spots are usually more frequent if the chromatogram contain an additional orange-yellow spot to the common one (spot number 1).

The figure also reveals that within each plant group (Lower marsh v. upper marsh), there is a tendency of subgrouping. This is, presumably, due to the phenomenon that a number of *Salicornia* populations (one or more) from one marsh able to produce spot or spots, which cannot be detected in other marsh populations, and vice versa. Similarly, members of one population or more could produce uncorrelated spot or spots, which are absent in the chromatograms of the other populations from the marsh. Though members of these populations could have similar chromosome numbers, or may belong to the same type. The presence of such a phenomenon could strengthen the belief that there is a good deal of local population differentiation and that what one call species X in one place is not identical with what one calls species X in another. This is probably due to the genetic separation, which is expected to be high between *Salicornia* populations, since a high number of the seeds, are self fertilized (Knuth 1909, Ball 1960, Dalby 1962, Fregreson 1964). In addition, *Salicornia* spp. showed differences in flowering

time, particularly between the upper and the lower marsh populations which may reduce the effect of gene flow on the genetic composition of the population. Such genetic separation could be followed by the accumulation of differences adaptive or random in the pattern of biosynthesis, in particular, as a result of the wide range of micro-habitats in the saltmarsh ecosystem.

SUMMARY

Introduction:-

The genus *Salicornia* belongs to the family Chenopodiaceae and like many other genera in the family it is a halophyte. The genus may be considered among the sub-cosmopolitan genera in its distribution. The aerial parts consist of a series of succulent internodes often called 'sterile segments', which are terminated by shorter ones known as 'fertile segments' which form the sessile-flowered spikes. The leaves are highly reduced with virtually no lamina. The life cycle of the annual species starts in Spring (March - May) by seed germination, the flowers usually become visible in the second half of July and the seeds reach maturity from September onwards. In general, the majority of flowers are apparently self-pollinated. The genus occupies a pioneer stage in the development of coastal and inland salt marshes. Combination of the high phenotypic variability in the genus with the breeding behaviour, which obviously were modified by the wide range of habitats in the salt marsh ecosystem (e.g. competation, aeration, nutrient availability, salinity), appear to be responsible for most of the taxonomic confusion experienced in the genus. Thus over the last century there have been very diverse views as to how many species may be recognised in North West Europe. This work culminated in the treatment of Ball (1964) in Flora Europaea, in which he recognised 10 species under two groups; *S. europaea* and *S. procumbens* based on studies of British Isles coasts. Though some of these species can be recognised in the field (e.g. *S. pusilla, S. ramosissima*), it is quite easy to find field specimens which cannot be classified satisfactorily with the key provided. The presence of such difficulty justifies further work seeking species limits and in assessing the nature and the scale of the morphological variation shown by these plants.

Culturing of *Salicornia*

All the growth experiments were carried out in a greenhouse at the Imperial College Field Station, using seeds collected from the field, although these were supplemented in some experiments by seeds from plants cultivated the previous year. Due to the nature of the present study extra attention was given to achieve uniform growth conditions by adapting an automatic subirrigation sand culture technique. The culture system consisted of 16 units, each containing a culture tank and a nutrient reservoir. The system was mainly operated by building up air pressure inside the nutrient reservoir to raise the solution to the culture tank situated above it. The nutrient reservoirs were all connected to a central bottle, ensuring that each of them received an equal air pressure. The system was arranged to operate twice daily with 12 hour intervals by using time switches and solenoid valves. The nutrient solution selected in this was that of Hoagland and Arnon (1938). Salinity levels were adjusted in the solutions by the addition of the appropriate weight of sodium chloride. The new complete solution was prepared on the same day as the previous solution needed to be changed. The sand used in the growth experiments was initially acid washed, and for each growth experiment a new sand sample was used.

Morphological behaviour of different types of *Salicornia* of known Chromosome number under uniform conditions

Most of the cultured *Salicornia* types produced well developed branches, flowers and seeds, with shoot morphology appearing comparable to that of the field material. Germinated seeds in the petridishes, also grew similarly to those originally sown in the culture tanks, when they were transplanted to the tanks. However, extra care was necessary to avoid damage to the

root tips during the process of transplanting. The seeds for the growth experiments were usually placed in paper bags and stored in the cold room (± 5°C) throughout the winter season. Chromosome counts were made on root tips from recent germinated seeds for certain samples to relate the grass morphology with the ploidy level. This work supported previous observations that British *Salicornia* is either diploid (2n = 18) or tetraploid (2n = 36), since no other number was encountered. Because of the general absence of the flower characters in *Salicornia* spp. attention was given to shoot characters, some associated with the flowering spikes. Comparisons were made both with and between different progeny lines. Lines of different origin generally remained statistically distinct in culture, and highest similarity in culture was shown between plants of common origin. In general, plants attributed to *S. dolichostachya* appeared to be more uniform in culture than those attributed to *S. europaea*. Of the gross morphology characters studied, only two ratios $\frac{C + D}{2B}$ and $\frac{D}{B}$ (principally concerned with the degree of compression of fertile segments) showed positive correlation with the chromosome number. In addition, anther length and to a less extent pollen grain diameter can be used to separate the diploid and tetraploid groups.

Chromatographic study of the phenolics of plants of known chromosome number

Oven dried material was examined chromatographically in the hope that this would provide an extra tool in the study of *Salicornia* taxonomy. One-dimensional chromatograms showed some degree of uniformity within the broad taxonomic species, but no sharp differences were revealed. Two-dimensional chromatograms for phenolic glycosides proved much more useful, however. Up to 29 spots were detected (though not identified in the present study), 6 of these were common to all the

specimens examined, whilst most of the remainder have more limited occurrence and may be useful taxonomically. Although no clear-cut pattern emerged on visual examination of the chromatograms (apart from the very distinct *S. pusilla*). Principal Component Analysis of the data revealed a real separation of *S. europaea* from *S. dolichostachya*, with *S. pusilla* and *S. ramosissima* coming within the range of the former, and *S. nitens* in the range of the latter. However, more variation was observed among *S. europaea* than among *S. dolichostachya*. Almost all the specimens in the *S. europaea* group proved to be diploid, and all those in *S. dolichostachya* group to be tetraploid, with only one tetraploid coming within the range of the diploid plants. This study gives further support to the recognition of ploidy level as being of primary taxonomic importance in *Salicornia*. Two-dimensional chromatograms of the phenolic acid and simple phenols proved to be of little taxonomic value, since the majority of the spots were common to all the analysed *Salicornia* plants.

Chromatographic analyses of plants grown at different nutrient levels:-

The effect of different levels of nitrogen and phosphorus on the phenolic glycosides in the culture medium was examined in *S. nitens*. The majority of the spots remained constant irrespective of nutrient level, and the few variation seen could not be correlated with experimental treatments. A tentative conclusion may be that the phenolic glycosides are not influenced by levels of nitrogen and phosphorus, an important point if these compounds are to be used for taxonomic purposes.

Culture experiments : initial studies:

It is necessary to assess the scale of morphological variation in respect to nutrient levels (Nitrogen and phosphorus), to sodium chloride

salinity and to light, since *Salicornia* taxonomy is very dependent on vegetative morphology, and it might be expected that vegetative morphological characters would be plastic in relation to environment. Initial experiments showed that 1) Absence of nitrogen had a very marked effect on plant morphology (e.g. dwarf growth, almost complete depression of the branching habit), but certain fertile segments dimensions and seed size increased, and flowering time was advanced by two weeks. 2) Absence of phosphorus had much less effect, although some abnormalities were seen in the terminal spikes (e.g. failure of some fertile segments to form flowers and seeds, cluster formation of small lateral branches). 3) Doubling of the light intensity inside the greenhouse led to a threefold increase in the total number of terminal spikes/plant, some which increased vegetative growth and delay in flowering time of about 10 days.

Culture experiments : second series:-

Following from the first experiments, a second series was carried out making use of four levels of nitrogen (5 - 135 p.p.m.), phosphorus (2 - 16 p.p.m.) and sodium chloride (0.65% - 5%). Nitrogen levels produced very interesting changes in the balance between the apical dominance and the dominance by strong growing lateral branches. Most of the vegetative characters (e.g. plant length, total number of primary branches from the main axis, etc.) showed a clear optimum at 45 p.p.m. nitrogen, but those associated with the inflorescence (e.g. terminal spike length, number of fertile segments in the terminal spike, etc.,) showed their optimum growth at 15 p.p.m. nitrogen. The angle of the uppermost branch and the lowermost branch with the main axis remain unaffected. The phosphorus experiment produced much less effect on morphology and no obvious correlation was observed with the phosphorus levels. The sodium chloride experiment showed a general decrease in growth for

almost all characters as salt levels increased and, in particular, the apical characters (terminal spike length, number of fertile segments in the terminal spike and the length of the uppermost branch from the main axis), but once again both angles of branching remained unaffected. Out of the experimented factors, lower concentration of nitrogen (5 - 15 p.p.m.) clearly stimulated the production of betacyanin in the superficial tissues of *Salicornia*, though it was more frequent in diploid forms than in tetraploid forms.

Data were examined by analysis of variance to show the components due respectively to differences in experimental treatment and genotype. Potentially important conclusions emerging are:-

1. That *Salicornia* appears to have evolved physiological mechanisms for coping with low nitrogen levels, and at low level the available nitrogen is preferentially transferred to the flowers and seeds. Nitrogen is generally assumed to a limiting factor to growth of plants and seed maturity.

2. No equivalent mechanism development for tolerance of low phosphorus levels, probably because this is not encountered in nature.

3. Morphological effects of response to high sodium chloride levels is probably associated with greater or less development of succulency in tissues as is commonly found in halophytes.

The experiments showed that the number of fertile segments in the terminal spike, and the angles of the uppermost branch and the lowermost branch with the main axis to be the most valuable from the taxonomic point of view.

Culture experiments : inbred lines:

Finally the progeny of eight self pollinated *Salicornia* plants

were cultured in uniform conditions and scored for 30 characters these characters being examined by principal component analysis. From this study a small number of characters (e.g. total number of primary branches from the main axis, number of sterile segments in the main axis, length of the uppermost branch from the main axis and terminal spike length) emerged as being additionally useful in separating different genetic lines.

Field studies : soil analyses from *Salicornia* populations:-

Soils from three salt marshes were analysed for total nitrogen, total phosphorus and sodium, using samples collected from the neighbourhood of annual *Salicornia* colonies. In general they show an increase of nitrogen and sodium with height up the marsh but with great variation at upper levels of the marsh. This trend was not so clearly detected in phosphorus levels. It is not easy to compare soil nutrient levels with those used in the greenhouse experiments because the values for the former include a proportion that is not available for plant growth. Field levels are nevertheless low. The majority of the analysed soil samples had total nitrogen ranging from 0.09% - 0.29% compared with fertile inland soils with values of 0.4% - 0.6%.

Populations of *Salicornia* collected from sites on the lower region of two marshes (Warham, Wells - next to the sea, Norfolk and Northney, Hayling Island) with very different soil nitrogen levels showed corresponding variation in each of some 7 morphological characters, with increased growth being found every time in the sites with higher nitrogen. In contrast, lower populations from a third marsh (Shingle Street, Suffolk), at sites with very similar nitrogen levels, show very little variation in these same characters. These observations reinforce the conclusions from the greenhouse experiments that nitrogen

is a limiting factor for the growth of *Salicornia*.

Field studies : chromatography of field populations:-

Field samples of *Salicornia* from four salt marshes were also analysed for their phenolic glycosides, using the same technique as was employed earlier for cultivated material. These showed a broad division into lower and upper samples, and the scatter diagram from the Principal Component Analysis showed the plants aggregating into two areas on the plot, but it did not provide a sharp dividing line. Such aggregation is almost certainly, because of differences in proportion of diploid and tetraploid plants at the two levels of the marsh, these having already been shown to be approximately separable in cultivated material. The study also revealed that glycosides complement differs slightly from marsh to marsh, supporting the suggestion that each marsh population has, to some extent, its own genetic (and so physiological) constitution.

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REFERENCES

ABRAHAM Fahn and TOVA-AREZEE (1959). Vascularization of articulated Chenopodiaceae and the nature of their fleshy cortex. *Amer. J. of Botany, 46* : 330 - 338.

ADAMS, D.A. (1963). Factors influencing vascular plant zonation in North Carolina salt marshes. *Ecology, 44* : 445-456.

ALBERT, R. (1975). Salt regulation in halophytes. *Oecologia (Berl.), 21* : 57-71.

ALSTON, R.E. and TURNER, B.L. (1963). *Biochemical Systematics.* Prentice Hall, Inc, Englwood Cliffs, N.J.

ARNON, D.I. and GROSSENBACHER, K.A. (1947) Nutrient culture of crops with the use of synthetic ion-exchange materials. *Soil Sci., 63* : 159-182.

ASTON, J.L. and BRASHAW, A.D. (1966). Evolution in closely adjacent plant populations II *Agrostis stolonifera* in maritime habitats. *Heredity, 21* : 649-664.

AUSTENFELD, F.R. (1974). The effect of NaCl and other alkaline salts on the nitrate reductase activity of *Salicornia europaea* L.. *Z. pflanzenphysiol. Bd., 71* : 288-296.

AUSTENFELD, F.R. (1976). The effect of various alkaline salts on the glycolate oxidase of *Salicornia europaea* and *Pisum satisum* in vitro. *Physiol. Plant., 36* : 82-87.

AUSTIN, M.P. and ORLOCI, L. (1966). Geometric models in ecology. II An evaluation of some ordination techniques. *J. of Ecology, 54* : 217 - 227.

BABINGTON, C.C. (1904). *Manual of British Botany.* P. 350. 9th ed. by H. and J. Groves. Gurney and Jackson, London.

BALL, P.W. (1960a) Collection and preservation of *Salicornia. Proc. B.S.B.L. 3* : 392-393

BALL, P.W. (1960b). *The Experimental Taxonomy of Salicornia.* Unpubl. Ph.D. thesis, University of Leicester.

BALL, P.W. (1964). *Salicornia* L., pp. 101-102. In *Flora Europaea.* Vol. 1. Eds. Tutin, T.G., Heywood, V.H., Burges, N.A., Valentine, D.H., Walters, S.M., Webb, D.A. Cambridge University Press, Cambridge.

BALL, P.W. and BROWN, K.G. (1970). A bio-systematic and ecological study of *Salicornia* in the Dee Estuary. *Watsonia, 8* : 27-40.

BALL, P.W. and Tutin, T.G. (1959). Notes on annual species of *Salicornia* in Britain. *Watsonia, 4* : 193-205.

BATALIN, A. (1876). Cultur der Salzpflanzen. *Regel, Gartenflora, 28.*

BATE-SMITH, E.C. (1954). Leuco-Anthocyanins. 1 - Detection and identification of anthocyanidins formed from Leuco-Anthocyanins in plant tissues. *Biochem. J., 58* : 122-132.

BATE-SMITH, E.C. (1962). The phenolic constituents of plants and their taxonomic significance. *J. Linn. Soc. (Bot.) 58* : 95-172.

BAUMEISTER, W. and SCHMIDT, L. (1962). Uber die Rolle des Natriums in pflanzlichen Stoffwechsel. *Flora oder Allgemeine Botanische Zeitung, 152* : 24-56.

BAUMGARTEL, O. (1917). Die Anatomie der Gattung *Arthrocnemum* Moqu. [The anatomy of the genus *Arthrocnemum* Moqu]. *Sitzungsber. K. Akad. Wiss. Wien (Math - Naturw). KI. 126* : 41-74.

BAXTER, W. (1839). *British Phaenogamous Botany.* Oxford.

BENTHAM, G. (1858). *Handbook of the British Flora.* Lovell Reeve, Ashford, Kent.

BRADSHAW, A.D. (1965). Evolutionary significance of phenotypic plasticity in plants. *Advances in Genetics, 13* : 115-155.

BREHM, B.C. and ALSTON, R.E. (1964). A chemotaxonomic study of *Baptisia leucophaea* Var. *laevicaulis* (Leguminosae) *Amer. J. Bot., 51* : 644-650.

BRERETON, A.J. (1971). The structure of the species population in the initial stages of salt-marshe succession. *J. of Ecol., 59* : 321-328.

BUTCHER, R.W. (1961). *A new Illustrated British Flora,* pp. 499-503. Vol. 1. Leonard Hill (Books) Ltd., London.

BUTCHER, R.W. and STRUDWICK, F.E. (1930). *Further Illustrations of British Plants.* 1st ed. L. Reeve & Co., Ltd., Ashford Kent.

CARNOY, J.B. (1886). *La Cellule, 3* : 1.

CHAPMAN, V.J. (1936a). The halophyte problem in the light of recent investigations. *Q. Rev. Biol., 11* : 209-220.

CHAPMAN, V.J. (1936b). *Salt Marshes and Salt Deserts of the World.* Leonard Hill, London.

CHAPMAN, V.J. (1938). Studies in salt marsh ecology. Section I - III. *J. of Ecol., 26* : 144-179.

CHAPMAN, V.J. (1941). Studies in salt marsh ecology. Part VIII. *J. of Ecol., 29* : 68-82.

CHAPMAN, V.J. (1942). The new perspective in the halophytes. *Q. Rev. Biol., 17* : 291-311.

CHAPMAN, V.J. (1960). *Salt Marshes and Salt Deserts of the World.* Leonard Hill, London.

CHAPMAN, V.J. (1964). *Coastal Vegetation.* Pergamon press, Oxford.

CHAPMAN, V.J. (1966). Vegetation and salinity, pp. 23-42. In *Salinity and Aridity,* new approaches to old problems. Ed. by H. Boyko. Junk, The Hague, Netherlands.

CHAPMAN, V.J. (1976). *Coastal Vegetation.* 2nd ed. Pergamon press Ltd., Great Britain.

CLAPHAM, A.R., TUTIN, T.G. and WARBURG, E.F. (1962). *Flora of the British Isles.* 2nd ed. Cambridge University press Cambridge.

COOK, M.A. (1911). Observations on *Salicornia australis. Trans Proc. New Zealand Institute, Art, XXX VII* : 349-362.

DALBY, D.H. (1955a). Some variation in *Salicornia* and its significance, pp. 134-135. In *Species Studies in the British Flora.* Ed. by J.E. Lousley, London.

DALBY, D.H. (1955b). Field Meetings 1954, Shingle Street. *Proc. B.S.B.I., 1* (4) : 550-551.

DALBY, D.H. (1956). *The Nature of Variation in the British Annual Glassworts (Salicornia* spp.). Unpubl.Ph.D. thesis, University of London.

DALBY, D.H. (1962). Chromosome number, morphology, and breeding behaviour in the British *Salicornia. Watsonia, 5* : 150-162.

DALBY, D.H. (1963). Seed dispersal in *Salicornia pusilla. Nature (Lond.), 199* : 197-198.

DAVIS, D.H. and HEYWOOD, V.H. (1973). *Principles of Angiosperm Taxonomy.* Krieger, New York.

DeFRAIN, E. (1912). The anatomy of the genus *Salicornia. J. Linn. Soc. (Bot.), London., 41* : 317-348.

DILLENIUS, J.J. (1724). In Ray, J., *Synopsis Methodica Stirpium Britannicarum.* Ed. 3.

DODOENS, R. (1554). Dan Kali, pp. ciiij - CV. In *Cruÿde Boeck.* Antverpiae.

DREIDING, A.S. (1961). The betacyanins, a class of red pigments in the Centrospermae, pp. 194-211. In *Recent Development in the Chemistry of Natural Phenolic Compounds.* Proceeding of the plant phenolic group symposium. Ed. by Ollis, W.D. Pergamon press, Oxford.

DUMORTIER, B.C. (1868). Bouquet du littoral Belg. *Bull. Soc. Bot. Belg., 7* (quoted in Townsend F. 1904).

DURRANT, A. (1972). Studies on reversion of induced plant weight changes in flax by out-crossing. *Heredity, 29* : 71-81.

DUVAL-JOUVE, J. (1868). Des *Salicornia* de l'Herault. *Bull. Soc. Bot. Fr. 15* : (Quoted in Townsend, F. 1904).

ELLISON, W.L., ALSTON, R.E. and TURNER, B.L. (1962). Methods of presentation of crude biochemical data for systematic purposes, with particular reference to the genus *Bahia* (Compositae) *Am. J. Bot., 49* : 599-604.

ERDTMAN, H. (1958). Conifer chemistry and taxonomy of conifers. *Proc. 4th Int. Congr. Biochem., 2* : 1 - 28.

FERGUSON, L.K. (1964). Notes on the stigma morphology and flowering behaviour in British *Salicornia. Watsonia, 6* : 25 - 27.

FLOWER, T.J. (1972). The effect of sodium chloride on enzyme activities from four halophyte species of Chenopodiaceae. *Phytochemistry 11* 1881-1886.

GANONG, W.F. (1903). Vegetation of the Bay of Fundy marshes. *Bot. Gaz., XXXV* : 357.

GIFFORD, G.F. and NELSON, E.D. (1965). Uptake of Na by intact seeds. *New phyto., 64* : 360 - 365.

GOLDBERG, E.D. (1963). The oceans as a chemical system, pp. 3-25. In *The Sea.* Vol. 2. Ed. by Hill, M.N., John Wiley and Sons, New York.

GOOD, R.E. (1972). Salt marsh production and Salinity. *Bull. Ecol. Soc. Amer., 53* : 22 (abstract).

GOOD, R.E. (1974). *The Geography of the Flowering Plants.* 4th ed. Longmans, London.

GOODMAN, M.M. and PATERNIANI, E. (1969). The races of Maize. III, Choices of appropriate characters for racial classification. *Econ. Bot., 23* : 256 - 273.

GRAM, K. (1922). In *Dansk Ekskursions - Flora.* Ed. by Raunkiaer, C.C. 4 Undgove. Gyldendals Forlagstrykkeri, København Denmark.

GRAM, K. (1934). *Salicornia*, pp. 108-109. Ibid. 5 Undgove. København, Denmark.

GRAY, A.J. (1974). Gene ecology of salt marsh plants. *Hydrol. Bull.*, *8* : 152-165.

GRAY, A.J. and BUNCE, R.C. (1972). The ecology of Morecombe Bay. VI Soils and vegetation of the salt marshes : a multivariate approach. *J. App. Ecol.*, *9* : 221-232.

GRAY, S.F. (1821). *A natural arrangement of British Plants* including those cultivated for use, with an introduction to Botany 2 Vol [in 3] illust. London.

GREENWAY, H. and OSMOND, C.B. (1972). Salt responses of enzymes differing in salt tolerance. *Plant Physiol.*, *49* : 256-259.

GREGOR, J.W. (1930). Experiments on the genetics of wild populations, 1. *Plantago maritima. J. Genet.*, *22* : 15-25.

GREGOR, J.W. (1946) Ecotypic differentiation. *New Phyto.*, *60* : 184-206.

GRISEBACH, H. (1961). Biosynthesis of Isoflavones, pp. 59-73. In *Recent Developments in the Chemistry of Natural Phenolic Compounds*. Ed. by Ollis, E.D. Pergamon press, New York.

GUPPY, H.B. (1917). *Plant Seeds and Currents in the West Indies and Azores*. Macmillan, London.

HALKET, A.C. (1915). The effect of salt on the growth of *Salicornia*. *Ann. Bot.*, *29* : 143-154.

HALKET, A.C. (1928). The morphology of *Salicornia* - an abnormal plant. *Annals of Botany, Vol. XLII No. CLXVI* : 525-530.

HALL, J.L. and FLOWER, T.J. (1973). The effect of salt on protein synthesis in the halophyte *Suaeda maritima*. *Planta (Berl.)*, *110* 361-368.

HAMBLER, D.J. (1954). Chromosome numbers in British *Salicornia*. *Nature (Lond.)*, *173* : 547.

HAMBLER, D.J. (1955). Some observations *on Salicornia Proc. B.S.B.I. 1* 385 - 386.

HANNON, M. and BRADSHAW, A.D. (1968). Evolution of salt tolerance in two co-existing species of grasses. *Nature (Lond.), 220* 1342-1343.

HANSEN, D.J. and WEBBER, D.J. (1975). Environmental factors in relation to the salt content of *Salicornia pacifica*, Var. *Utahensis*. *Great Basin Nat., 35* : 86-96.

HARBONE, J.B. (1973a). Flavonoids as systematic markers. *Nobel Symp., 25* : 103-115.

HARBONE, J.B. (1973b). *Phytochemical Methods*. Chapman and Hall Ltd., London.

HARNEY, P.M. and GRANT, W.F. (1965). A polygonal presentation of chromatographic investigations on the phenolic content of certain species of *Lotus*. *Can. J. Genet. Cytol. 7* : 40-51.

HASON-PORATH, E. and POLJAKOFF-MAYBER, A. (1969). The effect of salinity on the malic dehydrogenase of pea roots. *Plant Physiol., 44* : 1030-1034.

HEIMER, Y.M. (1973). The effect of sodium chloride, potassium chloride and glycerol on the activity of nitrate reductase of a salt tolerant and two non-tolerant plants. *Planta., 113* : 279-381.

HESLOP-HARRISON, J. (1955). *New Concepts in Flowering Plant Taxonomy*. Heinemann, -London.

HEWITT, E.J. (1966). *Sand and Water Culture Methods used in the study of nutrition*. Rev. 2nd ed. Farnham Royal, Bucks, Commonwealth Agricultural Bureaux. England.

HILL, J. (1967). The environmental induction of heritable changes in *Nicotiana rustica* parental and selection lines. *Genetics, 55* : 735-754.

HILTON, J.R. (1975). *Studies on the Biology of Salicornia dolichostachya*, Moth., Unpubl. Ph.D. thesis, University of Exeter.

HOAGLAND, D.R. and ARNON, D.I. (1938). In composition of the nutrient solution, pp. 187-246. In Hewitt, E.J. (1966).

HOAGLAND, D.R. and ARNON, D.I. (1950). The water-culture method for growing plants without soil. *Circ. Calif. Agric. Exp. Stat., No. 347.*

HOOKER, J.D. (1830). *The English Flora*, London.

HOOKER, J.D. (1884). *The Student's Flora of the British Isles* 3rd. ed. MacMillan and Co., London.

HUDSON, W. (1762). *Flora Anglica*, exhibens Plantas per regnum Angliae sponte crescentes, & C. pp. XV, 506. London

JEFFERIES, R.L. (1977). Growth responses of coastal halophytes to inorganic nitrogen. *J. of Ecol., 65* : 847-865.

JENSEN, A. (1974). A method of measuring salt marsh inudation. *Oikos, 25* : 252-254.

KALTSTIKES, P.J. and DEDIO, W. (1970). A thin-layer chromatographic study of the phenolics of the genus *Aegilops*. II - Numerical Chemotaxonomy of the polyploidy species. *Can. J. Bot., 48* 1781-1786.

KELLER, B. (1925). Halophyten - und Xerophytenstudien. *J. of Ecol., 13* : 224-261.

KNUTH, P. (1909). *Handbook of Flower Pollination.* Translated [from the German] by Ainsworth Davis, J.R. Vol. 3. Clarendon Press, Oxford.

KÖNING, D. (1939). Die Chromosomenverhaltnisse der deutschen *Salicornia Planta, 29* : 361-375.

LANGLOIS, J. (1967). Cultures san sol de *Salicornia stricta*, Dumort. *Rev. Gen. Bot., 74* : 176-196.

LEVITT, J. (1972). *Responses of Plants to Environmental Stresses.* Academic Press, New York.

LINNAEUS, C. (1753). *Species Plantarum.* 1st. ed. Holimae.

LINNAEUS, C. (1763). *Species Plantarum.* 2nd. ed. Holimae.

LOBELIUS, M. DE. (1570). *Stripium adversaria nova per facilis Vestigatio.* Purfoot, London.

MABRY, T.J., MARKHAM, K.R., and THOMAS, M.B. (1970). *The Systematic Identification of Flavonoids*. Springer-Verlag, Berlin.

MABRY, T.J., WYLER, H., SASSU, G., MERCIER, M., PARIKH, J. and DREIDING, A.S. (1962). Die Strucktur des Neobetanidins- Über die Konstitution des Randenfarbstoffes Betanin. *Helv. Chim. Acta., 45* : 640.

McCANN, C. (1952). Notes on the genus *Salicornia* L. (Chenopodiaceae). *J. Bomby Nat. Histor. Soc., 50* (4) : 870-873.

McCLURE, J.W. and ALSTON, R.E. (1963). Chromatographic patterns *Am. J. Bot., 50* : 636.

MERT, H.H. and VARDER, Y. (1976). Salinity, osmotic pressure and transpiration relationships of *Salicornia herbacea* in its natural habitat. *Phyton (Austria), 18* : 71 - 78.

METSON, A.J. (1961). *Methods of Chemical Analysis for Soil Survey Samples*. Issued by New-Zealand department of scientific and industrial research. *Soil Bureau, Bul.,* 12.

MOORING, M.T., COPPER, A.W. and SENECO, E.D. (1971). Seed germination response and evidence for height ecophenes in *Spartina alterniflora* from North Carolina. *Amer. J. Bot., 58* : 48-55.

MORSS, W.L. (1927). The plant colonisation of Merse lands in the estuary of the river Nith. *J. of Ecol. 15* : 310-343.

MOSS, C.E. (1911). Some species of *Salicornia. J. of Bot., 49* : 177-185.

MOSS, C.E. (1912). The international phytogeographical excursion in the British Isles. XII - Remarks on the characters and the nomenclature of some critical plants noticed on the excursion. *New phyto., 11* : 398-414.

MOSS, C.E. and SALISBURY, E.J. (1914). *Salicornia,* pp 187-196. In the Cambridge British Flora, Vol. 2. Ed. by Moss, C.E. University Press, Cambridge.

NANNFELATT, J.A. (1955). Något om släktet *Salicornia* i Sverige. *Svensk Bot. Tidskrift, 49* : 97-109.

NORDSTROM, C.G. and SWAIN, T. (1953). The flavonoid glycosides of *Dahlia variabilis*. Part 1 - General introduction. Cyanindin, apigenin and luteolin glycosides from the variety "Dandy". *J. Chem. Soc. 2764.*

OLIVER, F.W. (1907). The Bouch d'Erquy in 1907. *New Phyto., 6* : 244-252.

ORLOCI, L. (1966). Geometric models in ecology. 1. The theory and application of some ordination methods *J. of Ecol., 54* : 193-215.

PATRICK, W.H. Jr. and DELAUNE, R.D. (1976). Nitrogen and phosphorus utilization by *Spartina alterniflora* in a salt marsh in Barataria Bay, Louisiana. *Estuar. Coast. Mar. Sci., 4* : 59-64.

PIGOTT, C.D. (1969). Influence of mineral nutrition of the zonation of flowering plants in coastal salt marshes, pp. 25-35 In *Ecological Aspects of the Mineral Nutritions of Plants.* Ed. by Rorison, I.H. 9th Symp. Br. Ecol. Soc., Blackwell, Oxford.

PURER, E.A. (1942). Plant ecology of the coastal salt marsh lands of San Diego County, California. *Ecol. Monogr., 12* : 81-111.

RANWELL, D.S. (1972). *Ecology of Salt Marshes and Sand Dunes.* 1st. ed. Chapman and Hall Ltd., Great Britain.

RANWELL, D.S. BIRD, E.C., HUBBARD, J.C. and STEBBINGS, R.E. (1964). *Spartina* salt marshes in southern England. V. Tidal submergence and chlorinity in Poole Harbour. *J. of Ecol. 52*: 637-641.

RIBÉREAU-GAYON, P. (1972). *Plant Phenolics.* Oliver and Boyd, Edinburgh.

RIDLEY, H.N. (1930). *The Dispersal of Plants throughout the World.* L. Reeve and Co., Ltd., Ashford, Kent.

RIKLI, M. (1943). Das *Pflanzenkleid der Mittelmeerländer.* Vol. 1. Verlag Hans Huber, Bern.

RUSSELL, E.J. (1957). *The World of the Soil.* Collins, London.

RUSSELL, E.W. (1973). *Soil Conditions and Plant Growth.* 10th ed. William Clowes & Sons, Great Britain.

RYTHER, J.H. and DUNSTAN, W.M. (1971). Nitrogen, phosphorus, and eutrophication in the coastal marine environment. *Science Vol. 171, report No. 3975* : 1008-1013.

SCHISCHKIN, B.K. (1936). Chenopodiaceae, pp. 1-354. In *Flora U.R.S.S.* Vol. 6. Ed. by Komarov, V.L. Acdemiae Scientiarum URSS, Mosqua. Leningrad

SCHRADER, H.A. (1809). Ueber Palla's Hallophyta mit besonderer Rücksicht auf die Gattungen *Salsola* und *Suaeda.* Schrad. *Neue Jour. Bot. 3 (3-4),* 58-92. (Quoted in Uphof, J.C. (1941) Halophytes. *The Bot. Rev., 7* : 1-58).

SCOTT, A.J. (1977). Reinstatement and revision of *Salicorniaceae,* J. Agardh (Caryophyllales). *Bot. J. of the Linn. Soc., 75* 357-374.

SHARROSK, J.T.R. (1967). *A study of Morphological Variation in Halimione protulacoides* (L.) Aell. *in Relation to variation in the Habitat.* Unpubl.Ph.D. thesis, University of Southampton.

SHAW, G.W. (1973). *Chromosome Studies.* Heinemann Educational Books Ltd., London.

SHERMA, A.K. and SHERMA, A. (1972). *Chromosome Techniques Theory and Practice.* 2nd ed. Butterworth and Co. Ltd, London.

SHICHI, H. (1975). *Salicornia europaea* L. Chemical Compounds (its betacyanin structure). Translated from Japanese by The British Library. *Kagaku to Seibutsu (Chemistry and Biology)*, 13 : 701 - 703.

SMITH, J.E. (1797). *English Botany*, t. 415. London.

SMITH, J.E. (1800). *Flora Britannica.* Veneunt Apud J. White, London.

SMITH, J.E. (1813). *English Botany*, t. 2475. London

SMITH, J.E. (1828). *The English Flora.* Vol. 1. 2nd ed. Longman, London.

STALTER, R. and BATSON, W.T. (1969). Transplantation of salt marsh vegetation, Georgetown, South Carolina. *Ecol., 50* : 1087-1089.

STEBBINS, G.L. (1950). *Variation and Evolution in Plants.* Columbia University Press, New York.

STEWART, E.A., Max GRIMSHAW, H. PARKINSON, J.A. and QUARMBY, C. (1974) *Chemical Analysis of Ecological Materials.* Ed. by Stewart, E.A. Blackwell Scientific Publications, Oxford.

STEWART, G.R., LEE, J.A. and OREBAMJO, T.O. (1972) Nitrogen metabolism of halophytes. I - Nitrate reductase activity in *Suaeda maritima. New Phytol., 71* : 263-267.

STEWART, G.R., LEE, J.A. and OREBAMJO, T.O. (1973). Nitrogen metabolism of halophytes. II - Nitrate availability and utilization. *New Phytol., 72* : 539-546.

TOWNSEND, F. (1904). *Flora of Hampshire* (including the Isle of Wight). 2nd. ed., appendix. L. Reev and Co., London.

TUTIN, T.G. (1953). *Salicornia.* A display of ignorance. *Proc. B.S.B.L., 1* : 99.

TYLER, G. (1967). On the effect of phosphorus and nitrogen, supplied to Baltic Shore - Meadow vegetation, *Botaniska Notiser, 120* : 433-447.

TYLER, G. (1971a). Distribution and turnover of organic matter and minerals in a shore meadow ecosystem. *Oikos, 22* : 265 - 291.

TYLER, G. (1971b). Studies in the ecology of Baltic sea-shore meadows. III - Hydrology and Salinity of Baltic sea-shore meadows. *Oikos, 22* : 1 - 20.

UNGER, I.A. (1970). Species - soil relationships on sulphate dominated soils in South Dakota. *Am. Midl. Nat., 83* : 345 - 357.

UNGER, I.A., HOGAN, W. and McCLELLAND, M. (1969). Plant communities of saline soils at Lincoln, Nebraska. *Am. Midl. Nat., 82* : 564 - 577.

VALIELA, I. and TEAL, J.M. (1974). Nutrient limitation in salt marsh vegetation, pp. 574 - 563. In *Ecology of Halophytes.* Ed. by Reimold, R.J. and Queen, W.H. Academic Press, Inc., New York.

VAN EIJK, M. (1939). Analyse der Wirkung des NaCl auf die Entwicklung, Sukkulenz und Transpiration bei *Salicornia herbacea* sowie Untersuchugen Uber den Einfluss der Salzaufnahme auf die Wurzelatmung bei *Aster tripolium. Rec. Trav. Bot. Neer., 36* : 559 - 657.

VAN STEENIS, C.G.G.J. (1973). Modification of the phenotype, pp 336-349 In *Principles of Angiosperm Taxonomy.* Ed. by Davis, P.H. and Heywood, V.H. Krieger, New York.

WADDINGTON, C.H. (1957). *The Strategy of the Genes.* Allen and Unwin, London.

WAISEL, Y. (1972). *Biology of Halophytes.* Academic Press, New York.

WALLACE, T. (1961). *The Diagnosis of Mineral Deficiencies in plants by Visual Symptoms;* a colour atlas and guide. 3rd. ed. H.M. Stationery Office, London.

WEAVER, J.E. and CLEMENTS, F.F. (1938). *Plant Ecology*. 2nd ed. McGraw-Hill, New York.

WEBB, K.L. (1966). Nacl effects on growth and transpiration in *Salicornia bigelovii* a salt marsh halophyte. *Plant and Soil*, *24* (2) : 261-268.

WEBBER, D.J., Rasmussen, H.R. and Hess, W.M. (1977). Electron microprobe analyses of salt distribution in the halophyte *Salicornia pacifica* var.*utahensis*. *Can. J. of Bot.*, *55* : 1516-1523.

WEIMBERGE, R. (1967). The effect of sodium chloride on the activity of malt dehydrogenase from pea seeds. *J. Biol. Chem.*, *242* 3000 - 3006.

WHITEHEAD, F.H. (1962). Experimental studies of the effect of wind on plant growth and anatomy. II - *Helianthus annuus*. *New Phyto.*, *61* : 59-62.

WIEHE, P.O. (1935). A quantitative study of the influence of tide upon populations of *Salicornia europaea*. *J. of. Ecol. 23* : 323-333.

WILLMOTT, A.J. (1939). *Salicornia*, pp. 553-559. In *Flora of Devon*. Ed. by Martin, W.K. and Fraser, G.T. Arbroath.

WITHERING, W. (1776). *Botanical Arrangement*. Birmingham.

WOODS, J. (1851). On the various forms of *Salicornia*. *Proc. Linn. Soc.*, *2* : 109-113.

APPENDIX TABLES

Table A3.1. Measurements of the vegetative characters for the plants belonging to *Salicornia europaea* type, (from different localities). Growth experiment 1974.

1. Shoot length

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
2B	12	40.90	59.40	52.99	±5.27	42.46	63.52	27.708
4B	11	30.50	41.00	35.87	±2.76	30.35	41.39	7.626
6B	15	51.20	56.20	53.52	±1.27	50.99	56.05	1.602
8A	15	18.00	39.40	31.89	±6.26	19.37	44.40	39.197
9B	15	56.00	68.20	62.15	±2.86	56.42	67.87	8.198
16B	4	39.30	42.30	40.85	±1.27	38.31	43.39	1.610

2. Total number of primary branches from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
2B	12	54	76	68.33	±7.08	54.18	82.48	50.060
4B	11	38	44	40.55	±2.38	35.78	45.30	5.673
6B	15	18	46	54.80	±2.91	48.98	60.62	8.457
8A	14	12	56	38.36	±14.02	10.32	66.39	196.555
9B	15	52	66	61.20	±3.36	54.47	67.93	11.314
16B	4	60	64	63.00	±2.00	59.00	67.00	4.00

3. Number of sterile segments in the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
2B	12	23	40	34.58	±4.59	25.42	43.75	20.992
4B	11	19	24	21.46	±1.29	18.87	24.04	1.673
6B	15	26	31	28.13	±1.50	25.12	31.14	2.267
8A	15	6	29	18.73	±6.70	5.33	32.14	44.924
9B	15	28	38	31.80	±1.86	28.08	35.52	3.457
16B	4	28	33	31.25	±2.22	26.82	35.69	4.917

Table A 3.1 Continued

4. Terminal spike length

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
2B	12	3.3	6.2	5.29	±0.96	3.37	7.22	9.926
4B	11	0.8	3.2	1.85	±0.89	0.07	3.62	0.785
6B	15	8.4	5.5	4.52	±0.59	3.35	5.69	0.342
8A	15	0.4	10.8	3.03	±3.00	-2.97	9.04	9.00
9B	15	4.0	6.00	5.27	±0.49	4.28	6.26	0.245
16B	4	3.2	5.9	4.03	±1.27	1.49	6.56	1.609

5. Number of fertile segments in the terminal spike.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
2B	12	12	25	21.75	±4.18	13.39	30.11	17.478
4B	11	4	16	9.90	±3.99	1.94	17.88	15.89
6B	15	17	26	21.07	±2.91	15.24	26.89	8.495
8A	15	3	38	13.67	±10-30	-6.95	34.28	106.238
9B	15	17	26	21.87	±2.39	17.09	26.64	5.695
16B	4	16	24	18.00	±4.00	10.00	26.00	16.000

6. Length of the uppermost branch from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
2B	12	3.0	4.8	3.99	±0.53	2.94	5.04	0.280
4B	11	2.0	5.7	3.45	±1.36	0.73	6.16	1.849
6B	15	3.8	5.1	4.52	±0.49	3.54	5.50	0.240
8A	14	0.4	4.2	1.73	±1.28	-0.83	4.28	1.638
9B	15	3.8	5.5	4.6	±0.52	3.58	5.64	0.270
16B	4	2.9	3.2	3.08	±0.15	2.78	3.38	0.023

Table A.3.1 Continued:-

7. Length of the lowermost branch from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
2B	9	22.5	50.8	36.63	±7.43	21.78	51.49	55.1900
4B	10	14.7	32.0	21.51	±5.99	9.51	33.50	35.988
6B	15	28.5	37.3	32.67	±3.10	26.47	38.87	9.605
8A	13	6.9	30.0	16.50	±7.08	2.36	30.65	50.016
9B	12	32.0	56.2	46.85	±7.44	31.98	61.72	55.285
16B	4	24.2	34.8	29.33	±4.67	19.98	38.67	21.849

8. Angle of the uppermost branch with the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
2B	12	20	40	29.17	±6.34	16.49	41.84	40.152
4B	11	30	50	39.09	±5.39	28.30	49.88	29.090
6B	15	25	30	28.67	±2.29	24.08	33.24	5.238
8A	14	10	25	14.29	±6.20	2.61	26.96	34.066
9B	15	20	30	25.00	±3.78	17.44	32.56	14.286
16B	4			50.00	±8.17	33.67	66.33	66.667

9. Angle of the lowermost with the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
2B	9	40	50	43.33	±4.33	34.67	51.99	18.750
4B	11	40	50	49.09	±3.02	43.06	55.12	9.090
6B	15	30	50	34.00	±6.33	21.35	46.65	40.000
8A	14	20	60	50.36	±10.14	30.08	70.63	102.74
9B	12	20	40	28.33	±7.79	12.76	43.90	60.606
16B	4	50	65	58.13	±6.25	45.63	70.63	39.063

Table A 3.1 Continued:-

10. Length of the sterile segment below the terminal spike

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
2B	12	0.2	0.8	0.48	±0.20	0.08	0.89	0.042
4B	11	0.4	1.1	0.64	±0.22	0.20	1.07	0.047
6B	15	0.5	1.2	0.93	±0.19	0.54	1.32	0.038
8A	15	0.2	1.6	0.63	±0.40	-0.17	1.44	0.161
9B	15	1.0	1.4	1.21	±0.15	0.91	1.51	0.023
16B	4	0.4	0.8	0.58	±0.20	0.16	0.99	0.043

11. Length of the sterile segment in the lower part of the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
2B	12	1.2	1.7	1.37	±0.18	1.01	1.72	0.032
4B	11	1.5	1.6	1.52	±0.04	1.44	1.59	0.002
6B	15	1.6	2.0	1.73	±0.12	1.51	1.96	0.012
8A	15	1.2	1.6	1.45	±0.11	1.24	1.67	0.011
9B	15	1.7	1.8	1.76	±0.05	1.66	1.86	0.003
16B	4	1.0	1.3	1.18	±0.15	0.88	1.48	0.023

Table A.3.2 Measurements of the vegetative characters for the plants belonging to *Salicornia europaea* type, (from one population). Growth experiment 1974.

1. Shoot length.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
1B	15	40.20	54.30	47.20	±3.91	39.39	55.02	15.270
2A	10	36.90	50.40	45.05	±10.79	34.26	55.84	29.092
5B	15	34.70	42.00	38.01	±2.08	33.85	42.17	4.328
7B	15	38.50	55.50	49.27	±5.15	38.98	59.56	26.470
11A	10	21.20	51.60	36.93	±11.28	14.37	59.49	127.227
15B	10	35.00	50.00	43.20	±4.00	35.19	51.21	16.044

2. Total number of primary branches from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
1B	9	42	75	53.13	±8.26	36.63	69.64	68.124
2A	10	44	72	54.10	±8.55	37.01	71.19	72.989
5B	11	20	28	23.18	±2.49	18.22	28.15	6.164
7B	15	38	58	49.87	±6.74	36.39	63.34	45.409
11A	10	20	76	47.50	±20.97	5.56	89.44	439.833
15B	10	40	72	47.20	±9.75	27.70	66.70	95.067

3. Number of sterile segments in the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
1B	15	21	30	26.07	±3.82	20.24	31.89	8.495
2A	10	20	33	27.10	±4.84	17.42	36.78	23.433
5B	15	9	15	10.60	±1.64	7.32	13.88	2.686
7B	15	20	30	25.07	±3.58	17.92	32.22	12.781
11A	10	9	38	23.90	±10.03	3.85	43.95	100.544
15B	10	20	31	25.50	±4.25	17.00	33.99	18.056

Table A.3.2 Continued:-

4. Terminal spike length.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
1B	15	2.8	4.7	3.63	±0.54	2.54	4.72	0.296
2A	10	1.4	3.6	2.36	±0.64	1.09	3.63	0.405
5B	15	3.0	9.2	5.89	±2.14	1.63	10.16	4.552
7B	15	2.4	9.3	7.42	±1.87	3.69	11.15	3.472
11A	10	0.9	5.1	2.21	±1.30	-0.39	4.82	1.699
15B	10	1.9	4.3	3.29	±0.69	1.90	4.67	0.479

5. Number of fertile segments in the terminal spike.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
1B	15	14	22	17.80	±2.43	12.95	22.65	58.857
2A	10	9	19	13.60	±3.47	6.66	20.54	120.44
5B	15	16	38	26.53	±7.12	12.29	40.77	50.695
7B	15	11	39	31.80	±8.01	15.78	47.82	640.171
11A	10	6	27	11.80	±6.27	-0.74	24.34	39.289
15B	10	10	22	16.70	±3.47	9.77	23.63	12.011

6. Length of the upper most branch from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
1B	15	2.0	3.2	2.54	±0.41	1.72	3.36	0.168
2A	10	0.6	2.3	1.42	±0.50	0.42	2.42	0.250
5B	15	1.7	7.3	3.86	±1.67	0.52	7.19	2.789
7B	15	1.7	8.5	6.30	±1.98	2.36	10.25	3.920
11A	10	0.5	5.1	1.52	±1.44	-1.35	4.39	2.074
15B	10	1.2	3.0	2.08	±0.52	1.05	3.11	0.270

Table A.3.2 - Continued:-

7. Length of the lowermost branch from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
1B	8	18.5	36.7	28.69	±5.77	17.15	40.23	33.296
2A	10	6.2	33.6	28.06	±9.39	9.28	46.84	88.185
5B	14	6.3	34.2	13.79	±7.18	-0.56	28.15	51.513
7B	14	24.5	44.0	37.19	±6.85	23.49	50.89	46.932
11A	9	5.9	38.9	19.54	±10.90	-2.25	41.34	118.743
15B	9	20.8	46.5	29.96	±8.79	12.37	47.55	77.348

8. Angle of the uppermost branch with the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
1B	15	30°	50°	46.67	±6.17	34.32	59.01	38.095
2A	10	40°	60°	50.00	±6.24	37.53	62.47	38.889
5B	15	20°	50°	30.83	±9.34	12.16	49.51	87.202
7B	15	25°	50°	32.33	±8.71	15.92	49.75	67.381
11A	10	30°	90°	59.50	±16.74	26.02	92.98	280.278
15B	10	50°	70°	56.25	±8.27	39.70	72.79	68.403

9. Angle of the lowermost branch with the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
1B	15	50	60	52.00	±4.14	43.72	60.28	17.143
2A	10	40	50	48.00	±4.05	39.90	56.09	16.389
5B	14	30	50	39.29	±9.17	20.95	57.62	84.066
7B	14	45	60	48.93	±5.28	38.42	59.48	27.609
11A	9	52.5	90	70.28	±12.78	44.73	95.83	163.194
15B	9	40	55	47.22	±5.66	35.92	58.53	31.944

Table A.3.2 Continued:-

10. Length of the sterile segment below the terminal spike.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
1B	15	0.5	1.2	0.62	±0.18	0.26	0.98	0.033
2A	10	0.3	0.6	0.55	±0.15	0.25	0.85	0.023
5B	15	0.4	1.8	1.08	±0.50	0.07	2.09	0.255
7B	15	0.4	1.0	0.77	±0.24	0.29	1.24	0.57
11A	10	0.2	0.6	0.40	±0.16	0.09	0.71	0.024
15B	10	0.3	0.7	0.51	±0.14	0.24	0.78	0.019

11. Length of the sterile segment in the lower part of the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
1B	15	1.3	2.0	1.59	±0.22	1.17	2.02	0.045
2A	10	1.5	1.8	1.60	±0.12	1.37	1.83	0.013
5B	15	1.8	2.2	2.05	±0.16	1.74	2.36	0.024
7B	15	1.5	1.8	1.66	±0.09	1.49	1.83	0.007
11A	10.	1.3	2.2	1.58	±0.25	1.08	2.08	0.062
15B	10	1.4	1.9	1.74	±0.15	1.44	2.04	0.023

Table A 3.3 Measurements of the vegetative characters for the plants belonging to *Salicornia dolichostachya* type, (from different localities). Growth experiment 1974.

1. Shoot length.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
10B	9	41.00	57.00	49.42	±5.18	39.07	59.78	26.814
11B	11	42.50	51.10	48.14	±2.99	42.14	54.13	8.967
12B	8	34.40	50.40	41.54	±4.74	32.05	51.02	22.497
13B	15	39.50	55.50	49.44	±4.45	40.55	58.33	19.775
14A	15	44.80	60.00	52.20	±4.50	43.21	61.20	20.235

2. Total number of primary branches from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
10B	9	46°	66	58.22	±9.52	45.19	77.25	42.44
11B	11	46	60	56.00	±4.65	46.70	65.29	21.60
12B	7	42	58	50.29	±6.15	37.97	62.59	37.905
13B	15	46	74	62.53	±7.84	46.86	78.20	61.409
14A	15	48	80	61.20	±9.59	42.03	80.37	91.886

3. Number of sterile segments in the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
10B	9	21	34	28.78	±4.24	20.30	37.25	17.944
11B	11	27	33	30.09	±2.26	25.58	34.60	5.090
12B	8	23	36	27.50	±5.29	16.92	38.08	28.000
13B	15	24	39	33.13	±3.67	25.81	40.46	13.409
14A	15	21	42	31.40	±5.57	20.27	42.53	30.971

Table A 3.3 Continued:-

4. Terminal spike length.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
10B	9	1.9	7.5	4.50	±1.64	1.23	7.77	2.668
11B	11	2.4	7.5	4.54	±1.52	1.50	7.57	2.293
12B	8	3.0	5.7	4.45	±0.94	2.57	6.33	0.883
13B	15	2.6	7.5	4.68	±1.51	1.65	7.70	2.289
14A	15	0.7	5.0	2.95	±1.36	0.23	5.67	1.843

5. Number of fertile segments in the terminal spike.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
10B	9	9	26	17.67	±5.27	7.13	28.20	27.750
11B	11	12	28	18.82	±5.04	8.75	28.89	25.364
12B	8	17	23	19.50	±3.67	12.17	26.83	13.429
13B	15	9	25	16.80	±4.65	7.50	26.09	21.60
14A	15	4	23	13.60	±6.05	1.51	25.69	36.543

6. Length of the uppermost branch from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
10B	9	1.4	5.9	4.13	±1.37	1.39	6.87	1.877
11B	11	1.7	5.8	3.89	±1.23	1.43	6.35	1.513
12B	8	2.0	5.2	3.99	±1.19	1.62	6.36	1.416
13B	15	1.5	5.7	3.84	±1.23	1.36	6.30	1.513
14A	15	1.5	3.6	2.77	±0.79	1.19	4.34	0.624

Table A.3.3 Continued:-

7. Length of thelowermost branch from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
10B	7	21.6	46.2	36.49	±8.25	19.98	52.99	68.121
11B	11	14.6	32.2	23.98	±6.35	11.29	36.67	40.262
12B	7	18.0	38.8	30.29	±6.84	16.60	43.97	46.79
13B	15	15.2	51.7	33.68	±25.20	84.77	58.88	158.802
14A	13	29.7	51.7	37.73	±5.87	26.00	49.46	34.376

8. Angle of the uppermost branch with the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
10B	9	25°	35	29.44	±3.00	23.44	35.45	9.028
11B	11	30°	50°	40.90	±5.89	30.12	52.69	29.090
12B	8	20°	30°	23.75	±5.18	13.39	34.10	26.79
13B	15	35°	50°	40.00	±7.79	24.42	55.58	60.71
14A	14	25°	50°	34.64	±9.50	15.64	53.64	90.247

9. Angle of the lowermost branch with the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
10B	7	45.0	50	47.14	±3.93	39.28	55.01	15.476
11B	11	40.0	60	49.77	±4.54	40.70	58.84	20.568
12B	7	45.0	55	50.71	±3.46	43.81	57.62	11.905
13B	15	50	60	52.67	±4.19	44.33	61.05	17.381
14A	12	35	60	50.00	±6.03	37.94	62.06	36.364

Table A 3.3 Continued:-

10. Length of the sterile segment below the terminal spike.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
10B	9	0.5	1.4	0.78	±0.32	0.14	1.42	0.102
11B	11	0.5	1.1	0.76	±0.17	0.42	1.09	0.029
12B	8	0.5	0.9	0.74	±0.14	0.46	1.02	0.019
13B	15	0.3	1.1	0.69	±0.25	0.19	1.19	0.621
14A	15	0.3	0.8	0.48	±0.16	0.17	0.79	0.25

11. Length of the sterile segment in the lower part of the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
10B	9	1.3	1.8	1.46	±0.15	1.15	1.76	0.023
11B	11	1.5	1.8	1.70	±0.09	1.52	1.89	0.009
12B	8	1.2	1.6	1.40	±0.13	1.14	1.66	0.017
13B	15	1.1	1.5	1.23	±0.13	0.97	1.48	0.016
14A	15	1.3	1.8	1.47	±0.12	1.24	1.70	0.014

Table A.3.4 Measurements of the vegetative characters for the plants belonging to *Salicornia dolichostachya* type, (from one population). Growth experiment 1974.

1. Shoot length

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
3A	9	28.50	45.00	34.86	±6.09	22.69	47.01	36.950
4A	9	34.00	40.70	35.92	±2.68	30.57	41.28	7.167
7A	15	29.00	43.00	35.93	±3.58	28.78	43.08	12.779
12A	8	23.50	35.00	30.86	±4.22	22.44	39.29	17.751
15A	8	22.20	38.50	28.55	±10.37	18.18	38.92	26.889

2. Total number of primary branches from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
3A	-	-	-	-	-	-	-	-
4A	9	40.00	52.0	42.67	±7.35	27.97	57.36	54.000
7A	15	37.00	52.00	43.40	±4.33	34.76	52.05	18.686
12A	8	24.00	48	32.50	±8.67	15.16	49.84	75.143
15A	7	28.00	50.00	38.86	±7.67	23.52	54.19	58.809

3. Number of sterile segments in the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
3A	-	+	-	-	-	-	-	-
4A	9	18	27	22.33	±4.80	17.54	27.13	5.750
7A	15	17	28	21.40	±7.81	13.59	29.21	15.250
12A	8	11	25	18.63	±4.75	9.13	28.12	22.554
15A	7	12	24	18.86	±7.04	4.79	32.93	49.476

Table A 3.4 Continued:-

4. Terminal spike length

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
3A	9	2.0	7.0	4.19	±2.09	0.01	8.36	4.359
4A	9	1.5	3.5	2.43	±0.89	0.65	4.22	0.795
7A	15	0.9	4.0	2.45	±0.90	0.64	4.25	0.813
12A	8	1.5	4.0	2.74	±0.99	0.76	4.71	0.974
15A	7	1.2	4.3	2.77	±1.10	0.56	4.98	1.219

5. Number of fertile segments in the terminal spike.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
3A	9	12	27	17.22	±5.83	5.57	28.88	33.944
4A	9	9	19	13.44	±3.94	5.56	21.32	15.524
7A	15	7	19	13.33	±3.70	5.94	20.73	13.667
12A	8	8	16	12.50	±3.38	5.74	19.26	11.429
15A	7	6	19	12.29	±4.96	2.37	22.20	24.571

6. Length of the uppermost branch from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
3A	-	-	-	-	-	-	-	-
4A	9	0.6	2.4	1.55	±0.68	0.20	2.90	0.462
7A	15	0.4	3.0	1.58	±0.76	0.07	3.09	0.578
12A	5	0.2	2.0	1.36	±0.90	-0.45	3.17	0.810
15A	7	0.8	3.5	1.80	±1.05	-0.29	3.89	1.103

Table A.3.4 Continued:-

7. Length of the lowermost branch from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
3A	9	13.2	39.0	25.30	±8.25	8.79	41.80	68.085
4A	9	15.6	34.6	27.17	±7.19	12.79	41.55	51.708
7A	12	10.1	27.4	18.06	±5.32	7.43	28.69	28.237
12A	8	13.9	28.0	23.09	±4.92	13.26	32.92	24.164
15A	5	9.3	32.1	16.56	±9.05	-1.53	34.65	81.828

8. Angle of the uppermost branch with the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
3A	8	45°	90°	70.31	±18.78	32.76	107.87	352.567
4A	8	45	75	54.69	±10.89	32.90	76.47	118.638
7A	15	30	75	52.17	±12.13	27.90	76.43	147.20
12A	5	35	90°	57.00	±30.13	-3.25	117.25	907.500
15A	7	40	80°	57.14	±14.68	27.79	86.50	215.48

9. Angle of the lowermost branch with the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
3A	9	45	67.5	47.50	±8.50	32.50	62.50	56.250
4A	9	47.5	85.0	58.89	±13.98	30.93	86.85	195.486
7A	12	42.5	60.0	55.42	±6.29	42.83	68.00	39.583
12A	7	47.5	52.5	50.36	±2.67	45.01	55.70	7.143
15A	5	50.0	70.0	59.00	±8.95	14.11	76.89	80.000

Table A 3. 4 Continued:-

10. Length of the sterile segment below the terminal spike.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
3A	9	0.6	1.2	0.77	±0.21	0.34	1.19	0.045
4A	9	0.2	0.6	0.40	±0.15	0.10	0.70	0.023
7A	15	0.3	0.7	0.50	±0.15	0.20	0.80	0.022
12A	7	0.4	0.7	0.57	±0.11	0.35	0.79	0.012
15A	7	0.4	1.0	0.64	±0.19	0.26	1.02	0.036

11. Length of the sterile segment in the lower part of the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
3A	9	1.4	1.9	1.59	±0.18	1.24	1.94	0.031
4A	9	1.2	1.5	1.33	±0.09	1.16	1.50	0.008
7A	15	1.2	1.8	1.41	±0.22	0.97	1.85	0.048
12A	8	1.0	1.4	1.28	±0.18	0.93	1.63	0.030
15A	7	1.2	1.4	1.30	±0.08	1.14	1.46	0.007

Table A 3.5 Measurements of the vegetative characters for the plants belonging to *Salicornia ramosissima* type, (from different localities). Growth experiment 1974.

1. Shoot length

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
9A	6	40.00	48.20	45.00	±3.4	38.29	51.80	11.407
10A	10	27.90	36.50	33.85	±2.76	28.32	39.38	7.638
16A	7	26.80	37.00	31.24	±4.02	23.22	39.27	16.093

2. Total number of primary branches from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
9A	6	48	74	65.83	±10.40	45.03	86.63	108.167
10A	10	38	48	44.80	±3.29	38.21	51.39	10.844
16A	7	12	38	25.14	±9.86	5.43	44.86	97.1429

3. Number of sterile segments in the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
9A	6	26	36	33.50	±4.09	25.33	41.68	16.700
10A	10	17	27	23.30	±2.45	18.39	28.20	6.011
16A	7	5	18	12.00	±5.04	1.93	22.07	25.333

4. Terminal spike length

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
9A	6	0.9	2.4	1.48	±0.65	0.19	2.77	0.414
10A	9	0.6	1.8	1.54	±0.48	0.59	2.49	0.225
16A	7	1.8	13.5	5.26	±4.13	-3.01	13.52	17.086

Table A 3.5 Continued:-

5. Number of fertile segments in the terminal spike.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
9A	6	6	12	9.33	±2.50	4.33	14.34	6.267
10A	9	5	12	9.00	±2.24	4.53	13.47	5.000
16A	7	12	42	21.57	±10.69	1.91	42.95	11.429

6. Length of the uppermost branch from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
9A	6	0.5	1.00	0.68	±0.19	0.29	1.07	0.036
10A	10	0.7	1.6	1.02	±0.26	0.49	1.54	0.068
16A	5	1.2	8.5	1.90	±0.49	0.92	2.88	0.240

7. Length of the lowermost branch from the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
9A	6	21.4	36.3	31.22	±5.94	19.33	43.10	35.334
10A	9	8.5	32.7	18.32	±8.12	20.95	34.55	65.832
16A	6	18.2	27.6	22.50	±3.72	15.06	29.94	13.848

8. Angle of the uppermost branch with the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
9A	6	20	50	34.17	±11.14	11.88	56.45	124.167
10A	10	75	90	85.50	±5.99	73.53	97.47	35.833
16A	7	20	30	25.71	±3.46	18.81	32.62	11.905

Table A.3.5 Continued:-

9. Angle of the lowermost branch with the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
9A	6	40	50	47.50	±4.19	39.13	55.87	17.500
10A	10	30	55	45.00	±7.45	30.09	59.90	55.556
16A	6	40	60	50.42	±7.97	34.47	66.36	63.542

10. Length of the sterile segment below the terminal spike.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
9A	6	0.2	0.9	0.40	±0.25	-0.10	0.90	0.064
10A	10	0.2	0.6	0.45	±0.14	0.18	0.72	0.018
16A	6	0.5	1.5	0.87	±0.49	-0.12	1.85	0.243

11. Length of the sterile segment in the lower part of the main axis.

TANK NO.	N	Min	Max	Mean	S.D.	-2S	+2S	Variance
9A	6	1.3	2.0	1.53	±0.26	1.02	2.05	0.067
10A	10	1.2	1.9	1.38	±0.21	0.96	1.80	0.044
16A	7	1.4	1.8	1.53	±0.16	1.20	1.85	0.026

Table A3.6 Shows mean ($\bar{x}$), standard deviation (S.D.) and standard error of the mean (S.E. $\bar{x}$) of stomata length, pollen grain dimension and anther length for plant groups cultivated in 1974. (Measurements expressed as µm)

TANK NO.	Stomata length				Pollen grain dimension				Anther length			
	N	$\bar{x}$	S.D.	S.e.$\bar{x}$	N	$\bar{x}$	S.D.	S.e.$\bar{x}$	N	$\bar{x}$	S.D.	S.e.$\bar{x}$
3A	10	3.05	±0.19	±0.06	9	2.78	±0.17	±0.06	9	57.78	±2.96	±0.99
4A	8	3.08	±0.72	±0.07	7	2.97	±0.08	±0.03	8	49.07	±5.27	±1.86
7A	10	2.88	±0.14	±0.04	10	2.82	±0.12	±0.04	10	62.59	±4.39	±1.39
12A	8	3.08	±0.15	±0.05	7	2.98	±0.03	±0.01	8	67.95	±4.71	±1.67
15A	10	3.33	±0.33	±0.10	7	2.89	±0.07	±0.03	8	56.75	±5.66	±2.00
10B	9	3.39	±0.53	±0.18	9	2.91	±0.09	±0.03	9	56.11	±3.87	±1.29
11B	10	3.54	±0.40	±0.13	9	2.78	±0.16	±0.05	9	56.54	±5.54	±1.85
12B	8	3.45	±0.45	±0.16	10	2.97	±0.07	±0.02	5	62.24	±5.93	±2.65
13B	10	3.69	±0.27	±0.09	8	2.89	±0.09	±0.03	10	60.91	±4.19	±1.33
14A	10	3.47	±0.48	±0.15	8	0.72	±0.22	±0.08	10	62.45	±4.87	±1.54
1B	10	3.62	±0.13	±0.04	9	2.56	±0.18	±0.06	10	40.32	±3.02	±0.96
2A	10	3.04	±0.22	±0.07	10	2.45	±0.24	±0.08	9	42.14	±2.80	±0.93
5B	10	2.99	±0.05	±0.02	10	2.56	±0.17	±0.05	10	38.10	±3.09	±0.98
7B	10	3.66	±0.29	±0.09	10	2.64	±0.14	±0.05	10	41.97	±4.97	±1.57
11A	10	2.89	±0.18	±0.06	10	2.50	±0.20	±0.07	10	42.68	±3.40	±1.08
15B	10	3.59	±0.25	±0.08	10	2.69	±0.20	±0.06	10	41.76	±4.14	±1.30
2B	10	3.69	±0.45	±0.14	9	2.42	±0.24	±0.08	10	39.98	±2.93	±0.93
4B	10	3.37	±0.19	±0.06	10	3.07	±0.11	±0.04	10	57.24	±4.69	±1.51
6B	10	3.22	±0.18	±0.06	10	2.39	±0.13	±0.04	10	46.32	±2.63	±0.83
8A	10	2.51	±0.33	±0.10	10	2.25	±0.09	±0.03	10	40.44	±4.19	±1.33
9B	10	3.39	±0.25	±0.08	10	2.59	±0.16	±0.05	10	42.94	±2.91	±0.92
16B	4	3.04	±0.05	±0.03	4	2.85	±0.13	±0.06	4	41.35	±2.30	±1.15
9A	6	2.87	±0.15	±0.06	5	2.27	±0.10	±0.05	6	40.07	±2.59	±1.06
10A	10	2.96	±0.13	±0.04	5	2.32	±0.09	±0.04	10	36.43	±2.74	±0.87
16A	10	3.31	±0.42	±0.13	6	2.63	±0.09	±0.04	7	41.00	±5.29	±2.00

N = number of plants.

Table A 3.7 Shows means ($\bar{x}$) and standard deviation (S.D.) of the fertile segment components for plant groups cultivated in 1974. (Measurements expressed as mm).

TANK NO.	N	A *		B		C		D		E		F		G	
		$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
3A	9	2.8	±0.20	2.8	±0.34	2.54	±0.34	1.91	±0.31	1.72	±0.16	1.47	±0.26	1.02	±0.28
4A	8	3.25	±0.45	3.05	±0.29	2.89	±0.21	1.86	±0.42	1.79	±0.29	1.58	±0.35	1.14	±0.32
7A	15	2.68	±0.19	2.49	±0.27	2.38	±0.20	1.65	±0.38	1.41	±0.33	1.17	±0.35	0.71	±0.24
12A	8	3.08	±0.33	2.96	±0.35	2.68	±0.28	1.98	±0.30	1.69	±0.20	1.51	±0.25	1.16	±0.30
15A	8	3.24	±0.27	3.20	±0.26	2.80	±0.20	2.14	±0.18	1.75	±0.17	1.45	±0.23	1.09	±0.17
10B	9	3.33	±0.45	3.04	±0.44	2.80	±0.42	2.09	±0.55	1.79	±0.42	1.51	±0.38	0.89	±0.27
11B	10	3.36	±5.23	3.08	±0.48	2.67	±0.33	2.23	±0.41	2.11	±0.33	1.89	±0.45	1.48	±0.38
12B	8	3.35	±0.33	3.21	±0.37	2.94	±0.35	2.20	±0.28	1.93	±0.19	1.54	±0.22	0.89	±0.19
13B	13	3.80	±0.39	3.56	±0.33	3.29	±0.30	2.53	±0.17	2.40	±0.19	2.07	±0.29	1.50	±0.23
14A	14	3.77	±0.38	3.47	±0.33	3.19	±0.28	2.04	±0.34	1.98	±0.36	1.65	±0.39	0.95	±0.29
1B	15	4.59	±0.23	4.26	±0.26	3.59	±0.24	1.62	±0.29	1.83	±0.12	1.47	±0.13	1.17	±0.70
2A	15	3.88	±0.40	3.69	±0.48	2.98	±0.27	1.21	±0.18	1.45	±0.19	0.98	±0.25	0.75	±0.16
5B	14	4.71	±0.54	4.60	±0.49	3.30	±0.29	1.26	±0.13	1.69	±0.09	0.99	±0.14	0.60	±0.09
7B	15	5.02	±0.83	4.80	±0.74	3.53	±0.48	1.70	±0.28	2.12	±0.22	1.37	±0.30	0.49	±0.29
11A	10	3.73	±0.66	3.48	±0.73	2.77	±0.42	1.40	±0.33	1.43	±0.20	1.11	±0.26	0.85	±0.20
15B	10	4.31	±0.31	4.10	±0.33	3.19	±0.20	1.79	±0.17	1.85	±0.13	1.54	±0.16	1.09	±0.12
2B	12	4.22	±0.48	4.06	±0.38	3.35	±0.38	1.97	±0.23	1.83	±0.87	1.56	±0.08	0.83	±0.13
4B	5	2.77	±0.20	2.63	±0.25	2.37	±0.30	1.83	±0.25	1.70	±0.35	1.40	±0.60	0.80	±0.35
6B	14	4.10	±0.41	4.19	±0.47	3.10	±0.24	1.44	±0.10	1.80	±0.12	1.30	±0.15	0.58	±0.29
8A	15	3.54	±0.61	3.33	±0.65	2.46	±0.34	1.45	±0.36	1.50	±0.29	1.22	±0.33	0.79	±0.23
9B	15	4.83	±0.25	4.89	±0.38	3.54	±0.32	1.81	±0.34	2.09	±0.23	1.37	±0.34	0.58	±0.20
16B	5	3.78	±0.34	3.55	±0.10	2.88	±0.29	1.95	±0.64	1.93	±0.22	1.53	±0.33	1.10	±0.28
9A	6	3.22	±0.16	3.00	±0.17	2.32	±0.04	1.20	±0.14	1.37	±0.08	1.08	±0.08	0.65	±0.05
10A	9	3.11	±0.38	2.83	±0.41	2.47	±0.15	1.76	±0.10	1.56	±0.11	1.53	±0.10	0.97	±0.12
16A	7	3.59	±0.29	3.31	±0.29	2.63	±0.27	1.47	±0.55	1.51	±0.38	1.10	±0.36	0.74	±0.26

* See Figure 3.14

Table A 4.1 Shows the axes values(axis 1 and 2) for each of the 29 *Salicornia* types cultured, according to their phenolic glycosides based on the Principal Components Analysis.

CYCLE NUMBER = 1
ITERATION = 61 MAXIMUM ROOT = 26 VALUE OF .28084098E+02
PERCENT VARIANCE 20.95828

CYCLE NUMBER = 2
ITERATION = 46 MAXIMUM ROOT = 17 VALUE OF .21166582E+02
PERCENT VARIANCE 15.79596

CYCLE NUMBER = 3
ITERATION = 171 MAXIMUM ROOT = 16 VALUE OF .15589789E+02
PERCENT VARIANCE 11.63417
TOTAL VARIANCE = .13400000E+03

COORDINATES FOR PLOTTING

	1	2	3
1	.559	1.877	0
2	0	.333	1.887
3	.778	.369	.487
4	1.061	3.127	1.402
5	.239	0	1.543
6	.540	.045	1.655
7	.492	.756	1.149
8	.664	1.199	1.322
9	.665	1.057	1.368
10	.650	.830	.314
11	1.602	.361	2.659
12	.399	2.265	1.474
13	.532	2.583	1.640
14	.220	.168	1.548
15	.782	.432	.792
16	1.049	1.160	2.945
17	.480	3.445	1.829
18	1.414	.933	2.698
19	1.091	1.804	1.813
20	1.657	1.331	.209
21	1.892	1.366	1.610
22	2.944	1.140	1.174
23	1.852	.666	2.885
24	3.039	1.832	1.981
25	2.811	.945	.877
26	3.061	.934	.894
27	3.012	.447	1.046
28	2.784	1.375	1.216
29	2.392	1.689	1.705
AXIS ORIGINS	1.333	1.182	1.452

Table A 5.1 Measurement of the vegetative characters for *S. ramosissima* type grown in the complete nutrient solution. Growth experiment 1975.

1. Shoot length

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
11A	13	12.00	13.5	12.15	±1.009	1.014	1.417	1.0194
11B	11	7.00	14.0	10.76	±2.335	6.085	1.542	5.4507
12A	13	9.8	14.7	13.23	±1.477	10.276	16.185	2.1823
12B	13	9.2	15.00	11.82	±2.152	7.519	16.127	4.6303
13A	12	7.5	13.00	10.50	±1.449	7.600	13.400	2.1018
13B	9	10.3	14.20	11.73	±1.162	9.410	14.057	1.3500

2. Root Length

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
11A	13	6.5	10.00	8.231	±1.269	5.694	10.776	1.6090
11B	11	4.5	14.00	7.445	±2.677	2.091	12.800	7.1667
12A	13	5.0	10.5	7.615	±1.8502	3.915	11.316	3.4231
12B	13	4.5	9.0	6.208	±1.850	3.825	8.590	1.4191
13A	12	5.5	9.0	6.833	±1.174	4.485	9.182	1.3788
13B	9	6.0	11.5	7.611	±1.997	3.618	11.604	3.9861

Table A 5.1 Continued - Complete nutrient solution.

3. Total Number of Terminal Spikes/plant.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
11A	13	70	130	98.85	±18.84	61.17	136.52	354.946
11B	11	25	195	90.36	±62.65	-34.94	215.67	3925.023
12A	13	50	180	115.46	±41.20	33.05	197.88	1697.440
12B	13	30	170	77.08	±43.94	-10.80	165.96	1930.724
13A	12	20	64	38.00	±11.31	15.37	60.63	127.916
13B	9	33	107	62.00	±20.40	21.19	102.80	416.160

4. Terminal spike length

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
11A	13	2.0	3.7	2.89	±0.476	1.933	3.836	0.2264
11B	11	1.7	4.2	2.79	±0.712	1.367	4.215	0.5069
12A	13	1.8	4.0	3.05	±0.694	1.667	4.441	4.810
12B	13	2.0	4.7	3.24	±0.943	1.352	5.124	0.8892
13A	12	2.2	4.0	3.12	±0.669	1.785	4.448	0.4433
13B	9	2.4	3.8	3.34	±0.640	2.063	4.626	0.4103

5. Fertile segment number in the terminal spike.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
11A	13	11	14	11.62	±1.325	8.965	14.266	1.7564
11B	11	6	19	11.46	±3.616	4.223	18.686	13.0727
12A	13	7	15	11.08	±2.549	6.497	15.657	5.2436
12B	13	8	18	12.00	±3.674	4.652	19.348	13.5000
13A	12	10	17	13.00	±2.449	8.101	17.399	6.000
13B	9	10	20	14.00	±3.539	7.366	21.523	12.5278

Table A 5.2 Measurements of the vegetative characters for *S. ramosissima* type grown in nitrogen - deficient solution. Growth experiment, 1975.

1. Shoot length (cm.).

Tank No.	N	Min.	Max.	Mean	S.D.	-2S	+2S	Variance
8A	9	0.9	2.7	1.41	±0.573	0.265	2.558	0.3286
8B	9	1.0	2.9	1.68	±0.649	0.379	2.977	0.4219
9A	13	2.4	5.2	3.89	±0.806	2.272	5.497	0.6497
9B	13	2.7	6.2	3.90	±0.949	2.010	5.806	0.9008
10A	13	1.0	3.4	2.42	±0.643	1.130	3.701	0.4131
10B	13	2.0	6.0	3.72	±1.206	1.312	6.134	1.4536

2. Root length (cm.).

Tank No.	N	Min.	Max.	Mean	S.D.	-2S	+2S	Variance
8A	8	3.0	6.5	5.09	±1.410	2.276	7.909	1.9898
8B	8	3.5	9.5	6.28	±2.427	1.421	1.113	5.8907
9A	12	4.8	9.5	6.64	±1.487	3.667	9.616	2.2117
9B	13	5.0	8.0	6.18	±0.896	4.386	7.968	0.8019
10A	13	4.0	9.5	6.43	±1.616	3.198	9.663	2.6123
10B	13	4.0	11.5	7.45	±2.370	2.705	12.187	5.6194

3. Total number of Terminal spikes/plant.

Tank No.	N	Min.	Max.	Mean	S.D.	-2S	+2S	Variance
8A	9	1	1	1.00	±0.00	1.000	1.000	0.00
8B	9	1	1	1.00	±0.00	1.000	1.00	0.00
9A	12	1	2	1.17	±0.39	0.39	1.95	.152
9B	13	1	6	1.54	±1.39	-1.24	4.321	1.94
10A	13	1	1	1.00	±0.00	1.00	1.00	0.00
10B	13	1	5	1.92	±1.92	-0.96	4.80	2.08

Table A 5.2 Continued - (nitrogen-deficient treatment)

4. Terminal spike length (cm.).

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
8A	9	0.2	0.7	0.367	±0.141	0.084	0.650	0.0200
8B	9	0.2	0.6	0.322	±0.12	0.082	0.563	0.0144
9A	13	0.3	1.1	0.692	±0.275	0.142	1.243	0.0758
9B	13	0.4	1.0	0.677	±0.154	0.370	0.984	0.0236
10A	10	0.2	0.8	0.560	±0.165	0.231	0.889	0.0271
10B	13	0.4	1.4	0.900	±0.310	0.278	1.522	0.0967

5. Fertile segment number in the Terminal spike.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
8A	9	1	3	1.44	±0.727	-0.01	2.897	0.5278
8B	9	1	2	1.11	±0.333	0.444	1.778	0.1111
9A	13	1	4	2.69	±1.250	0.191	5.194	1.5641
9B	13	1	4	2.69	±0.855	0.983	4.402	0.7308
10A	13	1	3	1.77	±0.725	0.319	3.219	0.5256
10B	13	1	6	3.77	±1.480	0.808	6.731	2.1923

6. Total number of primary branches from the main axis.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
8A	9	0.00	0.00	0.00	±0.00	0.00	0.00	0.00
8B	9	0.00	0.00	0.00	±0.00	0.00	0.00	0.00
9A	13	0.00	1.00	0.538	±0.519	-0.499	1.576	0.2692
9B	13	0.00	8.00	0.769	±2.20	-3.639	5.178	4.8590
10A	13	0.00	0.00	0.00	±0.00	0.00	0.00	0.00
10B	13	0.00	4.00	0.92	±1.44	-1.959	3.805	2.0769

Table A 5.2 .Continued - (nitrogen-deficient treatment)

7. Total number of sterile segments in the main axis.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
8A	9	3	8	4.89	±1.965	0.959	8.819	3.861
8B	9	4	8	5.22	±1.564	2.095	8.349	2.44
9A	13	8	10	9.23	±0.725	7.781	10.681	0.526
9B	13	6	12	9.39	±2.103	5.178	13.591	4.423
10A	13	6	9	7.08	±1.115	4.847	9.307	1.244
10B	13	7	13	9.23	±2.743	3.744	14.717	7.526

8. Length of the lower most branch.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
8A	9	0.0	0.00	0.00	±0.00	0.00	0.00	0.00
8B	9	0.0	0.00	0.00	±0.00	0.00	0.00	0.00
9A	13	0.0	0.00	0.00	±0.00	0.00	0.00	0.00
9B	13	0.00	0.00	0.00	±0.00	0.00	0.00	0.00
10A	13	0.00	0.00	0.00	±0.00	0.00	0.00	0.00
10B	13	0.00	0.00	0.00	±0.00	0.00	0.00	0.00

9. Length of the upper most branch.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
8A	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9A	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9B	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10A	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10B	13	0.0	0.00	0.00	0.00	0.00	0.00	0.00

Table A 5.3 Measurements of the vegetative characters for *S. ramosissima* type grown in phosphorus - deficient solution. Growth experiment 1975.

1. Shoot length.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
5A	13	13.0	15.8	14.47	±1.05	12.352	16.586	1.1206
5B	13	11.0	17.0	12.98	±2.091	8.794	17.160	4.3736
6A	13	12.0	17.5	14.36	±1.717	10.927	17.796	2.9492
6B	13	10.0	17.8	12.52	±2.012	8.492	16.539	4.0464
7A	13	12.0	16.0	13.78	±1.208	11.361	16.192	1.4586
7B	13	8.4	16.8	13.22	±2.689	7.837	18.594	7.2331

2. Root length

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
5A	13	7.00	12.5	9.169	±1.631	5.907	12.432	2.6606
5B	13	44	11.0	7.800	±1.731	4.338	11.262	2.9967
6A	13	6.0	12.9	9.369	±2.149	5.071	13.668	4.6190
6B	13	5.0	14.3	7.623	±2.335	2.952	12.294	5.4536
7A	13	5.5	10.0	7.654	±1.586	4.481	10.826	2.5160
7B	13	6.5	11.3	8.169	±1.358	5.453	10.885	1.8440

3. Total number of terminal spikes/plant.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
5A	13	55.	17.0	111.769	±33.81	44.15	179.391	1143.116
5B	13	28.	27.0	77.308	±64.52	-51.74	206.354	4162.830
6A	13	45.	127.	85.154	±33.82	17.52	152.78	1143.792
6B	13	20.	130.	56.538	±30.37	-4.19	117.28	922.3369
7A	13	95.	225.	150.00	±41.42	67.15	232.84	1715.616
7B	13	2.5	163.	82.538	±39.69	3.16	161.91	1575.296

Table A 5.3 Continued - (Phosphorus-deficient treatment)

4. Terminal spike length

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
5A	13	2.0	4.5	3.023	±0.6392	1.75	4.30	0.4086
5B	13	2.0	4.4	3.069	±0.709	1.65	4.49	0.5023
6A	13	2.4	4.2	3.338	±0.750	1.85	4.84	0.5626
6B	13	1.7	3.0	2.562	±0.3404	1.88	3.24	0.1159
7A	13	1.5	2.3	1.954	±0.226	1.50	2.40	0.0510
7B	13	2.0	4.2	3.215	±0.679	1.86	4.57	0.4614

5. Fertile segment number in the terminal spike

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
5A	13	9.	12.	11.69	±2.529	6.634	16.751	6.3974
5B	13	9.	13.	12.23	±2.6506	6.930	17.532	7.0256
6A	13	10.	17.	13.00	±2.000	9.000	17.000	4.000
6B	13	8.	14.	11.231	±1.6408	7.949	14.512	2.6923
7A	13	7.	10.	8.358	±0.9608	6.463	10.306	9.231
7B	13	8.	15.	12.00	±2.1603	7.680	16.320	4.6667

6. Total Number of primary branches from the main axis.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
5A	13	24.0	3.2	28.462	±2.7269	23.008	33.915	7.4359
5B	13	16.0	4.0	25.385	±6.3448	12.695	38.074	40.2564
6A	13	22.0	32.	28.308	±3.9027	20.502	36.113	15.2308
6B	13	16.0	36.	23.538	±5.0434	13.452	33.625	25.4359
7A	13	26.0	3.2	29.077	±1.7541	25.569	32.585	3.0769
7B	13	16.0	3.2	24.923	±5.9786	12.960	36.880	35.7436

Table A 5.3 Continued - (Phosphorus-deficient treatment).

7. Total number of the sterile segment

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
5A	13	14.	19.	16.308	±1.7974	12.713	19.903	3.2308
5B	13	12.	19.	13.769	±2.3859	8.998	18.541	5.6923
6A	13	12.	20.	15.308	±2.5620	10.184	20.432	6.5641
6B	13	12.	18.	13.077	±2.0191	9.039	1.7115	4.0769
7A	13	12.	15.	14.462	±1.0500	12.361	16.562	1.1026
7B	13	8.	17.	12.615	±2.8148	6.986	18.245	7.9231

8. Length of the lowest branch.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
5A	13	7.5	10.4	8.615	±0.80	7.009	10.221	0.6447
5B	12	4.4	13.	7.542	±2.15	3.238	11.845	4.6299
6A	13	5.4	10.3	7.169	±1.50	4.152	10.186	2.2756
6B	13	3.5	8.7	6.715	±1.40	3.899	9.532	1.9831
7A	13	5.5	9.4	7.977	±1.19	5.602	10.352	1.4103
7B	13	4.6	11.2	8.115	±2.16	3.797	12.433	4.6614

9. Length of upper most branch.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
5A	13	1.7	3.2	2.562	±0.4628	1.636	3.487	0.2142
5B	13	2.4	4.1	2.900	±0.5916	1.717	4.083	0.3500
6A	13	1.8	3.4	2.608	±0.4406	1.727	3.489	0.1941
6B	13	1.5	3.2	2.292	±0.4645	1.363	3.221	0.2158
7A	13	2.0	3.2	2.508	±0.3904	1.727	3.289	0.1524
7B	13	1.8	3.0	2.600	±0.3416	1.917	3.283	0.1167

Table A 5.4 Measurements of the vegetative characters for *S. ramosissima* grown under an increased light intensity treatment. Growth experiment 1975.

1. Shoot length.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
2A	13	13.2	21.5	17.32	±2.460	12.403	22.243	6.052
2B	13	8.5	18.5	14.32	±3.059	8.198	20.433	9.356
3A	13	12.2	17.7	14.12	±1.783	10.557	17.689	3.179
3B	10	9.5	19.4	13.78	±2.993	7.794	19.766	8.957
4A	13	14.0	18.1	16.39	±1.339	13.713	19.071	1.794
4B	11	10.0	17.0	12.86	±1.85	9.164	16.564	3.423

2. Root length.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
2A	11	5.00	14.0	9.41	±2.468	4.473	14.345	6.090
2B	13	5.00	14.5	10.58	±2.398	5.781	15.373	5.750
3A	13	8.5	14.3	10.56	±1.757	7.048	14.075	3.086
3B	10	8.00	15.5	10.60	±1.983	6.633	14.567	3.933
4A	13.	9.5	12.5	10.24	±1.375	7.489	12.987	1.889
4B	11	5.5	10.5	8.76	±1.659	5.444	12.083	2.755

3. Total number of terminal spikes per plant.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
2A	12	115	685	447.0	±150.536	145.928	748.06	22661.087
2B	13	130	355	241.846	± 89.471	62.904	420.788	8005.059
3A	13	174	497	282.000	±103.024	75.951	488.049	10613.945
3B	-	-	-	-	-	-	-	-
4A	13	99	510.	276.85	±127.15	22.55	531.14	16167.123
4B	11	50	365	155.182	± 87.95	20.71	331.08	7735.203

Table A 5.4 Continued - (Increased light intensity treatment).

4. Terminal spike length.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
2A	13	2.0	8.7	4.100	±1.810	0.480	7.720	3.277
2B	13	1.8	5.0	2.785	±0.870	1.043	4.526	7.581
3A	13	1.00	6.7	3.108	±1.499	0.109	6.106	2.247
3B	10	1.1	5.4	3.470	±1.207	1.055	5.885	1.458
4A	13	2.5	6.8	3.538	±1.089	1.360	5.716	1.186
4B	10	1.6	3.8	2.800	±0.633	1.535	4.065	0.400

5. Fertile segment number in the terminal spike.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
2A	13	9	19	15.923	±6.448	3.027	28.819	41.577
2B	13	9	20	11.846	±3.105	5.636	18.056	9.6410
3A	13	6	24	12.385	±4.857	2.671	22.098	23.589
3B	10	7	17	13.100	±3.178	6.744	19.456	10.100
4A	13	9	27	14.077	±4.368	5.341	22.812	19.677
4B	10	10	15	11.900	±2.330	7.238	16.562	5.433

6. Total number of primary branches from the main axis.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
2A	13	14	36	27.692	±6.156	15.380	40.004	37.897
2B	13	16	38	25.231	±6.085	13.061	37.401	37.026
3A	13	18	30	24.462	±3.072	18.318	30.605	9.436
3B	10	12	30	22.600	±5.967	10.667	34.533	35.600
4A	13	22	34	30.000	±4.243	21.515	38.485	18.000
4B	11	18	30	21.636	±4.080	13.474	29.798	16.655

Table A 5.4 Continued - (Increased light intensity treatment).

7. Total number of sterile segments in the main axis.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
2A	13	9	19	14.769	±3.004	8.761	20.778	9.026
2B	13	10	20	13.923	±2.985	7.953	19.893	8.910
3A	13	12	16	13.692	±1.437	10.819	16.566	20.641
3B	10	8	16	12.500	±2.718	7.063	17.937	7.389
4A	13	13	17	15.000	±1.528	11.945	18.055	23.333
4B	11	10	15	12.364	±1.629	9.105	15.622	2.655

8. Length of the lowest branch from the main axis.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
2A	13	9.8	15.6	13.446	±1.779	9.887	17.006	3.168
2B	13	9.00	16.2	12.162	±1.941	8.279	16.044	3.768
3A	13	9.00	14.9	11.938	±1.649	8.639	15.237	27.209
3B	10	7.0	13.4	9.850	±2.386	5.078	14.622	5.694
4A	13	11.5	16.00	12.669	±1.252	10.165	15.173	1.5673
4B	11	5.1	11.5	9.627	±2.043	1.541	13.713	4.1742

9. Length of the upper most branch from the main axis.

Tank No.	N	Min.	Max.	Mean.	S.D.	-2S	+2S	Variance
2A	13	4.7	6.7	5.938	±0.709	4.521	7.356	0.5026
2B	13	3.4	8.00	4.662	±1.269	2.124	7.199	1.6092
3A	13	3.1	8.00	4.600	±1.234	2.133	7.067	1.5217
3B	10	3.4	6.00	4.570	±1.127	2.317	6.823	1.2690
4A	13	4.4	6.9	5.246	±0.889	3.467	7.025	0.7910
4B	11	3.5	4.8	3.845	±0.610	2.624	5.066	0.3727

Table A 5.5 Shows the minimum and the maximum measurements (mm) of fertile segment components for *Salicornia ramosissima* plants grown in a complete nutrient solution, in nitrogen-deficient solution, in phosphorus-deficient solution and under an increased light intensity. Growth experiments of 1975.

Treatments	N	A*		B		C		D		E		F		G	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1. Plants grown in a complete nutrient solution	15	2.3	3.5	2.0	3.2	2.3	2.7	1.6	1.9	1.4	1.7	1.4	1.7	0.7	1.1
2. Plants grown in nitrogen-deficient solution.	15	3.0	3.5	2.8	3.4	2.3	2.7	2.0	2.4	1.8	2.2	1.6	2.0	1.0	1.2
3. Plants grown in phosphorus-deficient solution.	50	2.2	3.3	2.2	3.0	1.7	2.5	1.5	2.2	1.4	2.2	1.4	1.7	0.7	1.1
4. Plants grown under an increased light intensity.	56	2.2	3.1	2.0	3.2	1.5	2.3	1.4	2.5	1.3	1.9	1.1	2.0	0.6	1.4

N = number of plants measured. * See Figure 3.14

Table A 6.1 Measurements of the vegetative characters (cm.) and the fertile segment components (mm) of the parent plants which their seeds cultured in the nutrient experiments of 1976.

Salicornia groups/ plant reference and habit. / I. Vegetative characters	*S. dolichostachya*			*S. nitens*		*S. ramosissima*		
	1 decumbant	2 erect	3 erect	8 erect	12 erect	13 strict habit	14 more spreading	15 more spreading still
1. Shoot length	30.2	30.9	32.5	20.0	28.33	24.9	27.22	22.91
2. Total number of primary branches from the main axis.	34	38	36	26	30	36	32	28
3. Number of sterile segments in the main axis.	17	19	18	13	15	18	16	14
4. Terminal spike length	4.4	3.2	3.4	3.2	2.8	4.0	2.3	1.6
5. Number of fertile segments in the terminal spike.	15	11	11	10	9	15	8	7
6. Length of the uppermost branch from the main axis.	3.1	1.7	2.2	1.7	2.3	2.3	1.9	1.3
7. Length of the lowermost branch from the main axis.	9.8	12	8.5	8.3	7.0	5.7	5.8	10.5
8. Angle of the uppermost branch with the main axis.	60^{o}	60^{o}	50^{o}	60^{o}	60^{o}	40^{o}	40^{o}	50^{o}

Table A 6.1 (Continued)

Salicornia groups/ plant reference and habit / II. Fertile segment components	*S. dolichostachya*			*S. nitens*		*S. ramosissima*		
	1 decumbant	2 erect	3 erect	8 erect	12 erect	13 strict habit	14 more spreading	15 more spreading still
1. Maximum width of the second fertile segment (A).	5.2	4.5	5.9	3.8	5.5	3.8	4.5	5.3
2. Maximum width of the fourth fertile segment (B).	5.0	4.5	5.3	3.4	5.2	3.8	4.8	5.5
3. Minimum width of the third fertile segment (C).	4.2	3.8	4.0	3.3	4.0	3.2	3.7	4.0
4. Observed length of the segment (D)	1.9	2.4	2.5	1.9	3.8	3.06	2.8	3.3
5. Total length of the central flower (E).	2.2	2.6	2.4	1.6	3.2	2.8	2.9	3.1
6. Observed length of the central flower (F).	1.9	2.4	2.3	1.5	2.9	2.4	2.2	2.8

*Key to the number of the vegetative characters, (Growth experiments of 1976):-

1= Shoot length.

2= Root length.

3= Total number of primary branches from the main axis.

4= Number of sterile segments in the main axis.

5= Terminal spike length.

6= Number of fertile segments in the terminal spike.

7= Length of the lowermost branch from the main axis.

8= Length of the uppermost branch from the main axis.

9= Angle of the uppermost branch with the main axis.

10 =Angle of the lowermost branch with the main axis.

Table A 6.2. Minimum, maximum, mean, standard deviation (S.D.), variance and 95% confidence limit values for *Salicornia dolichostachya* vegetative characters in the four nitrogen levels.

TANK NO. 3A - Nitrogen level 5 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	12	10.00	13.80	11.5	±1.176	1.383	10.80	12.29
2	12	5.5	8.00	6.95	±0.844	0.712	06.41	07.49
3	12	24.0	30.00	26.67	±1.969	3.879	25.42	27.92
4	12	12	15	13.33	±0.779	0.606	12.84	13.83
5	12	1.1	1.4	1.23	±0.107	0.012	01.17	01.30
6	12	4	5	4.25	±0.45	0.20	03.96	04.54
7	12	1.9	8.2	2.95	±2.016	4.063	01.67	04.23
8	12	0.4	1.0	0.66	±2.065	4.265	05.27	07.89
9	12	30°	40°	32.50	±4.523	20.455	29.63	35.37
10	12	30°	40°	38.75	±6.784	46.023	34.44	43.06

TANK NO. 4A - Nitrogen level 15 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	12	15.2	19.5	17.217	±1.506	2.269	16.26	18.17
2	11	6.0	10.0	7.91	±1.323	1.749	07.02	08.79
3	12	30	38	34.2	±2.758	7.606	32.41	35.92
4	12	15.0	19.0	17.17	±1.267	1.606	16.36	17.97
5	12	1.7	2.2	1.87	±0.144	0.020	01.78	01.96
6	12	6	8	6.75	±0.754	0.568	06.27	07.23
7	11	3.5	14.0	7.68	±3.685	13.582	05.20	10.16
8	12	0.5	1.5	0.94	±0.268	0.072	07.71	11.12
9	12	30°	40°	34.17	±5.149	26.515	30.89	37.44
10	12	40°	40°	40.00	±0.000	0.00	40.00	40.00

Table A 6.2. Continued - (*Salicornia dolichostachya*)

TANK NO. 5A - Nitrogen level 45 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	15	17.9	22.8	20.94	±1.523	2.319	20.09	21.78
2	15	8.0	11.5	9.67	±1.079	1.164	09.06	10.26
3	15	36.0	44.0	40.00	±2.619	6.857	38.55	41.45
4	15	19.0	22.0	20.13	±1.126	1.267	19.51	20.76
5	15	1.3	2.3	1.73	±0.258	0.066	01.58	01.87
6	15	5	8.0	6.13	±0.916	0.838	05.63	06.64
7	15	6.2	17.0	9.88	±2.699	7.287	08.39	11.38
8	15	0.5	1.6	0.99	±1.075	1.155	00.79	01.18
9	15	30°	50°	42.00	±7.746	60.00	37.71	46.29
10	15	30°	40°	33.67	±5.499	30.238	30.62	36.71

TANK NO. 6A - Nitrogen level 135 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	15	16.00	20.8	18.29	±1.524	2.323	17.44	19.13
2	15	6.00	9.5	7.80	±1.279	1.637	07.09	08.50
3	15	32.0	44.	35.60	±3.719	13.829	33.54	37.66
4	15	16.0	21.0	17.67	±1.759	3.096	16.69	18.64
5	15	0.9	1.4	1.16	±0.475	0.226	01.08	01.24
6	15	4.0	6.0	4.60	±0.633	0.400	04.25	04.95
7	14	5.3	12.5	8.01	±1.783	3.178	06.99	09.04
8	15	0.5	1.0	0.78	±0.167	0.028	00.68	00.88
9	15	30°	50°	36.67	±7.238	52.381	32.66	40.68
10	15	30°	40°	32.00	±4.140	17.143	29.70	34.29

*See page 383

Table A 6.3 Minimum, maximum, mean, standard deviation (S.D.) variance and 95% confidence limit values for *Salicornia nitens* vegetative characters in the four nitrogen levels.

TANK NO. 3B - Nitrogen level 5 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	12	15.6	21.8	19.433	±2.008	4.033	18.16	20.70
2	12	7.0	11.5	9.833	±1.271	1.615	09.05	10.62
3	12	16.0	19.0	35.167	±1.992	3.969	33.90	36.43
4	12	32.0	38.0	17.50	±1.087	1.182	16.80	18.19
5	12	0.8	1.3	1.01	±0.150	0.023	00.91	01.10
6	12	4.	7.0	5.33	±1.073	1.152	04.65	06.02
7	12	2.4	5.1	3.67	±2.633	6.933	03.14	04.19
8	12	0.6	1.2	0.88	±0.233	0.054	00.74	01.03
9	12	30°	50°	35.83	±7.929	62.879	30.79	40.87
10	12	30°	40°	40.00	±6.030	36.364	36.17	43.83

TANK NO. 4B - Nitrogen level 15 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	12	23.3	28.7	26.283	±2.182	4.759	24.89	27.67
2	12	8.5	14.0	10.767	±1.489	2.217	09.82	11.71
3	12	32.0	44.0	40.00	±3.81	14.546	37.58	42.42
4	12	16.0	22.0	19.917	±1.564	2.447	16.36	17.97
5	12	1.2	2.2	1.76	±0.290	0.085	01.57	01.94
6	12	6	10.0	8.58	±1.240	1.538	07.79	09.37
7	12	5.3	10.8	7.66	±1.852	3.428	06.48	08.84
8	12	0.9	1.7	1.29	±0.214	0.048	01.15	01.43
9	12	30°	40°	32.08°	±3.965	15.719	29.56	34.60
10	12	30°	50°	35.83°	±7.929	62.879	30.79	40.87

* See page 383

Table A.6.3. Continued - (*Salicornia nitens*)

TANK NO. 5B - Nitrogen level 45 p.p.m.

Vegetative Character No*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	12	27.8	32.3	29.500	±2.181	4.758	28.81	30.89
2	12	9.0	14.0	11.63	±1.773	3.142	10.49	12.75
3	12	44.	50.	46.17	±1.800	3.242	45.02	47.31
4	12	21.0	25.	22.75	±1.138	1.296	22.03	23.47
5	12	1.5	1.8	1.65	±0.232	0.054	01.50	01.79
6	12	6.0	9.0	8.33	±0.888	0.788	07.77	08.89
7	12	8.2	15.2	12.33	±2.879	8.289	10.50	14.16
8	12	0.7	1.1	1.03	±0.166	0.028	00.92	01.13
9	12	30°	50°	38.33	±5.774	33.333	34.67	42.00
10	12	30°	50°	40.83	±5.149	26.515	37.56	44.10

TANK NO. 6B - Nitrogen level 135 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	12	22.0	26.5	25.108	±1.29	1.689	24.28	25.93
2	11	9.5	12.0	11.091	±0.800	0.640	10.55	11.63
3	12	36.0	44.0	42.00	±2.558	6.546	40.37	43.63
4	12	18.0	22.0	20.917	±1.24	1.538	20.13	21.70
5	12	0.8	1.2	1.083	±0.111	0.012	01.01	01.15
6	12	4.0	5.0	4.667	±0.491	0.242	04.35	04.98
7	11	9.7	12.5	10.836	±1.264	1.599	09.99	11.69
8	12	0.5	1.2	0.908	±0.183	0.034	00.79	01.03
9	11	40°	60°	48.18	±6.030	36.364	44.13	52.23
10	11	50°	60°	54.44	±5.222	27.273	51.04	58.05

* See page 383

Table A.6.4 Minimum, maximum, mean, standard deviation (S.D.), variance and 95% confidence limit for *Salicornia ramosissima* characters in the four nitrogen levels.

TANK NO. 3C - Nitrogen level 5 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Varience	-95CL	+95CL
1	15	12.7	16.1	14.887	±1.019	1.038	14.32	15.45
2	15	4.5	12.5	6.633	±1.923	3.696	05.57	07.69
3	15	24.0	30.0	26.933	±1.830	3.352	25.92	27.95
4	15	12.0	15.0	13.533	±0.834	0.695	13.08	13.99
5	15	0.7	1.2	0.900	±0.114	0.013	00.84	00.96
6	15	4.0	5.0	4.33	±0.488	0.238	04.06	04.60
7	15	1.4	3.5	2.02	±0.732	0.536	01.62	02.43
8	15	0.5	0.7	0.633	±0.072	5.238	00.59	00.67
9	15	30°	40°	36.333	±5.499	30.238	33.29	39.38
10	15	30°	50°	40.667	±7.988	63.809	36.24	45.09

TANK NO. 4C - Nitrogen level 15 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Varience	-95CL	+95CL
1	15	18.6	24.5	21.980	±1.819	3.286	20.98	22.98
2	15	5.0	8.5	6.933	±1.163	1.352	06.29	07.58
3	15	32	38	34.533	±2.199	4.838	33.32	35.75
4	15	16	19	17.267	±1.033	1.067	16.69	17.84
5	15	0.9	1.4	1.107	±0.149	0.022	01.02	01.19
6	15	4.0	7.0	5.533	±2.637	6.952	05.07	05.99
7	15	1.6	4.5	3.007	±0.837	0.7007	02.54	03.47
8	15	0.4	0.8	0.660	±0.159	0.025	00.57	00.75
9	15	25°	30°	29.667	±4.083	16.667	28.95	30.38
10	15	20°	40°	32.00	±5.606	31.429	28.89	35.10

* See page 383

Table A 6.4 Continued - (*Salicornia ramosissima*)

TANK NO. 5C - Nitrogen level 45 p.p.m.

Vegetative Character No.*	N.	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	15	21.5	26.8	24.587	±1.675	2.804	23.66	25.5
2	14	5.5	9.5	7.464	±1.117	1.249	06.82	08.10
3	15	30	40	36.267	±2.815	7.924	34.70	37.83
4	15	14	20	17.867	±1.552	2.409	17.00	18.73
5	15	0.9	1.6	1.247	±0.188	0.036	01.14	01.35
6	15	5	8	6.733	±0.884	0.781	06.24	07.22
7	15	4.0	7.7	6.227	±1.492	2.226	05.40	07.05
8	15	0.5	1.0	0.793	±0.133	0.018	00.72	00.87
9	15	50°	60°	54.00	±5.070	25.714	51.19	56.80
10	-	-	-	-	± -	-	-	-

TANK NO. 6C - Nitrogen level 135 p.p.m.

Vegetative Character No.*	N.	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	15	15.3	23.2	18.427	±2.083	4.338	17.27	19.58
2	14	5.5	8.5	6.614	±0.873	0.761	06.11	07.12
3	15	24	34	30.667	±2.992	8.952	29.01	32.32
4	15	12	17	15.333	±1.496	2.238	14.50	16.16
5	15	0.4	0.9	0.527	±0.144	0.020	00.45	00.60
6	15	2.0	4.0	3.00	±8.452	71.43	02.53	03.47
7	15	4.0	9.8	5.83	±1.411	1.991	05.05	06.62
8	15	0.3	0.6	0.467	±0.105	0.0110	00.40	00.53
9	15	50°	60°	51.667	±3.619	13.096	49.66	53.67
10	-	-	-	-	± -	-	-	-

* See page 383

Table A.6.5 Minimum, maximum, mean, standard deviation (S.D.), variance and 95% confidence limit values for *Salicornia dolichostachya* vegetative characters in the four phosphorus levels.

TANK NO. 7A - phosphorus level 2 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	15	15.5	19.8	18.287	±1.238	1.533	17.60	18.97
2	15	5.5	10.0	7.633	±1.382	1.909	06.87	08.39
3	14	26.0	4.0	35.857	±3.880	15.055	33.62	38.09
4	14	13.0	20.0	17.786	±1.888	3.566	16.69	18.88
5	15	1.3	2.3	1.74	±0.463	0.214	01.48	01.99
6	15	4.0	9.	6.333	±1.345	1.809	05.59	07.08
7	13	5.6	15.2	8.44	±2.569	6.598	06.89	09.99
8	15	0.8	2.5	1.293	±0.422	0.178	01.06	01.53
9	15	30°	30°	30.00	±0.000	0.000	30.00	30.00
10	15	30°	40°	34.000	±5.070	25.714	31.19	36.80

TANK NO. 8A - phosphorus level 4 p.p.m.

Vegetative Character No*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	15	1o.1	24.60	22.340	±1.835	3.368	21.32	23.36
2	15	5.5	9.3	6.92	±1.280	1.639	06.21	07.63
3	15	34	48	42.800	±3.986	15.888	40.59	45.00
4	15	18	24	21.333	±1.952	3.809	20.25	22.41
5	15	1.2	2.3	1.827	±0.326	0.106	01.65	02.00
6	15	5	8	6.600	±0.910	0.829	06.09	07.10
7	14	7.0	17.2	11.50	±2.731	7.735	09.90	13.11
8	15	0.8	1.4	1.020	±0.178	0.032	00.92	01.12
9	15	30°	40°	34.333	±4.952	24.524	31.59	37.08
10	15	30°	40°	37.333	±4.169	17.381	35.02	39.64

* See a e 383

Table A.6.5 Continued - *Salicornia dolichostachya*

TANK NO. 9A - phosphorus level 8 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	15	12.5	18.2	15.247	±1.959	3.838	14.16	16.33
2	13	3.5	8.5	6.000	±1.291	1.667	05.22	06.78
3	15	24.0	36	30.267	±4.464	19.924	27.79	32.74
4	15	12.0	19	15.267	±2.154	4.638	14.07	16.46
5	15	1.2	2.5	1.567	±0.337	0.114	01.38	01.75
6	15	4.0	9.0	6.000	±1.309	1.714	05.28	06.73
7	15	7.4	13.0	10.100	±1.588	2.521	09.22	10.98
8	15	0.6	3.0	1.247	±1.919	3.684	00.91	01.58
9	15	30°	45°	33.667	±5.499	30.238	30.62	36.71
10	15	30°	50°	40.667	±7.988	63.809	36.24	45.09

TANK NO. 10A - phosphorus level 16 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	14	13.0	21.5	16.187	±5.414	29.303	13.19	19.19
2	14	5.0	8.0	5.673	±1.719	2.956	04.72	06.63
3	14	26.0	40.0	31.20	±9.821	96.457	25.76	36.64
4	14	13.0	20.0	15.333	±4.879	23.809	12.63	18.04
5	14	0.8	2.4	1.687	±0.778	0.606	01.26	02.12
6	14	3	9	6.467	±2.774	7.695	04.93	08.00
7	14	5.3	13.8	9.021	±3.482	12.123	07.011	11.03
8	14	0.8	1.8	1.17	±0.456	0.208	00.92	01.43
9	14	25°	40°	29.667	±9.348	87.381	24.49	34.84
10	14	30°	50°	40.667	±13.345	178.095	33.28	48.06

* See page 383

Table A 6.6 Minimum, maximum, mean, standard deviation (S.D.), variance and 95% confidence limit values for *Salicornia nitens* vegetative characters in the four phosphorus levels.

TANK NO. 7B - phosphorus level 2 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	12	25.5	29.0	27.175	±1.290	1.666	26.36	27.99
2	12	5.5	14.0	9.083	±2.353	5.538	07.59	10.58
3	12	40.0	50.0	45.167	±3.353	11.242	43.04	47.29
4	12	20.0	24.0	22.417	±1.379	1.902	21.54	23.29
5	12	1.2	1.9	1.65	±0.219	0.048	01.51	01.79
6	12	7.	9.	7.833	±0.937	0.879	07.24	08.43
7	11	7.5	16.7	10.609	±2.970	8.825	08.61	12.60
8	12	0.6	1.5	1.183	±0.233	0.054	01.04	01.33
9	12	40°	65°	52.500	±7.834	61.364	47.52	57.48
10	12	45°	60°	51.250	±6.077	36.932	47.39	55.11

TANK NO. 8B - phosphorus level 4 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	12	28.5	34.0	31.717	±1.641	2.694	30.67	32.76
2	9	6.0	12.5	9.278	±2.450	6.007	07.39	11.16
3	12	44	52	49.167	±3.353	11.241	47.04	51.29
4	12	23	26	24.583	±1.505	2.265	23.63	25.54
5	12	1.2	2.5	1.74	±0.332	0.109	01.531	01.95
6	12	6	11	8.000	±1.279	1.636	07.19	08.81
7	12	8.6	16.2	12.792	±2.949	8.700	10.92	14.67
8	12	1.0	1.9	1.317	±0.244	0.059	01.16	01.47
9	12	40°	60°	52.500	±6.216	38.636	48.55	56.45
10	12	50°	60°	52.500	±4.523	20.455	49.62	55.37

* See page 383

Table A 6.6 Continued *(Salicornia nitens)*

TANK NO. 9B - phosphorus level 8 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	12	20.8	29.5	25.208	±3.393	11.512	23.05	27.36
2	12	6.0	11.5	9.292	±2.094	4.385	07.96	10.62
3	12	30	44.	39.333	±4.849	23.512	36.25	42.41
4	12	15.	22.	19.667	±2.425	5.879	18.13	21.20
5	12	1.4	2.1	1.642	±0.318	0.100	01.44	01.84
6	12	6	10.0	8.583	±1.443	2.083	07.67	09.50
7	12	12.00	19.2	15.650	±2.517	6.333	14.05	17.25
8	12	0.9	1.4	1.108	±0.247	0.060	00.95	01.27
9	12	30°	50°	35.00	±6.742	45.455	30.72	39.28
10	12	40°	60°	45.833	±9.003	81.060	40.11	51.55

TANK NO. 10B - phosphorus level 16 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	11	23.5	33.8	29.155	±3.597	12.940	26.74	31.57
2	9	6.5	13.0	10.500	±2.345	5.500	08.69	12.30
3	11	34	56	46.727	±6.649	44.211	42.26	51.19
4	11	16	28	23.091	±3.448	11.890	20.77	25.40
5	11	1.0	1.4	1.155	±0.113	0.013	01.08	01.23
6	11	4	6.0	5.364	±0.674	0.455	04.91	05.82
7	11	5.5	21.0	12.582	±4.907	24.075	09.29	15.88
8	11	0.7	1.0	0.873	±0.142	0.020	00.78	00.97
9	11	40°	55°	49.545	±3.503	12.273	47.19	51.89
10	11	40°	70°	55.455	±8.202	67.273	49.95	60.96

* See page 383

Table A.6.7 Minimum, maximum, means, standard deviation (S.D.), variance and 95% confidence limit values for *Salicornia ramosissima* vegetative characters in the four phosphorus levels.

TANK NO. 7C - phosphorus level 2 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	15	16.00	23.80	20.087	±2.269	5.153	18.83	21.34
2	13	6.00	8.5	7.154	±0.944	0.891	06.58	07.72
3	15	26.00	38.00	32.667	±3.266	10.667	30.86	34.48
4	15	13.	18.	16.200	±1.521	2.314	15.36	17.04
5	15	0.5	1.2	0.940	±0.203	0.041	0.83	1.07
6	15	3	8	6.13	±1.356	1.838	5.38	6.88
7	15	4.5	13.6	6.960	±2.146	4.60	05.77	08.15
8	14	0.4	0.9	0.95	±0.207	0.043	0 83	0 06
9	15	40°	75°	55.33	±13.292	176.667	47.97	62.69
10	-	-	-	-	± -	-	-	-

TANK NO. 8C - phosphorus level 4 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	10	22.5	27.8	24.930	±1.941	3.769	23.54	26.32
2	9	5.0	10.5	7.333	±1.837	3.375	05.92	08.75
3	10	34.	44.	37.00	±3.558	12.66	34.45	39.54
4	10	17.	21.	18.400	±1.578	2.489	17.27	19.53
5	10	0.3	1.2	0.700	±0.313	0.098	00.48	00.92
6	10	2.0	8.0	4.300	±2.003	4.011	02.87	05.73
7	10	3.5	9.0	6.50	±2.535	6.424	04.69	08.31
8	10	0.3	1.0	0.550	±0.255	0.065	00.37	00.73
9	7	30°	40°	35.90	±5.000	25.000	30.38	39.62
10	8	40°	50°	48.75	±3.536	12.500	45.79	51.70

* See page 383

Table A.6.7 Continued (*Salicornia ramosissima*)

TANK NO. 9C - phosphorus level 8 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	15	18.3	28.2	24.007	±2.807	7.879	22.44	25.56
2	15	6.00	10.5	8.300	±1.320	1.743	07.57	09.03
3	15	30.0	38.0	33.733	±1.656	13.63	31.69	35.78
4	15	13.0	19.0	16.800	±1.671	2.793	15.88	17.72
5	15	0.9	2.1	1.407	±0.347	0.120	01.21	01.59
6	15	6.0	11.0	8.067	±1.387	1.924	07.29	08.84
7	15	9.2	16.4	12.40	±2.485	6.172	11.02	13.78
8	15	0.5	1.6	1.100	±0.278	0.077	00.95	01.25
9	15	40°	60°	50.667	±4.577	20.952	48.13	53.20
10	15	50°	70°	56.33	±6.114	37.381	52.95	59.72

TANK NO. 10C - phosphorus level 16 p.p.m.

Vegetative Character No.*	N	Min.	Max.	Mean.	S.D.	Variance	-95CL	+95CL
1	11	23.00	29.2	26.927	±2.261	5.1122	25.40	28.45
2	11	7.5	14.5	9.636	±1.976	3.905	08.30	10.96
3	11	36.	46.	41.818	±3.282	10.769	39.61	44.02
4	11	18.0	23.0	20.818	±1.6011	2.564	19.74	21.89
5	11	0.3	0.9	0.555	±0.220	0.049	00.40	00.70
6	11	2	6	3.364	±1.433	2.055	02.40	04.32
7	11	9.0	14.2	11.600	±1.574	2.476	10.54	12.66
8	11	0.4	0.6	0.491	±0.104	0.010	00.42	00.56
9	11	30°	60°	42.727	±2.969	8.818	36.65	48.80
10	11	50°	70°	55.455	±8.202	67.272	49.95	60.96

* See page 383

Table A 6.8 Minimum, maximum, mean, standard deviation (S.D.), variance and 95% Confidence limit values for *Salicornia dolichostachya* vegetative character in the four sodium chloride levels.

TANK NO. 13A - Sodium chloride level 0.65%

Vegetative Character No.*	N	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	12	31.2	38.4	35.10	±2.117	4.482	33.755	36.445
2	10	7.5	11.0	10.00	±1.633	2.667	8.832	11.168
3	12	44.	52.	47.00	±3.668	13.455	44.669	49.331
4	12	21.	26.	23.75	±1.485	2.205	22.807	24.693
5	12	1.6	4.5	2.63	±1.090	1.189	1.940	3.326
6	12	7.	19.	11.50	±5.126	26.273	3.243	14.757
7	12	8.2	19.0	15.46	±3.876	15.025	12.996	17.921
8	12	0.9	2.9	1.98	±0.690	0.477	1.536	2.414
9	12	30.	50.	37.08	±6.200	38.447	33.144	41.023
10	12	30.	40.	38.33	±3.892	15.152	35.860	40.807

TANK NO. 12A - Sodium chloride level 1.3%

Vegetative Character No.*	N	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	12	25.0	30.8	29.283	±1.671	2.792	28.222	30.345
2	12	9.0	13.0	9.625	±1.785	3.188	8.491	10.759
3	12	36.0	42.	39.333	±1.775	3.152	38.205	40.461
4	12	19.0	20.	19.833	±0.718	0.515	19.377	20.289
5	12	0.6	2.3	1.275	±0.605	0.366	0.891	1.66
6	12	2.	8.	4.333	±1.826	3.333	3.173	5.493
7	12	6.	16.8	10.275	±2.836	8.042	8.473	12.077
8	12	0.9	2.5	1.533	±0.605	0.248	1.217	1.850
9	12	25.°	30.°	29.583	±1.443	2.083	28.666	30.500
10	12	30.°	35.°	30.417	±1.443	2.083	29.500	31.334

* See page 383

Table A 6.8. (Continued) - *Salicornia dolichostachya*

TANK NO. 14A - Sodium chloride level 2.5%

Vegetative Character No.*	N	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	15	22.3	28.5	24.980	±2.055	4.223	23.842	26.118
2	13	6.5	15.0	10.808	±2.213	4.897	9.470	12.145
3	14	32.	40.	36.571	±2.652	7.033	35.040	33.102
4	15	16.	20.	18.133	±1.246	1.552	17.443	18.823
5	15	0.6	1.6	1.127	±0.306	0.094	0.957	1.296
6	15	3.	7.	5.00	±1.254	1.571	4.306	5.694
7	15	4.4	14.9	9.167	±9.366	8.772	7.526	10.807
8	15	0.8	1.2	1.053	±0.229	0.053	0.926	1.180
9	15	20.°	30.°	25.667	±4.169	17.381	23.358	27.976
10	15	20.°	30.°	26.667	±4.499	20.238	24.175	29.158

TANK NO. 11A - Sodium chloride level 5%

Vegetative Character No.*	N	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	15	20.3	25.00	23.047	±1.264	1.598	22.346	23.747
2	15	7.0	13.00	9.633	±1.922	3.695	3.369	10.698
3	15	32.	38.	34.267	±2.120	4.494	33.092	35.441
4	15	15.	19.	17.00	±1.254	1.571	16.306	17.694
5	14	0.2	0.6	0.314	±0.175	0.030	0.213	0.415
6	14	1.	2.	1.357	±0.633	0.401	0.992	1.723
7	15	5.2	8.8	6.48	±1.669	2.785	5.556	7.404
8	15	0.5	1.2	0.667	±0.188	0.035	0.563	0.771
9	15	30.°	50.°	34.33	±6.779	45.952	30.579	38.088
10	15	25.°	30.°	31.00	±3.873	15.000	28.855	33.145

* See page 383

Table A 6.9 Minimum, maximum, mean, standard deviation (S.D.), variance and 95% confidence limit values for *Salicornia nitens* vegetative characters in the four sodium chloride levels.

TANK NO. 13B - Sodium chloride level 0.65%

Vegetative Character No.*	N	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	7	32.7	41.6	36.229	±3.188	10.162	33.280	39.177
2	5	7.5	10.5	8.700	±1.095	1.200	7.340	10.060
3	7	56.0	68.0	60.857	±4.450	19.809	56.741	64.974
4	7	28.0	36.0	30.857	±2.854	8.143	28.218	33.496
5	7	1.9	3.8	2.300	±0.721	0.520	1.633	2.967
6	7	9.	19.	11.286	±4.192	17.571	7.409	15.163
7	6	4.0	24.2	11.067	±7.559	57.130	3.133	19.00
8	7	1.5	3.8	2.086	±0.812	0.658	1.335	2.836
9	7	30.°	40.°	31.429	±2.439	5.952	29.172	33.685
10	7	30.°	40.°	34.286	±5.345	28.571	29.342	39.229

TANK NO. 12B - Sodium Chloride level 1.3%

Vegetative Character No.*	N	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	6	28.2	34.2	30.483	±2.519	6.345	27.839	33.127
2	5	9.5	11.5	10.504	±0.7906	0.625	9.519	11.481
3	6	56.0	70.0	57.667	±6.623	43.867	50.715	64.618
4	6	26.0	36.0	28.500	±3.988	15.900	24.315	32.685
5	6	1.2	2.5	1.800	±0.4899	0.2400	1.286	2.314
6	6	6.	13.0	8.833	±2.927	8.567	5.761	11.905
7	6	8.6	21.4	13.767	±4.627	21.410	8.910	18.623
8	6	1.3	2.9	1.883	±0.557	0.309	1.299	2.467
9	6	15.0°	40.0°	30.833	±9.174	84.167	21.204	40.463
10	6	30.0°	50.0°	40.00	±8.944	80.000	30.612	49.388

* See page 383

Table A.6.9 (Continued) - *Salicornia nitens*

TANK NO. 14B - Sodium chloride level 2.5%

Vegetative Character No.*	N	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	15	23.2	28.2	25.473	±1.440	2.075	24.676	26.271
2	15	6.0	12.0	9.600	±2.038	4.150	8.472	10.728
3	15	46.0	54.0	50.667	±2.350	5.524	49.365	51.968
4	15	23.0	27.0	25.267	±1.279	1.638	24.558	25.976
5	15	0.9	1.4	1.467	±0.427	0.182	1.230	1.703
6	15	5.0	11.0	7.867	±2.066	4.267	6.723	9.011
7	15	4.5	13.5	9.167	±2.600	6.764	7.726	10.607
8	15	0.8	1.6	1.133	±0.843	0.710	0.986	1.281
9	9	30.°	40.°	32.222	±3.632	13.194	29.430	35.014
10	9	30.°	50.°	42.778	±6.667	44.444	37.653	47.902

TANK NO. 11B - Sodium chloride level 5%.

Vegetative Character No.*	N	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	12	14.2	23.6	19.167	±2.642	6.982	17.488	20.846
2	12	8.5	12.0	9.167	±1.775	3.152	8.039	10.295
3	12	34.	44.0	38.833	±3.459	11.969	36.635	41.032
4	12	17.	22.0	19.500	±1.732	3.000	18.399	20.601
5	12	0.2	0.7	0.325	±0.142	0.020	0.235	0.415
6	12	1.	3.0	1.667	±0.985	0.969	1.041	2.292
7	12	3.2	10.2	5.233	±1.970	3.884	3.931	6.486
8	12	0.4	0.9	0.642	±0.193	0.037	0.519	0.764
9	12	30.°	40.°	30.833	±2.887	8.333	28.999	32.668
10	12	30.	60.	45.833	±9.962	99.242	39.504	52.163

* See page 383

Table A 6.10 Minimum, maximum, mean, standard deviation (S.D.), variance and 95% confidence limit values for *Salicornia ramosissima* vegetative character in the four sodium chloride levels.

TANK NO. 13C - Sodium chloride level 0.65%

Vegetative Character No.*	N.	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	10	35.5	44.8	39.87	±2.332	5.438	38.202	11.538
2	9	9.0	13.5	10.611	±1.537	2.361	9.430	11.792
3	10	50.	66.0	59.20	±4.022	16.178	56.325	62.077
4	10	25.	32.	29.10	±1.853	3.433	27.375	30.425
5	10	1.2	3.2	2.41	±0.595	0.354	1.984	2.836
6	10	7.0	16.0	1.310	±2.601	6.767	11.239	14.961
7	10	10.1	25.8	22.51	±11.092	123.032	14.576	30.444
8	10	1.1	2.0	1.530	±0.365	0.133	1.269	1.791
9	10	30.°	40.°	33.500	±4.743	22.500	30.107	36.893
10	10	40.°	50.°	38.00	±7.888	62.222	32.358	43.642

TANK NO. 12C - Sodium chloride level 1.3%

Vegetative Character No.*	N	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	11	28.	33.80	31.327	±1.726	2.978	30.168	32.487
2	11	6.0	14.00	9.364	±2.314	5.355	7.809	10.918
3	11	44.	56.	49.636	±3.075	9.455	47.57	51.702
4	11	22.	28.	24.818	±1.537	2.364	23.785	25.851
5	11	0.9	1.2	1.227	±0.649	0.422	1.089	1.365
6	11	6.	9.	7.545	±1.281	1.273	6.788	8.303
7	11	7.0	20.7	12.818	±3.799	14.438	10.266	15.371
8	11	0.5	1.2	0.845	±0.589	0.347	0.720	0.971
9	11	30.°	30.°	30.00	±0.00	0.00	30.000	30.000
10	11	30.°	30.°	29.545	±1.508	2.273	28.533	30.558

* See page 383

Table A 6.10 (Continued) - *Salicornia ramosissima*

TANK NO. 14C - Sodium Chloride level 2.5%

Vegetative Character No.*	N	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	15	23.5	27.8	26.67	±1.114	1.240	26.056	27.290
2	15	6.0	8.5	7.542	±1.177	1.385	6.794	8.289
3	15	38	46	42.533	±2.066	4.267	41.389	43.677
4	15	19	23	21.400	±1.121	1.257	20.779	22.021
5	15	0.3	1.0	0.660	±0.203	0.041	0.548	0.772
6	15	2	6	3.933	±1.099	1.209	3.324	4.542
7	15	7.5	16.2	11.886	±2.583	6.670	10.395	13.377
8	15	0.3	0.9	0.587	±0.173	0.029	0.491	0.682
9	15	25°	40°	31.000	±3.873	15.000	28.855	33.145
10	15	20°	30°	21.333	±3.519	12.381	19.385	23.282

TANK NO. 11C - Sodium Chloride level 5%

Vegetative Character No.*	N	Min	Max	Mean	S.D.	Variance	-95cl	+95cl
1	12	20.3	24.5	22.658	±1.362	1.854	21.793	23.523
2	12	8.0	14.0	10.908	±1.526	2.328	9.939	11.878
3	12	36	42	38.00	±2.828	8.000	36.203	39.797
4	12	18	21	18.833	±1.404	1.969	17.942	19.725
5	12	0.2	0.4	0.233	±0.065	0.004	0.192	0.275
6	12	1	3	1.333	±0.651	0.424	0.919	1.747
7	12	6.0	11.8	8.008	±1.798	3.234	6.866	9.151
8	12	0.2	0.6	0.350	±0.125	0.016	0.271	0.429
9	12	30°	40°	31.667	±3.893	15.152	29.193	34.140
10	12	30°	50°	39.167	±6.708	44.697	34.919	43.415

* See page 383

Table A 6.11 Shows the minimum and the maximum measurements (mm) of the fertile segment components for plant groups cultivated in 1976.

Treatments	TANK NO.	N	A*		B		C		D		E		F		G	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
A complete nutrient solution	1A	7	2.5	3.5	1.5	3.0	1.3	2.3	1.0	1.5	1.8	2.2	0.9	1.4	0.4	0.7
	1B	10	2.7	3.4	1.8	3.0	1.6	2.4	1.2	1.7	1.9	2.3	1.0	1.5	0.6	0.9
	2A	10	2.9	3.2	2.0	3.1	1.8	2.4	1.3	1.8	2.0	2.3	1.1	1.5	0.8	1.0
	2B	10	3.0	4.2	3.0	4.2	2.5	3.0	2.0	2.5	2.0	2.7	1.8	2.1	0.7	1.5
5 p.p.m. nitrogen	3A	10	3.5	4.0	3.2	4.0	2.5	2.7	2.1	2.4	2.1	2.6	1.7	2.0	1.2	1.4
	3B	10	3.4	3.9	3.2	3.8	2.0	2.5	1.3	1.9	1.7	2.4	1.2	1.7	0.4	0.8
	3C	10	2.8	3.3	2.6	3.7	2.0	2.4	1.4	2.2	2.0	2.2	1.2	1.8	0.4	1.0
15 p.p.m. nitrogen	4A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4B	10	3.5	3.8	3.2	3.5	2.2	2.5	1.7	2.0	1.9	2.2	1.4	1.9	0.6	1.0
	4C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45 p.p.m. nitrogen	5A	10	3.0	3.5	3.0	3.5	2.2	2.5	1.8	2.4	1.8	2.3	1.5	2.1	0.8	1.2
	5B	10	3.2	3.8	3.1	3.7	1.9	2.3	1.5	2.1	1.9	2.3	1.3	1.8	0.5	1.2
	5C	10	2.7	3.2	2.7	3.1	2.0	2.3	1.3	1.9	1.8	2.0	1.2	1.5	0.5	0.8
135 p.p.m. nitrogen	6A	5	3.2	4.0	3.0	3.8	2.5	2.8	2.0	2.5	2.1	2.5	1.6	2.2	1.1	1.6
	6B	10	3.2	3.8	3.0	3.6	2.2	2.6	1.3	1.8	1.8	2.4	1.2	1.7	0.5	1.0
	6C	7	2.5	3.0	2.5	3.0	2.0	2.3	1.2	2.0	1.7	2.1	1.0	1.7	0.4	1.0
2 p.p.m. phosphorus	7A	5	3.0	3.5	3.0	3.4	2.3	2.5	1.8	2.6	2.0	2.4	1.7	2.1	0.8	1.0
	7B	10	3.5	3.9	3.2	3.6	2.0	2.6	1.2	1.8	2.0	2.3	1.0	1.5	0.4	0.8
	7C	6	2.2	3.0	2.4	2.9	1.6	2.2	1.3	2.0	1.6	2.0	1.0	1.6	0.5	0.8
4 p.p.m. phosphorus	8A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8B	10	3.6	4.5	3.5	4.3	2.4	3.0	1.5	2.2	2.0	2.5	1.4	2.1	0.4	0.8
	8C	5	2.6	2.9	2.4	3.0	1.8	2.0	1.5	1.8	2.0	2.2	1.5	1.7	0.5	0.9

* See Figure 3.14

Table A 6.11 (Continued)

Treatments	TANK NO.	N	A		B		C		D		E		F		G	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
8 p.p.m. phosphorus	9A	10	3.1	3.9	2.8	3.5	2.2	2.8	2.0	2.3	1.8	2.2	1.5	2.0	0.8	1.1
	9B	9	3.4	4.1	3.4	4.0	2.3	2.8	1.1	2.0	2.0	2.6	1.3	2.0	0.5	1.0
	9C	10	2.8	3.0	2.5	3.0	1.8	2.2	1.3	2.1	1.8	2.0	1.2	2.0	0.7	0.9
	10A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16 p.p.m. phosphorus	10B	10	3.1	3.8	3.0	3.8	2.2	2.8	1.2	1.9	2.0	2.2	1.1	1.8	0.5	1.0
	10C	10	2.3	3.0	2.2	3.0	1.5	2.2	1.4	1.8	1.7	2.0	1.2	1.5	0.6	0.9
5% Nacl	11A`	5	3.2	3.8	3.0	3.2	2.4	3.1	1.9	2.3	2.2	2.4	1.8	1.9	1.2	1.4
	11B`	10	2.6	3.2	2.4	2.9	2.0	2.6	1.4	2.2	1.2	1.8	0.8	1.3	0.5	1.0
	11C`	5	2.5	2.9	2.4	2.8	2.0	2.2	1.2	1.7	1.6	2.0	1.0	1.5	0.5	0.7
1.3% Nacl	12A`	8	3.5	4.3	3.4	4.0	2.4	3.5	2.1	2.8	2.3	3.2	2.0	2.6	0.9	1.6
	12B`	6	3.0	4.2	3.0	3.5	2.0	3.0	1.3	2.2	1.4	2.5	1.1	2.2	0.7	1.3
	12C`	10	2.8	3.5	2.5	3.2	2.0	2.8	1.2	2.1	1.7	2.3	1.2	1.7	0.5	1.1
0.65% Nacl	13A`	10	3.5	4.8	3.2	4.6	3.0	3.6	2.1	2.6	2.2	2.8	1.8	2.2	0.9	1.6
	13B`	5	2.8	3.4	2.9	3.2	2.5	2.5	2.0	2.3	2.0	2.5	1.6	2.0	1.0	1.1
	13C`	8	3.0	4.1	2.8	3.6	2.0	2.7	1.5	2.0	1.9	2.5	1.2	1.8	0.6	0.9
2.5% Nacl	14A`	8	3.2	3.5	3.0	3.5	2.0	2.5	1.8	2.2	2.3	2.7	1.8	2.2	0.8	1.3
	14B`	5	3.6	3.8	3.0	3.0	2.5	2.5	1.4	1.8	1.8	2.2	1.4	1.7	0.7	0.9

A and A` Plants belong to *Salicornia dolichostachya.*
B and B` Plants belong to *S. nitens.*
C and C` Plants belong to *S. ramosissima.*

Table A 6.12

Results of analysis of variance for the:-

1- Vegetative characters, 2 - Fertile segment components and 3- Fertile segments indecis of the three types of *Salicornia* in the four levels of nitrogen treatment. Growth experiment 1976.

A - Key for the race number:-

1. *Salicornia dolichostachya*
2. *Salicornia nitens*
3. *Salicornia ramosissima*

B - Key for the treatments number:-

1. Experimental level of nitrogen 5 p.p.m.
2. Experimental level of nitrogen 15 p.p.m.
3. Experimental level of nitrogen 45 p.p.m.
4. Experimental level of nitrogen 135 p.p.m.

Table A 6.12 : 1-Vegetative characters-

1. Shoot length.

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	11.55	17.22	20.94	18.29
RACES 2	19.43	26.28	29.50	25.11
3	14.89	21.98	24.59	18.43

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	147.34	49.11	48.79	4.76	9.78	23.70
RACES	2	133.70	66.85	66.41	5.14	10.90	27.00
ERROR	6	6.04	1.01				
TOTAL	11	287.08					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .966

2. Root length.

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	6.95	7.91	9.67	7.80
RACES 2	9.83	10.77	11.62	11.09
3	6.63	6.93	7.46	6.61

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	4.85	1.62	7.91	4.76	9.78	23.70
RACES	2	32.36	16.18	79.23	5.14	10.90	27.00
ERROR	6	1.23	.20				
TOTAL	11	38.43					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 5.919

Table A 6.12 : I- Vegetative characters (Continued)

3. Total number of the primary branches from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	26.67	34.17	40.00	35.60
RACES	2	35.17	40.00	46.17	42.00
	3	26.93	34.53	36.27	30.67

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	191.71	63.90	25.15	4.76	9.78	23.70
RACES	2	167.38	83.69	32.93	5.14	10.90	27.00
ERROR	6	15.25	2.54				
TOTAL	11	374.34					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .682

4. Total number of sterile segments in the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	13.33	17.17	20.13	17.67
RACES	2	17.50	19.92	22.75	20.92
	3	13.53	17.27	17.37	15.33

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	45.50	15.20	22.23	4.76	9.78	23.70
RACES	2	39.48	19.74	28.87	5.14	10.90	27.00
ERROR	6	4.10	.68				
TOTAL	11	89.18					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .863

Table A 6.12 : 1- Vegetaive characters (Continued)

5. Terminal spike length.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	1.23	1.87	1.73	1.16
RACES	2	1.01	1.76	1.65	1.08
	3	.90	1.11	1.25	.53

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	1.01	.34	21.20	4.76	9.78	23.70
RACES	2	.67	.34	21.06	5.14	10.90	27.00
ERROR	6	.10	.02				
TOTAL	11	1.78					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .648

6. Number of fertile segments in the terminal spike.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	6.73	3.00	-0	5.33
RACES	2	4.60	-0	-0	4.33
	3	4.67	-0	4.25	6.75

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	53.07	17.69	6.25	4.76	9.78	23.70
RACES	2	6.94	3.47	1.23	5.14	10.90	27.00
ERROR	6	16.99	2.83				
TOTAL	11	77.00					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .021

Table A 6.12 : 1- Vegetative characters (Continued)

7. Length of the lowermost branch from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	2.95	7.60	9.88	8.01
RACES	2	3.67	7.65	12.33	10.84
	3	2.02	3.01	6.23	5.83

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	75.00	25.00	18.29	4.76	9.78	23.70
RACES	2	39.12	19.56	14.31	5.14	10.90	27.00
ERROR	6	8.20	1.37				
TOTAL	11	122.33					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .492

8. Length of the uppermost branch from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.65	.94	.99	.78
RACES	2	.88	1.29	1.02	.91
	3	.63	.66	.79	.47

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.16	.05	4.53	4.76	9.78	23.70
RACES	2	.30	.15	13.01	5.14	10.90	27.00
ERROR	6	.07	.01				
TOTAL	11	.53					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 1.379

Table A 6.12 : 1- Vegetative characters (Continued)

9. Angle of the uppermost branch from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	32.50	34.17	42.00	36.67
RACES	2	35.83	32.08	38.33	48.18
	3	36.33	29.67	54.00	51.67

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	424.99	141.66	4.55	4.76	9.78	23.70
RACES	2	89.44	44.72	1.44	5.14	10.90	27.00
ERROR	6	186.94	31.16				
TOTAL	11	701.37					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .050

10. Angle of the lowermost branch from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	38.75	40.00	33.67	32.00
RACES	2	40.00	35.83	40.83	54.55
	3	40.67	32.00	0	0

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	411.80	137.27	.69	4.76	9.78	23.70
RACES	2	1298.08	649.04	3.28	5.14	10.90	27.00
ERROR	6	1189.03	198.17				
TOTAL	11	2898.91					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .634

Table A 6.12 : 2-Fertile segment components (Continued)

1. Maximum width of the 2nd segment (A).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.38	0	.34	.35
RACES 2	.37	.36	.35	.36
3	.31	0	.30	.28

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.11	.04	3.98	4.76	9.78	23.70
RACES	2	.04	.02	2.10	5.14	10.90	27.00
ERROR	6	.05	.01				
TOTAL	11	.20					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .138

2. Maximum width of the 4th segment (B).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.35	0	.33	.34
RACES 2	.35	.33	.33	.34
3	.29	0	.29	.27

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.10	.03	4.03	4.76	9.78	23.70
RACES	2	.03	.02	1.84	5.14	10.90	27.00
ERROR	6	.05	.01				
TOTAL	11	.18					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .104

Table A 6.12 : 2- Fertile segment components (Continued)

3. Minimum width of the 4th segment at the base (C).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.26	0	.24	.25
RACES 2	.23	.23	.21	.25
3	.23	0	.21	.21

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.05	.02	3.74	4.76	9.78	23.70
RACES	2	.01	.00	.96	5.14	10.90	27.00
ERROR	6	.03	.00				
TOTAL	11	.09					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.005

4. Length of the segment (D).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.23	0	.21	.22
RACES 2	.15	.19	.18	.16
3	.17	0	.16	.16

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.03	.01	2.59	4.76	9.78	23.70
RACES	2	.01	.00	.67	5.14	10.90	27.00
ERROR	6	.03	.00				
TOTAL	11	.06					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.054

Table A 6.12 : 2- Fertile segment components-(Continued)

5. Total length of the central flower (E).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.24	0	.21	.23
RACES	2	.20	.21	.21	.22
	3	.21	0	.19	.18

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.04	.01	4.00	4.76	9.78	23.70
RACES	2	.01	.00	1.14	5.14	10.90	27.00
ERROR	6	.02	.00				
TOTAL	11	.08					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .018

6. Observed length of the central flower (F).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.20	0	.17	.19
RACES	2	.14	.16	.15	.14
	3	.15	0	.14	.14

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.02	.01	2.96	4.76	9.78	23.70
RACES	2	.00	.00	.72	5.14	10.90	27.00
ERROR	6	.02	.00				
TOTAL	11	.05					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.042

Table A 6.12 : 2-Fertile segment components-(Continued)

7. Observed length of the lateral flower (G).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.13	0	.10	.13
RACES 2	.06	.08	.08	.67
3	.07	0	.07	.71

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.44	.15	5.19	4.76	9.78	23.70
RACES	2	.04	.02	.75	5.14	10.90	27.00
ERROR	6	.17	.03				
TOTAL	11	.66					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.026

8. Length of the scarious border width at its tip (E-F).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.04	0	.03	.04
RACES 2	.06	.05	.06	.08
3	.06	0	.05	.05

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	6.93	4.76	9.78	23.70
RACES	2	.00	.00	8.23	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .607

Table A 6.12 :2-Fertile segmenet components-(Continued)

9. Distance between the top of the central flower and the top of the segment (D-F).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.03	0	.04	.04
RACES	2	.01	.03	.03	.02
	3	.02	0	.02	.03

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	1.43	4.76	9.78	23.70
RACES	2	.00	.00	.81	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.00					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.042

Table A 6.12 : 3-Fertile segment indecis-(Continued)

1. Minimum width of the segment/Maximum width of the segment (C/B).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	7.00	0	7.10	7.60
RACES 2	6.60	6.90	6.40	7.40
3	7.80	0	7.30	7.60

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.08	.03	3.91	4.76	9.78	23.70
RACES	2	.01	.00	.69	5.14	10.90	27.00
ERROR	6	.04	.01				
TOTAL	11	.12					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.039

2. Length of the segment/Maximum width of the segment (D/B).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	6.40	0	6.40	6.60
RACES 2	4.40	5.60	5.40	4.80
3	5.80	0	5.40	5.00

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.06	.02	3.25	4.76	9.78	23.70
RACES	2	.00	.00	.37	5.14	10.90	27.00
ERROR	6	.04	.01				
TOTAL	11	.10					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.090

Table A 6.12 : 3-Fertile segment indecis-(Continued)

3. Observed length of the lateral flower/observed length of the central flower.

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	6.50	0	5.50	7.20
RACES 2	4.30	4.90	5.10	4.70
3	4.40	0	4.90	5.20

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.06	.02	3.65	4.76	9.78	23.70
RACES	2	.01	.00	.57	5.14	10.90	27.00
ERROR	6	.03	.01				
TOTAL	11	.09					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.057

4. Total length of the central flower/length of the segment (E/D).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	10.10	0	9.80	10.20
RACES 2	13.20	11.10	11.90	13.70
3	12.60	0	12.10	11.20

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.12	.04	5.08	4.76	9.78	23.70
RACES	2	.03	.02	1.96	5.14	10.90	27.00
ERROR	6	.05	.01				
TOTAL	11	.20					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .102

Table A 6.12 : 3-Fertile segment indecis-(Continued)

5. Observed length of the lateral flower/length of the segment (G/D).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	5.60	0	4.50	6.00
RACES 2	4.00	4.20	4.40	4.20
3	3.90	0	4.20	4.30

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.05	.02	3.88	4.76	9.78	23.79
RACES	2	.01	.00	.68	5.14	10.90	27.00
ERROR	6	.02	.00				
TOTAL	11	.08					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.041

6. Observed length of the central flower/length of the segment (F/D).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	8.50	0	8.30	8.40
RACES 2	9.40	8.50	8.60	8.80
3	9.00	0	8.70	8.20

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.09	.03	4.32	4.76	9.78	23.70
RACES	2	.02	.01	1.21	5.14	10.90	27.00
ERROR	6	.04	.01				
TOTAL	11	.15					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .025

Table 6.12 : 3-Fertile segment indecis-(Continued)

7. Distance between the top of the central flower and the segment top/ total length of the central flower + distance between the top of the central flower and the segment top. (D-F/E+D-F)

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	1.29	0	1.52	1.37
RACES 2	.47	1.19	1.06	.79
3	.74	0	.96	1.26

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.01	.00	2.23	4.76	9.78	23.70
RACES	2	.00	.00	.25	5.14	10.90	27.00
ERROR	6	.01	.00				
TOTAL	11	.02					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.134

8. Covered part of the central flower/total length of the central flower + distance between the top of the central flower and the segment top (E-F/E+D-F).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	1.40	0	1.30	1.50
RACES 2	2.80	2.00	2.50	3.30
3	2.70	0	2.50	2.20

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.02	.01	6.64	4.76	9.78	23.70
RACES	2	.01	.01	4.76	5.14	10.90	27.00
ERROR	6	.01	.00				
TOTAL	11	.04					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .327

Table 6.12 : 3-Fertile segment indecis-(Continued)

9. Minimum width of the segment + length of the segment/2 x maximum width of the segment. (C+D/2B).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	6.70	0	6.80	7.10
RACES 2	5.50	6.30	5.90	6.00
3	6.80	0	6.30	6.80

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.07	.02	3.55	4.76	9.78	23.70
RACES	2	.01	.00	.51	5.14	10.90	27.00
ERROR	6	.04	.01				
TOTAL	11	.11					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.066

10. Maximum width of the 2nd segment from the base + maximum width of the 4th segment from the base/2 x minimum width of the 3rd segment. (A+B/2C).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	14.50	0	14.30	13.40
RACES 2	16.30	14.90	16.20	13.90
3	15.60	0	13.90	13.20

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.15	.05	4.26	4.76	9.78	23.70
RACES	2	.03	.02	1.42	5.14	10.90	27.00
ERROR	6	.07	.01				
TOTAL	11	.26					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .051

Table 6.12 : 3-Fertile segment indecis-(Continued)

11. Total length of the central flower/length of the scarious border width at its tip (E/E-F).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	61.80	0	64.40	56.50
RACES 2	34.20	42.40	36.00	27.90
3	34.80	0	35.70	39.00

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.52	.17	2.56	4.76	9.78	23.70
RACES	2	.08	.04	.56	5.14	10.90	27.00
ERROR	6	.41	.07				
TOTAL	11	1.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.072

Table A 6.13

Results of analysis of variance for the 1-- Vegetative characters, 2 - Fertile segment components, and 3 - Fertile segments indecis of the three types of *Salicornia* in the four levels of phosphorus treatment. Growth experiment 1976.

A - Key for the race number:-

1. *Salicornia dolichostachya*
2. *Salicornia nitens*
3. *Salicornia ramosissima*

B - Key for the treatments number:-

1. Experimental level of phosphorus 2 p.p.m.
2. Experimental level of phosphorus 4 p.p.m.
3. Experimental level of phosphorus 8 p.p.m.
4. Experimental level of phosphorus 16 p.p.m.

Table A 6.13 : 1-Vegetative characters-

1. Shoot length.

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1*	.18E+09*	.22E+09*	.15E+09*	.16E+09
RACES 2*	.27E+09*	.31E+09*	.25E+09*	.29E+09
3*	.20E+09*	.24E+09*	.24E+09*	.26E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.453E+16*	.151E+16	2.80	4.76	9.78	23.70
RACES	2 *	.213E+17*	.106E+17	19.81	5.14	10.90	27.00
ERROR	6 *	.323E+16*	.539E+15				
TOTAL	11 *	.291E+17					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 2.939

2. Root length.

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1*	.76E+08*	.69E+08*	.60E+08*	.56E+08
RACES 2*	.90E+08*	.92E+08*	.92E+08*	.10E+09
3*	.71E+08*	.73E+08*	.83E+08*	.96E+08

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.117E+15*	.390E+14	.37	4.76	9.78	23.70
RACES	2 *	.177E+16*	.889E+15	8.40	5.14	10.90	27.00
ERROR	6 *	.635E+15*	.105E+15				
TOTAL	11 *	.253E+16					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 2.343

Table A 6.13 : 1-Vegetative characters-(Continued)

3. Total number of the primary branches from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.35E+09*	.42E+09*	.30E+09*	.31E+09
RACES	2*	.45E+09*	.49E+09*	.39E+09*	.46E+09
	3*	.32E+09*	.37E+09*	.33E+09*	.41E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.115E+17*	.385E+16	2.70	4.76	9.78	23.70
RACES	2 *	.240E+17*	.120E+17	8.40	5.14	10.90	27.00
ERROR	6 *	.858E+16*	.143E+16				
TOTAL	11 *	.442E+17					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 1.182

4. Total number of sterile segments in the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.17E+09*	.21E+09*	.15E+09*	.15E+09
RACES	2*	.22E+09*	.24E+09*	.19E+09*	.23E+09
	3*	.16E+09*	.18E+09*	.16E+09*	.20E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.277E+16*	.924E+15	2.50	4.76	9.78	23.70
RACES	2 *	.596E+15*	.298E+15	8.07	5.14	10.90	27.00
ERROR	6 *	.221E+16*	.369E+15				
TOTAL	11 *	.109E+17					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 1.177

Table A 6.13 : 1-Vegetative characters-(Continued)

5. Terminal spike length.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.17E+08*	.18E+08*	.15E+08*	.16E+08
RACES	2*	.16E+08*	.17E+08*	.16E+08*	.11E+08
	3*	.94E+07*	.70E+07*	.14E+08*	.55E+07

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.276E+14*	.922E+13	1.43	4.76	9.78	23.70
RACES	2 *	.145E+15*	.727E+14	11.26	5.14	10.90	27.00
ERROR	6 *	.387E+14*	.645E+13				
TOTAL	11 *	.211E+15					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 2.244

6. Number of fertile segments in the terminal spike.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.63E+08*	.66E+08*	.60E+08*	.64E+08
RACES	2*	.78E+08*	.80E+08*	.85E+08*	.53E+08
	3*	.61E+08*	.43E+08*	.80E+08*	.33E+08

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.973E+15*	.324E+15	2.04	4.76	9.78	23.70
RACES	2 *	.786E+15*	.393E+15	2.48	5.14	10.90	27.00
ERROR	6 *	.952E+15*	.158E+15				
TOTAL	11 *	.271E+16					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .774

Table A 6.13 : 1-Vegetative characters-(Continued)

7. Length of the lowermost branch from the main axis (cm)

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1*	.84E+08*	.11E+09*	.10E+09*	.90E+08
RACES 2*	.10E+09*	.12E+09*	.15E+09*	.12E+09
3*	.69E+08*	.65E+08*	.12E+09*	.11E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.255E+16*	.851E+15	2.43	4.76	9.78	23.70
RACES	2 *	.301E+16*	.150E+16	4.29	5.14	10.90	27.00
ERROR	6 *	.210E+16*	.350E+15				
TOTAL	11 *	.766E+16					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .558

8. Length of the uppermost branch from the main axis (cm)

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1*	.12E+08*	.10E+09*	.12E+08*	.11E+08
RACES 2*	.11E+08*	.13E+09*	.11E+08*	.87E+07
3*	.95E+07*	.55E+07*	.11E+08*	.49E+07

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.197E+14*	.658E+13	1.82	4.76	9.78	23.71
RACES	2 *	.390E+14*	.195E+14	5.41	5.14	10.90	27.00
ERROR	6 *	.216E+14*	.361E+13				
TOTAL	11 *	.805E+14					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .865

Table A 6.13 : 1-Vegetative characters-(Continued)

9. The Angle of the uppermost branch from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.30E+09*	.34E+09*	.33E+09*	.29E+09
RACES	2*	.52E+09*	.52E+09*	.35E+09*	.49E+09
	3*	.55E+09*	.39E+09*	.50E+09*	.42E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.719E+16*	.239E+16	.36	4.76	9.78	23.70
RACES	2 *	.583E+17*	.291E+17	4.42	5.14	10.90	27.00
ERROR	6 *	.396E+17*	.661E+16				
TOTAL	11 *	.105E+18					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 1.084

10. The Angle of the lowermost branch from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.34E+09*	.37E+09*	.40E+09*	.40E+09
RACES	2*	.51E+09*	.52E+09*	.45E+09*	.55E+09
	3	0*	.48E+09*	.56E+09*	.55E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.901E+17*	.300E+17	1.33	4.76	9.78	23.70
RACES	2 *	.398E+17*	.199E+17	.88	5.14	10.90	27.00
ERROR	6 *	.135E+18*	.226E+17				
TOTAL	11 *	.266E+18					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.027

Table A 6.13 : 2-Fertile segment components-(Continued)

1. Maximum width of the 2nd segment (A).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.32	0	.35	0
RACES	2	.36	.41	.37	.35
	3	.26	.27	.29	.27

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.04	.01	.91	4.76	9.78	23.70
RACES	2	.08	.04	3.10	5.14	10.90	27.00
ERROR	6	.08	.01				
TOTAL	11	.20					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .543

2. Maximum width of the 4th segment (B).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.31	0	.32	0
RACES	2	.34	.39	.37	.35
	3	.26	.27	.28	.26

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.03	.01	.91	4.76	9.78	23.70
RACES	2	.08	.04	3.52	5.14	10.90	27.00
ERROR	6	.07	.01				
TOTAL	11	.18					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .649

Table A 6.13 : 2-Fertile segment components-(Continued)

3. Minimum width of the 4th segment at the base (C).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.24	0	.25	0
RACES 2	.22	.28	.26	.25
3	.19	.19	.20	.20

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.02	.01	.82	4.76	9.78	23.70
RACES	2	.03	.02	2.36	5.14	10.90	27.00
ERROR	6	.04	.01				
TOTAL	11	.09					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .361

4. Length of the segment (D).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.22	0	.21	0
RACES 2	.16	.20	.17	.16
3	.16	.17	.17	.16

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.01	.00	.86	4.76	9.78	23.70
RACES	2	.01	.00	.89	5.14	10.90	27.00
ERROR	6	.03	.01				
TOTAL	11	.06					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.028

Table A 6.13 : 2-Fertile segment components- (Continued)

5. Total length of the central flower (E).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.21	0	.20	0
RACES	2	.22	.23	.21	.21
	3	.17	.21	.19	.19

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.01	.00	.70	4.76	9.78	23.70
RACES	2	.03	.01	2.71	5.14	10.90	27.00
ERROR	6	.03	.01				
TOTAL	11	.07					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .475

6. Observed length of the central flower (F)

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.19	0	.17	0
RACES	2	.13	.17	.16	.15
	3	.13	.16	.15	.14

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.01	.00	.71	4.76	9.78	23.70
RACES	2	.01	.00	1.14	5.14	10.90	27.00
ERROR	6	.02	.00				
TOTAL	11	.04					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .040

Table A 6.13 : 2-Fertile segment components-(Contiued)

7. Observed length of the lateral flower (G)

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.10	0	.10	0
RACES	2	.06	.07	.07	.07
	3	.06	.07	.08	.07

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	.95	4.76	9.78	23.70
RACES	2	.00	.00	.41	5.14	10.90	27.00
ERROR	6	.01	.00				
TOTAL	11	.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.151

8. Length of the scarious border width at its tip (E-F).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.03	0	.00	0
RACES	2	.08	.01	.01	.06
	3	.04	.01	.04	.05

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	3.43	4.76	9.78	23.70
RACES	2	.00	.00	3.03	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .281

Table A 6.13 : 2-Fertile segment components-(Continued)

9. Distance between the top of the central flower and the top of the segment. (D-F).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.03	0	.04	0
RACES	2	.02	.02	.01	.01
	3	.03	.07	.01	.02

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	.65	4.76	9.78	23.70
RACES	2	.00	.00	.91	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.00					

RACE/(TREATMENT * ERROR) VARIANCE RATIO = -.025

Table A 6.13 : 3-Fertile segment indecis-(Continued)

1. Minimum width of the segment/Maximum width of the segment (C/B).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	7.70	0	7.70	0
RACES 2	6.60	7.20	7.00	7.10
3	7.50	6.90	7.20	7.60

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.03	.01	.95	4.76	9.78	23.70
RACES	2	.05	.02	2.51	5.14	10.90	27.00
ERROR	6	.05	.01				
TOTAL	11	.12					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .384

2. Length of the segment/Maximum width of the segment (D/B).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	6.90	0	6.70	0
RACES 2	4.70	5.00	4.60	4.50
3	6.40	6.20	5.90	6.10

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.02	.01	.98	4.76	9.78	23.70
RACES	2	.03	.02	1.93	5.14	10.90	27.00
ERROR	6	.05	.01				
TOTAL	11	.10					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .234

Table A 6.13 : 3-Fertile segment indecis-(Continued)

3. Observed length of the lateral flower/observed length of the central flower.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	5.20	0	5.90	0
RACES	2	4.60	3.80	4.20	4.40
	3	4.80	4.40	5.00	5.30

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.02	.01	1.12	4.76	9.78	23.70
RACES	2	.03	.01	2.06	5.14	10.90	27.00
ERROR	6	.04	.01				
TOTAL	11	.08					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .255

4. Total length of the central flower/length of the segment (E/D).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	9.80	0	9.30	0
RACES	2	13.70	11.80	12.40	13.50
	3	10.60	12.80	11.40	11.60

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.03	.01	.87	4.76	9.78	23.70
RACES	2	.11	.05	4.63	5.14	10.90	27.00
ERROR	6	.07	.01				
TOTAL	11	.21					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .947

Table A 6.13 : 3-Fertile segment indecis-(Continued)

5. Observed length of the lateral flower/length of the segment (G/D).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	4.40	0	4.90	0
RACES 2	3.90	3.30	3.80	4.20
3	3.80	4.20	4.70	4.50

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.02	.01	1.01	4.76	9.78	23.70
RACES	2	.02	.01	2.24	5.14	10.90	27.00
ERROR	6	.03	.01				
TOTAL	11	.07					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .310

6. Observed length of the central flower/length of the segment (F/D).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	8.60	0	8.20	0
RACES 2	8.50	8.80	9.20	9.40
3	8.00	9.60	9.20	8.60

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.03	.01	.87	4.76	9.78	23.70
RACES	2	.06	.03	3.21	5.14	10.90	27.00
ERROR	6	.06	.01				
TOTAL	11	.15					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .578

Table A 6.13 : 3-Fertile segment indecis-(Continued)

7. Distance between the top of the central flower and the segment top/total length of the central flower + distance between the top of the central flower and the segment top. (D-F/E+D-F).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	1.24	0	1.60	0
RACES	2	.99	.94	.64	.40
	3	1.60	.30	.64	1.07

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.01	.00	1.70	4.76	9.78	23.70
RACES	2	.00	.00	.69	5.14	10.90	27.00
ERROR	6	.01	.00				
TOTAL	11	.02					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.062

8. Covered part of the central flower/total length of the central flower + distance between the top of the central flower and the segment top (E-F/E+D-F).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	1.00	2.20	-0	3.40
RACES	2	0	-0	-0	2.00
	3	2.90	-0	1.00	0

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.01	.00	.59	4.76	9.78	23.70
RACES	2	.01	.01	.95	5.14	10.90	27.00
ERROR	6	.04	.01				
TOTAL	11	.07					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.015

Table A 6.13 : 3-Fertile segment indecis-(Continued)

9. Minimum width of the segment + length of the segment/2 x maximum width of the segment. (C+D/2B).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	7.30	0	7.20	0
RACES 2	5.70	6.10	5.80	5.80
3	6.90	6.50	6.60	6.90

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.02	.01	.96	4.76	9.78	23.70
RACES	2	.04	.02	2.22	5.14	10.90	27.00
ERROR	6	.05	.01				
TOTAL	11	.11					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .308

10. Maximum width of the 2nd segment from the base + maximum width of the 4th segment from the base/2 x minimum width of the 3rd segment. (A+B/2C).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	13.30	0	13.60	0
RACES 2	15.70	14.30	14.20	14.20
3	13.30	14.50	14.10	13.40

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.05	.02	1.05	4.76	9.78	23.70
RACES	2	.11	.05	3.41	5.14	10.90	27.00
ERROR	6	.09	.02				
TOTAL	11	.25					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .595

Table A.6.13 : 3-Fertile segment indecis-(Continued)

11. Total length of the central flower/length of the scarious border width at its tip (E/E-F).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	81.50	0	80.70	0
RACES 2	26.10	39.20	38.20	32.90
3	40.90	40.00	51.40	39.70

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.44	.15	1.06	4.76	9.78	23.70
RACES	2	.05	.02	.17	5.14	10.90	27.00
ERROR	6	.83	.14				
TOTAL	11	1.33					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.202

Table A 6.14

Results of analysis of variance for the 1- Vegetative characters, 2 - Fertile segment components, and 3- Fertile segments indecis of the three types of *Salicornia* in the four levels of sodium chloride treatment. Growth experiment 1976.

A - Key for the race number:-

1. *Salicornia dolichostachya*
2. *Salicornia nitens*
3. *Salicornia ramosissima*

B - Key for the treatments number:-

1. Experimental level of Sodium chloride 5%
2. Experimental level of Sodium chloride 1.3%
3. Experimental level of Sodium chloride 0.65%
4. Experimental level of Sodium chloride 2.5%

Table A 6.14 : 1-Vegetative characters-

1. Shoot length.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.23E+09*	.29E+09*	.35E+09*	.24E+09
RACES	2*	.19E+09*	.30E+09*	.36E+09*	.25E+09
	3*	.22E+09*	.31E+09*	.39E+09*	.26E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.395E+17*	.131E+17	62.83	4.76	9.78	23.70
RACES	2 *	.126E+16*	.630E+15	3.00	5.14	10.90	27.00
ERROR	6 *	.125E+16*	.209E+15				
TOTAL	11 *	.420E+17					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .023

2. Root length.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.95E+08*	.98E+08*	.10E+09*	.10E+09
RACES	2*	.91E+08*	.10E+09*	.87E+08*	.96E+08
	3*	.10E+09*	.93E+08*	.10E+09*	.75E+08

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.629E+14*	.209E+14	.14	4.76	9.78	23.70
RACES	2 *	.609E+14*	.304E+14	.20	5.14	10.90	27.00
ERROR	6 *	.908E+15*	.151E+15				
TOTAL	11 *	.103E+16					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.280

Table A 6.14 : 1-Vegetative characters-(Continued)

3. Total number of the primary branches from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.34E+09*	.39E+09*	.47E+09*	.36E+09
RACES	2*	.38E+09*	.57E+09*	.60E+09*	.50E+09
	3*	.36E+09*	.49E+09*	.59E+09*	.42E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.569E+17*	.189E+17	17.65	4.76	9.78	23.70
RACES	2	.330E+17*	.165E+17	15.38	5.14	10.90	27.00
ERROR	6	.645E+16*	.107E+16				
TOTAL	11	.964E+17					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .549

4. Total number of sterile segments in the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.17E+09*	.19E+09*	.23E+09*	.18E+09
RACES	2*	.19E+09*	.23E+09*	.30E+09*	.25E+09
	3*	.18E+09*	.24E+09*	.29E+09*	.21E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.145E+17*	.486E+16	23.98	4.76	9.78	23.70
RACES	2	.819E+16*	.409E+16	20.20	5.14	10.90	27.00
ERROR	6	.121E+16*	.202E+15				
TOTAL	11	.240E+17					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .554

Table A 6.14 : 1-Vegetative characters-(Continued)

5. Terminal spike length.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.31E+07*	.12E+08*	.26E+08*	.11E+08
RACES	2*	.32E+07*	.18E+08*	.23E+08*	.14E+08
	3*	.23E+07*	.12E+08*	.24E+08*	.66E+07

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.719E+15*	.239E+15	40.22	4.76	9.78	23.70
RACES	2 *	.235E+14*	.117E+14	1.97	5.14	10.90	27.00
ERROR	6 *	.357E+14*	.596E+13				
TOTAL	11 *	.779E+15					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .017

6. Number of fertile segments in the terminal spike.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.13E+08*	.43E+08*	.11E+09*	.50E+08
RACES	2*	.16E+08*	.88E+08*	.11E+09*	.78E+08
	3*	.13E+08*	.75E+08*	.13E+09*	.39E+08

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.168E+17*	.562E+16	23.96	4.76	9.78	23.70
RACES	2 *	.696E+15*	.348E+15	1.48	5.14	10.90	27.00
ERROR	6 *	.140E+16*	.234E+15				
TOTAL	11 *	.189E+17					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .014

Table A 6.14 ; 1-Vegetative characters-(Contiued)

7. Length of the lowermost branch from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.64E+08*	.10E+09*	.15E+09*	.91E+08
RACES	2*	.52E+08*	.13E+09*	.11E+09*	.91E+08
	3*	.80E+08*	.12E+09*	.22E+09*	.11E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	* .150E+17*	.502E+16	6.81	4.76	9.78	23.78
RACES	2	* .376E+16*	.188E+16	2.55	5.14	10.90	27.00
ERROR	6	* .443E+16*	.738E+15				
TOTAL	11	* .232E+17					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .132

8. Length of the uppermost branch from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.66E+07*	.15E+08*	.19E+08*	.10E+08
RACES	2*	.64E+07*	.18E+08*	.20E+08*	.11E+08
	3*	.35E+07*	.84E+07*	.15E+08*	.58E+07

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	* .294E+15*	.983E+14	46.42	4.76	9.78	23.78
RACES	2	* .820E+14*	.410E+14	16.88	5.14	10.90	27.00
ERROR	6	* .145E+14*	.243E+13				
TOTAL	11	* .391E+15					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .281

Table A 6.14 : 1-Vegetative characters-(Continued)

9. Angle of the uppermost branch from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.33E+09*	.31E+09	-0*	.30E+09
RACES	2*	.25E+09	-0	-0*	.31E+09
	3*	.32E+09	-0*	.34E+09*	.29E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.116E+18*	.388E+17	1.91	4.76	9.78	23.70
RACES	2 *	.245E+17*	.122E+17	.61	5.14	10.90	27.00
ERROR	6 *	.121E+18*	.203E+17				
TOTAL	11 *	.262E+18					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.076

10. Angle of the lowermost branch from the main axis.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1*	.31E+09*	.30E+09*	.38E+09*	.26E+09
RACES	2*	.45E+09*	.40E+09*	.34E+09*	.42E+09
	3*	.39E+09*	.29E+09*	.38E+09*	.21E+09

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3 *	.126E+17*	.420E+16	1.12	4.76	9.78	23.70
RACES	2 *	.212E+17*	.106E+17	2.83	5.14	10.90	27.00
ERROR	6 *	.224E+17*	.374E+16				
TOTAL	11 *	.563E+17					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .441

Table A 6.14 : 2-Fertile segment components-(Continued)

1. Maximum width of the 2nd segment (A).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.35	.38	.43	.35
RACES	2	.30	.34	.31	.36
	3	.28	.31	.35	.30

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	1.73	4.76	9.78	23.70
RACES	2	.01	.01	5.69	5.14	10.90	27.00
ERROR	6	.01	.00				
TOTAL	11	.02					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .944

2. Maximum width of the 4th segment (B).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.31	.34	.42	.33
RACES	2	.26	.31	.30	.30
	3	.26	.28	.33	.23

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.01	.00	5.09	4.76	9.78	23.70
RACES	2	.01	.01	9.81	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.03					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .932

Table A 6.14 : 2-Fertile segment components-(Contiued)

3. Minimum width of the 4th segment at the base (C).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.27	.27	.32	.22
RACES 2	.22	.25	.25	.25
3	.21	.23	.24	.19

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	3.54	4.76	9.78	23.70
RACES	2	.01	.00	6.79	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .784

4. Length of the segment (D).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.21	.24	.23	.21
RACES 2	.17	.17	.21	.15
3	.14	.17	.16	.12

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	7.75	4.76	9.78	23.70
RACES	2	.01	.01	39.11	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.02					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 2.932

Table A 6.14 ; 2-Fertile segment components-(Continued)

5. Total length of the central flower (E).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.23	.27	.25	.25
RACES	2	.16	.19	.22	.18
	3	.18	.21	.22	.19

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	6.04	4.76	9.78	23.70
RACES	2	.01	.00	25.79	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 2.405

6. Observed length of the central flower (F).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.19	.23	.21	.20
RACES	2	.12	.15	.18	.15
	3	.12	.16	.14	.17

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	4.06	4.76	9.78	23.70
RACES	2	.01	.01	28.53	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.02					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 3.408

Table A 6.14 : 2-Fertile segment components-(Cotinued)

7. Observed length of the lateral flower (G).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.13	.13	.13	.10
RACES 2	.07	.08	.10	.07
3	.06	.07	.07	.06

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	4.03	4.76	9.78	23.71
RACES	2	.01	.00	52.54	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 6.410

8. Length of the scarious border width at its tip (E-F).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.04	.04	.04	.05
RACES 2	.04	.04	.04	.03
3	.06	.05	.08	.08

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	.47	4.76	9.78	23.70
RACES	2	.00	.00	7.34	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.00					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 1.925

Table A 6.14 : 2-Fertile segment components-(Continued)

9. Distance between the top of the central flower and the top of the segment (D-F).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	.02	.08	.02	.00
RACES	2	.05	.02	.03	.06
	3	.02	.06	.02	0

TABLE OF ANALYSIS OF VARIANCE

	OF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	.90	4.76	9.78	23.70
RACES	2	.00	.00	.26	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.192

Table A 6.14 : 3-Fertile segment indecis-(Contiued)

1. Minimum width of the segment/Maximum width of the segment (C/B).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	8.90	7.90	7.60	6.80
RACES	2	8.30	8.00	8.30	8.20
	3	8.20	8.30	7.50	7.90

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	1.55	4.76	9.78	23.70
RACES	2	.00	.00	.67	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.00					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.069

2. Length of the segment/Maximum width of the segment (D/B).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	6.90	6.90	5.50	6.40
RACES	2	6.60	5.40	6.90	4.90
	3	5.60	5.90	9.40	5.60

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	.84	4.76	9.78	23.70
RACES	2	.00	.00	.28	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.190

Table A 6.14 : 3-Fertile segment indecis-(Continued)

3. Observed length of the lateral flower/observed length of the central flower.

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	6.90	5.40	5.90	5.00
RACES	2	6.00	5.60	5.60	5.70
	3	4.80	4.20	5.00	4.90

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	1.92	4.76	9.78	23.70
RACES	2	.00	.00	7.20	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.00					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 1.186

4. Total length of the central flower/length of the segment (E/D).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	10.70	11.40	10.70	12.20
RACES	2	9.40	11.30	10.60	12.40
	3	12.50	12.50	13.50	14.40

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	7.74	4.76	9.78	23.70
RACES	2	.00	.00	19.97	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 1.461

Table A 6.14 : 3-Fertile segment indecis-(Continued)

5. Observed length of the lateral flower/length of the segment (G/D).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	6.10	5.20	5.50	4.90
RACES	2	4.30	4.90	4.90	4.90
	3	4.00	4.00	4.30	4.30

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	.16	4.76	9.78	23.70
RACES	2	.00	.00	9.74	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.00					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 3.038

6. Observed length of the central flower/length of the segment (F/D).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	8.90	9.70	9.10	9.60
RACES	2	7.10	8.80	8.70	8.60
	3	8.50	9.60	8.60	8.70

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	4.61	4.76	9.78	23.70
RACES	2	.00	.00	5.44	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.00					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .617

Table A 6.14 : 3-Fertile segment indecis-(Continued)

7. Distance between the top of the central flower and the segment top/total length of the central flower + distance between the top of the central flower and the segment top. (D-F/E+D-F).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	.96	.27	.74	.29
RACES 2	2.36	.95	1.12	.99
3	1.09	.28	.93	.80

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	9.27	4.76	9.78	23.70
RACES	2	.00	.00	11.60	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = .705

8. Covered part of the central flower/total length of the central flower + distance between the top of the central flower and the segment top (E-F/E+D-F).

SUMMARY OF DATA

	TREATMENTS 1	2	3	4
1	1.50	1.40	1.30	1.90
RACES 2	1.90	1.99	1.60	2.70
3	2.90	2.20	3.30	3.60

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	4.08	4.76	9.78	23.70
RACES	2	.01	.00	21.98	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.01					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 2.589

Table A 6.14 : 3-Fertile segment indecis-(Continued)

9. Minimum width of the segment + length of the segment/ 2 x maximum width of the segment. (C+D/2B).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	7.90	7.50	6.60	6.60
RACES	2	7.40	6.70	7.60	6.60
	3	6.90	7.30	6.50	6.80

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	1.27	4.76	9.78	23.70
RACES	2	.00	.00	.32	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.00					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.156

10. Maximum width of the 2nd segment from the base + maximum width of the 4th segment from the base/ 2x minimum width of the 3rd segment (A+B/2C).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	12.00	13.20	13.40	15.10
RACES	2	12.80	13.90	12.20	13.40
	3	12.60	12.70	13.90	14.20

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.00	.00	3.70	4.76	9.78	23.70
RACES	2	.00	.00	.85	5.14	10.90	27.00
ERROR	6	.00	.00				
TOTAL	11	.00					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = -.019

Table A 6.14 : 3-Fertile segment indecis-(Continued)

11. Total length of the central flower/length of the scarious border width at its tip. (E/E-F).

SUMMARY OF DATA

		TREATMENTS 1	2	3	4
	1	59.50	68.10	83.00	49.30
RACES	2	43.80	45.60	55.50	33.20
	3	31.00	43.80	27.50	25.00

ARCSINE TRANSFORMATION APPLIED TO DATA

TABLE OF ANALYSIS OF VARIANCE

	DF	SUM SQS	MEAN SQS	F	CRITICAL F VALUES 0.05	0.01	0.001
TREATMENTS	3	.08	.03	3.52	4.76	9.78	23.70
RACES	2	.25	.12	16.58	5.14	10.90	27.00
ERROR	6	.04	.01				
TOTAL	11	.37					

RACE/(TREATMENT + ERROR) VARIANCE RATIO = 2.117

Table A 6.15 Shows the axes values (axis 1 and 2) for each of the 8 *Salicornia* types cultured according to their morphological characters, based on the Principal Component Analysis.

CYCLE NUMBER = 1
ITERATION = 5 MAXIMUM ROOT = 1 VALUE OF .23340431E+06
PERCENT VARIANCE 98.04686

CYCLE NUMBER = 2
ITERATION = 333 MAXIMUM ROOT = 3 VALUE OF .19224420E+04
PERCENT VARIANCE .80757

CYCLE NUMBER = 3
ITERATION = 16 MAXIMUM ROOT = 8 VALUE OF .18653257E+04
PERCENT VARIANCE .78357
TOTAL VARIANCE = .23805384E+06

COORDINATES FOR PLOTTING

	1	2	3
1	493.069	24.006	29.121
2	245.116	27.656	0
3	318.886	50.736	22.892
4	376.065	.478	9.021
5	79.659	0	33.048
6	0	25.991	1.067
7	36.430	29.999	12.725
8	61.710	29.191	46.005
AXIS ORIGINS	201.367	23.507	19.235

15.57.47. 79/03/12. I.C.C.C. NETWORK OPERATING SYSTEM. NOS 1.1-430.
ORIGINAL FILE NAME - OUTPUT QUEUE NAME - W9AUDAP JO

Table A 7.1 Shows total nitrogen, total phosphorus and sodium in p.p.m. for the soils from Shingle Street.

The elements/ weight/vol. used. / Soil reference number		Total nitrogen p.p.m. 0.25g/50ml		Total phosphorus p.p.m. 1.5g/50ml		Sodium p.p.m. 1.5g/50ml	
		$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
Lower marsh populations	1A	26.03	±1.15	20.42	±0.63	388.33	±36.89
	1B	29.42	±2.24	18.33	±2.02	460.00	±52.92
	1C	32.87	±4.54	22.83	±1.23	465.00	±18.03
	1D	35.37	±1.60	20.33	±0.88	338.33	±12.58
	1E	17.75	±0.90	16.92	±0.63	328.33	±20.20
Lower marsh populations	2A	42.03	±2.52	36.08	±2.00	708.33	±52.04
	2B	30.37	±0.29	33.08	±2.25	641.67	±38.84
	2C	36.53	±5.92	34.83	±3.79	705.00	±0.00
	2D	33.95	±1.77	30.00	±5.68	650.00	±34.64
	2E	31.97	±5.51	34.58	±1.90	711.67	±11.55
Lower marsh (middle marsh) populations	3A	12.20	±1.00	27.08	±1.90	366.67	±14.43
	3B	12.53	±1.76	26.83	±0.29	368.33	±40.72
	3C	12.75	±1.15	30.58	±5.56	400.00	±00.00
	3D	13.87	±0.58	28.17	±0.29	353.33	±25.66
	3E	13.37	±0.76	32.50	±4.58	336.67	±20.20
"	4A	12.53	±1.01	25.83	±1.38	326.67	±32.53
	4B	12.05	±1.03	26.67	±0.29	318.33	±28.43
	4C	10.73	±1.03	25.92	±1.23	320.00	±17.32
	4D	10.45	±0.75	25.00	±0.75	293.33	±17.56
	4E	13.87	±0.80	23.08	±3.71	325.00	±25.00
"	5A	12.37	±1.80	26.42	±0.88	273.33	±12.58
	5B	13.83	±0.32	27.00	±0.50	308.33	±32.53
	5C	13.95	±1.02	23.92	±3.09	303.33	±25.66
	5D	11.35	±0.80	25.75	±1.32	338.33	±12.58
	5E	13.89	±1.00	25.92	±1.42	308.33	±42.52

Table A 7.1 — (Continued)

The elements/ weight/vol. used. / Soil reference number		Total nitrogen p.p.m. 0.25g/50ml		Total phosphorus p.p.m. 1.5g/50ml		Sodium p.p.m. 1.5g/50ml	
		$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
Upper marsh populations	6A	15.3	±1.43	27.17	±0.29	303.33	±11.55
	6B	15.70	±1.00	27.25	±0.66	273.33	±12.58
	6C	13.70	±0.00	29.08	±0.76	268.33	±14.42
	6D	16.37	±1.65	29.00	±1.75	283.33	±20.20
	6E	13.62	±1.59	28.17	±1.91	240.00	±22.91
Upper marsh populations	7A	14.78	±	26.5	±0.66	311.67	±37.53
	7B	14.37	±1.44	26.58	±1.84	370.00	±65.38
	7C	14.45	±0.00	26.50	±2.38	308.33	±32.53
	7D	14.58	±0.18	27.08	±0.72	310.00	±00.00
	7E	13.37	±1.04	25.83	±1.84	275.00	±26.46

* each value is a mean of 3 samples.

Table A 7.2 Shows total nitrogen, total phosphorus and sodium in p.p.m. for the soils from Northney, Hayling Island.

The elements/ weight/vol. used. / Soil reference number		Total nitrogen p.p.m. 0.25g/50ml		Total phosphorus p.p.m. 1.5g/50ml		Sodium p.p.m. 1.5g/50ml	
		$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
Lower marsh populations	1A	13.91	±1.07	23.33	±0.50	270	±2.64
	1B	14.40	±2.01	23.30	±1.27	285	±7.64
	1C	19.19	±1.10	26.83	±0.38	295	±5.00
	1D	18.16	±1.09	25.89	±0.22	305	±4.36
	1E	20.06	±4.49	25.94	±1.57	330	±3.28
Upper marsh populations	2	31.44	±2.89	-	± -	-	± -

* each value is a mean of 9 samples.

Table A 7. 3 Shows total nitrogen, total phosphorus and sodium in p.p.m. for the soils from Warham, Wells next to the sea, Norfolk.

Soil reference number / The elements/ weight/vol. used.		Total nitrogen p.p.m. 0.25g/50ml		Total phosphorus p.p.m. 1.5g/50ml		Sodium p.p.m. 1.5g/50ml	
	1A	4.97	±0.97	24.90	±2.84	220	±3.4
	1B	9.59	±1.26	28.92	±1.23	-	± -
Lower marsh	1C	6.86	±7.48	-	± -	-	± -
	1D	2.77	±1.03	24.53	±5.34	220	±9.75
	1E	10.39	±1.07	-	± -	-	±
	2A	4.5	±2.5	14.17	±2.98	120	±7.74
	2B	12.79	±1.68	-	± -	-	± -
Lower marsh	2C	3.19	±2.09	-	± -	-	± -
	2D	9.20	±1.69	-	± -	-	± -
	3A	8.58	±1.85	22.80	±5.66	270.0	±12.47
Lower marsh	3B	6.00	±1.81	18.04	±1.92	180.0	± 9.12
(middle marsh)	3C	10.40	±2.72	22.63	±3.99	290.0	±9.32
	4A	17.05	±0.89	28.25	±2.76	220	± 5.66
Upper marsh	4B	10.73	±0.98	24.54	±2.48	340	±12.15
	4C	17.04	±3.37	29.68	±2.67	260	± 7.89
	4D	12.42	±2.41	12.42	±2.41	260	± 7.89
	4E	26.09	±4.91	26.09	±4.91	480	±10.68

* each value is a mean of 9 samples.

Table A. 7.4 Shows the minimum and maximum values for the morphological characters of *Salicornia* populations occupying soils differing in their total nitrogen content in the lower marsh of Warham.

Population number/total nitrogen / Vegetative characters	N	1D 0.06% Min.	1D 0.06% Max.	1B 0.19% Min.	1B 0.19% Max.	2C 0.06% Min.	2C 0.06% Max.	2B 0.26% Min.	2B 0.26% Max.
1. Shoot length	15	10.4	20.2	19.0	29.5	6.4	17.5	17.2	25.5
2. Number of sterile segments in the main axis.	15	9	16	10	18	6	12	10	18
3. Total number of primary branches from the main axis.	15	14	30	20	32	12	24	20	36
4. Terminal spike length.	15	1.2	4.0	2.6	9.7	2.1	4.9	2.4	5.2
5. Number of fertile segments in the terminal spike.	15	3	13	8	18	5	14	7	14
6. Length of the uppermost branch from the main axis.	15	0.8	1.8	1.2	5.6	1.2	3.1	1.6	3.3
7. Length of the lowermost branch from the main axis.	15	4.0	13.3	5.0	16.2	4.9	9.5	3.3	12.8
8. Angle of the uppermost branch with the main axis.	15	30°	50°	30°	50°	25°	40°	30°	40°

Table A. 7.5 Shows the minimum and maximum values for the morphological characters of *Salicornia* populations occupying soils differing in their total nitrogen content in the lower marsh of Northney, Hayling Island.

Population number/ total nitrogen		1A 0.28%		1E 0.39%	
Vegetative characters	N	Min.	Max.	Min.	Max.
1. Shoot length	15	20.2	31.0	24.5	33.7
2. Number of sterile segments in the main axis.	15	14	23	16	22
3. Total number of primary branches from the main axis.	15	26	46	32	44
4. Terminal spike length	15	1.8	3.5	2.4	3.5
5. Number of fertile segments in the terminal spike.	15	6	12	7	13
6.Length of the uppermost branch from the main axis.	15	1.0	4.2	1.3	2.8
7. Length of the lowermost branch from the main axis.	15	10.2	17.7	13.3	24.8
8. Angle of the uppermost branch with the main axis.	15	30°	50°	30°	50°

Table A. 7.6 Shows the minimum and maximum values for the morphological characters of *Salicornia* populations occupying soils relatively with similar total nitrogen content in the lower marsh of Shingle Street.

Vegetative characters \ Population number/total nitrogen	N	11 0.28% Min.	11 0.28% Max.	12 0.28% Min.	12 0.28% Max.	13 0.25% Min.	13 0.25% Max.	14 0.26% Min.	14 0.26% Max.
1. Shoot length	15	24.6	32.5	20.2	33.0	21.3	30.2	19.3	35.6
2. Number of sterile segments in the main axis.	15	13	19	13.0	19.0	14.0	19.0	12	20
3. Total number of primary branches from the main axis.	15	24	40	26.0	40.0	30	38	24	42
4. Terminal spike length.	15	4.3	6.8	2.2	6.4	2.8	6.7	4.0	7.6
5. Number of fertile segments in the terminal spike.	15	12	17	9	17	9	19	11	22
6. Length of the uppermost branch from the main axis.	15	1.8	3.8	1.3	4.0	1.5	4.2	1.7	5.2
7. Length of the lowermost branch from the main axis.	16	6.6	20.2	7.2	20.6	-	-	9.2	24.2
8. Angle of the uppermost branch with the main axis.	15	40^{o}	60^{o}	50^{o}	60^{o}	50^{o}	60^{o}	40^{o}	60^{o}

Table A 7. 7 Showing the presence of the phenolic glycosides spots isolated in two-dimensional paper chromatography for the analysed individuals of *Salicornia* from Shingle Street, Suffolk, Warham, Wells next to the sea, Norfolk, Pagham harbour, Sussex and Northney, Hayling Island populations.

1. Shingle Street, Suffolk

Population and plant number	Spots colour in U.V. + NH_3 * and number	O.Y.	Y.G.	O.Y.	O.Y.	BL.	O.Y.	F.YG.	F.YG.	BL.	BL.	BL.	BL.	BL/YG.	BL/YG.	BL/F.BL.	BL.	YG.	YG.	YG.	O.Y.	O.Y.	BL.	BL/YG.	Chlo.	F.YG	Y.	BL/YG.	BL.	D.O.Y.	BL.	D.O.Y.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
I	3	+	+	−	−	−	+	+	+	−	+	−	−	+	+	+	−	−	+	+	+	−	−	+	+	−	−	−	−	−	−	−	−
	2	+	+	−	−	−	+	+	+	−	+	−	−	+	+	+	−	−	+	+	+	−	−	+	+	−	−	−	−	−	−	−	−
	4	+	+	−	−	−	+	+	+	−	+	−	−	+	+	+	−	−	+	+	+	−	−	+	+	−	−	−	−	−	−	−	−
II	1	+	−	−	−	−	−	+	−	−	+	−	−	+	−	−	−	−	−	+	+	−	−	−	+	−	−	−	−	−	−	−	−
	2	+	+	−	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
	3	+	+	−	−	−	+	+	+	−	−	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
III	2	+	+	−	−	−	−	+	+	−	+	−	−	+	+	+	+	+	+	+	+	−	−	+	+	−	−	−	−	−	−	−	−
	3	+	+	−	−	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
	5	+	+	−	−	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
IV	1	+	+	−	−	−	+	+	+	−	+	−	−	+	−	+	−	+	−	+	+	−	−	−	+	−	−	−	−	−	−	−	−
	2	+	−	−	−	+	+	+	+	−	−	−	−	+	+	+	−	−	−	−	+	−	−	−	+	−	−	−	−	−	−	−	−
	3	+	+	−	−	+	+	+	+	−	+	−	−	+	+	+	−	−	−	+	+	−	−	−	+	−	−	−	−	−	−	−	−
	5	+	+	−	−	+	−	+	−	−	+	−	−	+	−	+	−	−	−	−	+	−	−	−	+	−	−	−	−	−	−	−	−
V	1	+	+	+	−	−	−	+	+	−	+	−	−	+	−	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
	8	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
	11	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	−	−	−	−	+	−	−	−	−	−	−	−	−

* See page 121.

Table A 7.7 (Continued)

1. Shingle Street, Suffolk

Population and plant number	Spots colour in U.V. + NH_3 and number	O.Y. 1	Y.G. 2	O.Y. 3	O.Y. 4	BL. 5	O.Y. 6	F.YG. 7	F.YG. 8	BL. 9	BL. 10	BL. 11	BL. 12	BL. 13	BL/YG. 14	BL/YG. 15	BL/F.BL. 16	BL. 17	YG. 18	YG. 19	YG. 20	O.Y. 21	O.Y. 22	BL. 23	BL/YG. 24	Chlo. 25	F.YG 26	Y. 27	BL/YG. 28	BL. 29	D.O.Y. 30	BL. 31	D.O.Y. 32
V (continued)	10	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−
	17	+	+	+	−	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−
VI	1	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	−	−	−
	2	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−
	3	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	−	−	−
	4	+	+	+	−	−	−	+	+	−	+	−	−	−	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−
	5	+	+	+	−	−	−	+	+	−	+	−	−	−	−	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−
VII	1	+	+	−	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	−	−	−	−	+	−	−	−	−	−	−	−
	2	+	+	−	+	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	−	−	−	−	+	−	−	−	−	−	−	−
	3	+	+	−	+	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	−	−	−	−	+	−	−	−	−	−	−	−
	5	+	+	+	−	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−
VIII	4	+	+	−	+	+	−	+	+	−	−	−	−	+	+	+	−	+	+	−	−	−	−	−	+	−	+	−	−	−	−	−
	5	+	+	−	−	−	−	+	+	−	−	−	−	+	+	+	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−
	6	+	+	−	+	+	−	+	+	−	+	−	−	−	−	+	−	+	+	−	−	−	−	−	+	−	+	−	−	−	−	−

Table A 7. 7 (Continued)

1. Shingle Street, Suffolk.

Population and plant number	Spots colour in U.V. + NH_3 and number	1 O.Y.	2 Y.G.	3 O.Y.	4 O.Y.	5 BL.	6 O.Y.	7 F.YG.	8 F.YG.	9 BL.	10 BL.	11 BL.	12 BL.	13 BL/YG.	14 BL/YG.	15 BL/F.BL.	16 BL.	17 YG.	18 YG.	19 YG.	20 O.Y.	21 O.Y.	22 BL.	23 BL/YG.	24 Chlo.	25 F.YG	26 Y.	27 BL/YG.	28 BL.	29 D.O.Y.	30 BL.	31 D.O.Y.	32
IX	1	+	+	+	+	+	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
	2	+	+	−	+	+	−	+	+	−	−	+	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
	3	+	+	−	+	+	−	+	+	−	−	+	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
	5	+	+	−	+	+	−	+	+	−	−	+	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	−	−	−	−
XA	1	+	+	+	−	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	+	−	−	−
	2	+	+	−	−	+	−	+	+	−	+	−	−	+	+	+	+	+	+	−	+	−	−	−	+	−	−	−	−	+	−	−	−
	3	+	+	−	+	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	+	−	−	−	−	+	−	−	−
	4	+	−	−	−	−	−	+	+	−	−	−	−	+	−	+	−	−	−	−	+	−	−	−	+	−	−	−	−	+	−	−	−
	5	+	+	+	−	−	−	+	+	−	−	−	−	+	−	+	−	+	+	−	+	−	−	−	+	−	−	−	−	+	−	−	−
XB	1	+	−	−	−	+	−	+	+	−	−	−	−	+	+	+	−	−	−	−	+	−	−	−	−	−	−	−	−	+	−	−	−
	2	+	−	−	−	+	−	+	+	−	−	−	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+
	3	+	−	−	−	+	−	+	+	−	−	−	−	+	+	+	−	−	−	−	+	−	−	−	−	−	−	−	−	+	−	−	+
XC	1	+	+	−	−	+	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	+	−	−	−	−	−	+	−	−	+
	2	+	+	+	−	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	+	−	−	−	−	−	+	−	−	−
	3	+	+	+	−	+	−	+	+	−	+	−	−	+	+	+	−	+	+	+	+	−	−	+	−	−	−	−	−	+	−	−	−

Table A 7.7 (Continued)

1. Shingle Street, Suffolk.

Population and plant number	Spots colour in U.V. + NH_3 and number	O.Y. 1	Y.G. 2	O.Y. 3	O.Y. 4	BL. 5	O.Y. 6	F.YG. 7	F.YG. 8	BL. 9	BL. 10	BL. 11	BL. 12	BL/YG. 13	BL/YG. 14	BL/F.BL. 15	BL. 16	YG. 17	YG. 18	YG. 19	O.Y. 20	O.Y. 21	BL. 22	BL/YG. 23	Chlo. 24	F.YG 25	Y. 26	BL/YG. 27	BL. 28	D.O.Y. 29	BL. 30	D.O.Y. 31	V. 32
XI	1	+	+	−	−	+	+	+	+	−	+	−	−	+	+	+	−	+	+	+	−	−	−	+	−	−	−	−	−	−	−	−	−
	2	+	+	+	−	+	−	+	+	−	+	+	−	+	+	+	−	+	+	+	+	−	−	+	−	−	−	−	−	−	−	−	+
	3	+	+	+	−	−	+	+	+	−	+	+	−	+	+	+	−	+	+	+	+	−	−	+	−	−	−	−	−	−	−	−	+
XII	1	+	+	+	−	−	−	+	+	−	+	−	−	+	+	+	+	+	+	−	+	−	−	+	−	−	−	−	−	−	−	−	−
	2	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	+	−	−	−	−	−	−	−	−	−
	3	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	−	−	+	−	−	−	−	−	−	−	−	−
XIII	1	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	+	−	−	−	+	−	−	−	−	−	−	−	−	−
	2	+	+	+	+	−	+	+	+	−	−	−	−	+	+	+	−	+	+	−	−	−	−	+	−	−	−	−	−	−	−	−	−
	4	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	+	−	−	−	+	−	−	−	−	−	−	−	−	−
XIV	1	+	+	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−
	2	+	+	+	−	+	+	+	+	−	+	+	−	+	+	+	+	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−
	3	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	+	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−

Table A 7.7 (Continued)

2. Warham populations.

Population and plant number	Spots colour in U.V. + NH_3 and number	O.Y. 1	Y.G. 2	O.Y. 3	O.Y. 4	BL. 5	O.Y. 6	F.YG. 7	F.YG. 8	BL. 9	BL. 10	BL. 11	BL. 12	BL. 13	BL/YG. 14	BL/YG. 15	BL/F.BL. 16	BL. 17	YG. 18	YG. 19	YG. 20	O.Y. 21	O.Y. 22	BL. 23	BL/YG. 24	Chlo. 25	F.YG 26	Y. 27	BL/YG. 28	BL. 29	D.O.Y. 30	BL. 31	D.O.Y. 32
1	A_1	+	+	+	+	−	−	+	+	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	+	−	−	+	−	−	−
	A_3	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	+	−	−	−	−	+	−	−	+	−	−	−
	A_4	+	+	+	+	−	−	+	+	−	+	−	−	+	+	+	+	+	+	+	+	−	−	+	−	−	+	−	−	+	−	−	−
1	B_1	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	−	−	−	−	−	+	−	−	+	−	−	−
	B_2	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	+	−	+	−	+	−	−	−	−	−	+	−	−	−
	B_4	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	+	−	+	−	−	+	−	−	+	−	−	−
1	C_1	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	+	−	−	−	−	−	−	−	−	+	−	−	−
	C_2	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	+	−	−	−	−	+	−	−	+	−	−	−
	C_3	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	+	−	−	−	−	−	−	−	+	−	−	−
1	D_1	+	+	+	+	−	+	−	+	−	+	−	−	+	+	+	−	−	−	−	−	+	−	−	−	−	+	−	−	−	−	−	−
	D_2	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	−	−	−	+	+	−	−	−	−	+	−	−	+	−	−	−
	D_3	+	−	+	+	−	+	+	−	−	−	−	−	−	−	−	+	−	−	−	+	+	−	−	−	−	−	−	−	+	−	−	−

Table A 7.7 (Continued)

2. Warham populations.

Population and plant number	Spots colour in U.V. + NH_3 and number	1 O.Y.	2 Y.G.	3 O.Y.	4 O.Y.	5 BL.	6 O.Y.	7 F.YG.	8 F.YG.	9 BL.	10 BL.	11 BL.	12 BL.	13 BL/YG.	14 BL/YG.	15 BL/F.BL.	16 BL.	17 YG.	18 YG.	19 YG.	20 O.Y.	21 O.Y.	22 BL.	23 BL/YG.	24 Chlo.	25 F.YG	26 Y.	27 BL/YG.	28 BL.	29 D.O.Y.	30 BL.	31 D.O.Y.	32
1	$E_1 1$	+	+	+	+	−	+	+	+	−	+	−	+	+	−	+	−	+	+	−	−	+	−	−	−	−	+	−	−	+	−	−	−
	$E_1 2$	+	+	+	+	−	+	+	+	−	+	−	+	+	−	+	+	+	+	−	+	+	−	−	−	−	−	−	−	+	−	−	−
	$E_1 5$	+	+	+	+	−	+	+	+	−	+	−	+	+	−	+	+	+	+	−	+	+	−	−	−	−	+	−	−	+	−	−	−
1	$E_2 1$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	−	−	−	−	−	−	+	−	−	−
	$E_2 2$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	−	−	−	−	−	−	+	−	−	−
	$E_2 3$	+	−	+	+	−	+	+	+	−	+	−	−	+	−	+	−	−	−	−	+	+	−	−	−	−	−	−	−	+	−	−	−
2	$A_1 1$	+	+	+	+	−	+	+	+	−	+	−	−	+	−	+	−	+	−	−	+	+	−	−	−	−	−	−	−	+	−	−	−
	$A_1 2$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	+	−	−	+	−	−	−	−	−	+	−	−	+	−	−	−
	$A_1 3$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	−	−	−	+	+	−	−	−	−	+	−	−	+	−	−	−
2	$A_2 1$	+	+	+	+	−	+	+	−	−	+	−	−	+	+	+	−	−	−	−	+	−	−	−	−	−	+	−	−	+	−	−	−
	$A_2 2$	+	+	+	+	−	+	+	−	−	+	−	−	+	+	+	−	−	−	−	+	−	−	−	−	−	+	−	−	+	−	−	−
	$A_2 3$	+	+	+	+	−	+	+	−	−	+	−	−	+	+	+	−	−	−	−	+	−	−	−	−	−	+	−	−	+	−	−	−

Table A 7. 7 (Continued)

2. Warham populations.

Population and plant number	Spots colour in U.V. + NH_3 and number	O.Y. 1	Y.G. 2	O.Y. 3	O.Y. 4	BL. 5	O.Y. 6	F.YG. 7	F.YG. 8	BL. 9	BL. 10	BL. 11	BL. 12	BL/YG. 13	BL/YG. 14	BL/F.BL. 15	BL. 16	YG. 17	YG. 18	YG. 19	O.Y. 20	O.Y. 21	BL. 22	BL/YG. 23	Chlo. 24	F.YG 25	Y. 26	BL/YG. 27	BL. 28	D.O.Y. 29	BL. 30	D.O.Y. 31	v. 32
2	$B_1 1$	+	+	+	+	−	+	−	+	+	+	−	−	+	+	+	−	+	+	−	+	+	−	−	−	−	−	−	−	−	−	−	+
	$B_1 2$	+	+	+	+	−	+	−	+	+	+	−	−	+	+	+	−	+	+	−	+	+	−	+	−	−	−	−	−	−	−	−	+
	$B_1 3$	+	+	+	+	−	+	−	+	+	+	−	−	+	+	+	−	+	+	−	+	−	−	+	−	−	−	−	−	−	−	−	−
2	$B_2 1$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	+	−	−	−	−	−	+	−	−	+	−	−	−
	$B_2 2$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	−	−	−	+	−	−	+	−	−	−
	$B_2 3$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	−	−	−	+	−	−	+	−	−	−
2	$C_1 1$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	+	−	−	+	−	−	+	−	−	−
	$C_1 2$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	+	−	−	+	−	−	+	+	+	−
	$C_1 3$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	+	−	−	+	−	−	+	+	+	−
2	$C_2 1$	+	+	+	−	−	+	+	+	−	+	−	−	+	−	+	−	−	−	+	+	+	−	−	−	−	+	+	−	−	−	−	−
	$C_2 3$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	+	+	−	−	+	−	−	−	−	−	+	−	−	−
	$C_2 5$	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	+	−	−	+	+	−	+	−	−	−

Table A 7.7 (Continued)

2. Warham populations.

Population and plant number	Spots colour in U.V. + NH_3 and number	O.Y. 1	Y.G. 2	O.Y. 3	O.Y. 4	BL. 5	O.Y. 6	F.YG. 7	F.YG. 8	BL. 9	BL. 10	BL. 11	BL. 12	BL/YG. 13	BL/YG. 14	BL/F.BL. 15	BL. 16	YG. 17	YG. 18	YG. 19	O.Y. 20	O.Y. 21	BL. 22	BL/YG. 23	Chlo. 24	F.YG 25	Y. 26	BL/YG. 27	BL. 28	D.O.Y. 29	BL. 30	D.O.Y. 31	32
2	D_1^2	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	+	−	−	+	−	−	+	−	−	−
	D_1^4	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	+	−	−	+	−	−	+	−	−	−
	D_1^5	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	+	+	−	+	−	−	−	−	−	+	−	−	−
2	D_2^1	+	+	+	+	−	+	+	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−	+	−	−	+	−	−	+	−	−	−
	D_2^2	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	+	−	−	+	−	−	−	−	−	+	−	−	−
	D_2^3	+	−	+	+	−	−	+	+	−	+	−	−	−	−	+	−	−	−	−	+	−	−	+	−	−	+	−	−	+	−	−	−
2	D_3^3	+	+	+	−	−	+	+	+	−	−	−	−	+	+	+	−	−	−	−	+	−	−	+	−	−	+	−	−	−	−	−	−
	D_3^4	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−
	D_3^5	+	+	+	−	−	+	+	+	−	+	−	−	+	+	−	−	−	−	−	−	−	−	+	−	−	+	−	−	−	−	−	−
3	A_1	+	−	+	+	−	+	+	+	−	+	−	−	−	−	+	−	−	−	−	+	−	−	+	−	−	+	+	−	+	−	−	−
	A_2	+	−	+	+	−	+	+	+	−	+	−	−	−	−	+	−	−	−	−	+	−	−	+	−	−	+	−	−	+	−	−	−
	A_3	+	−	+	+	−	+	+	+	−	+	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−

Table A.7.7 (Continued)

2. Warham populations.

Population and plant number	Spots colour in U.V. + NH_3 and number	O.Y. 1	Y.G. 2	O.Y. 3	O.Y. 4	BL. 5	O.Y. 6	F.YG. 7	F.YG. 8	BL. 9	BL. 10	BL. 11	BL. 12	BL. 13	BL/YG. 14	BL/YG. 15	BL/F.BL. 16	BL. 17	YG. 18	YG. 19	YG. 20	O.Y. 21	O.Y. 22	BL. 23	BL/YG. 24	Chlo. 25	F.YG 26	Y. 27	BL/YG. 28	BL. 29	D.O.Y. 30	BL. 31	D.O.Y. 32
3	B_1	+	−	+	+	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	+	+	−	+	−	−	+	−	−	+	−	−	−
	B_2	+	−	+	+	−	+	+	+	−	+	−	−	+	−	+	+	−	−	−	−	−	−	+	−	−	+	−	−	+	−	−	−
	B_3	+	−	+	+	−	+	+	+	−	+	−	−	+	+	+	+	−	−	−	+	+	−	+	−	−	+	−	−	+	−	−	−
3	C_1	+	−	+	−	−	+	+	+	−	+	+	−	−	−	+	+	−	−	−	−	+	−	+	−	−	+	−	−	−	−	−	−
	C_2	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	+	−	−	−	+	+	−	+	−	−	+	−	−	−	−	−	−
	C_3	+	+	+	+	−	−	+	+	−	−	+	−	+	+	+	−	−	−	−	+	−	−	+	−	−	+	−	−	−	−	−	−
4	A_1	+	−	−	−	−	+	+	+	−	+	−	−	−	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−
	A_2	+	−	−	−	−	+	+	+	−	+	−	−	+	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−
	A_3	+	−	−	−	−	+	+	+	−	+	−	−	+	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−
4	$B_1 1$	+	−	+	−	−	−	+	+	−	+	−	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	$B_1 2$	+	−	+	+	−	−	+	+	−	+	−	−	+	+	+	+	−	−	−	−	−	−	−	−	−	+	−	−	+	−	−	−
	$B_1 3$	+	−	+	+	−	−	+	+	−	+	−	−	+	+	+	+	−	−	−	−	−	−	−	−	−	+	−	−	+	−	−	−

Table A 7.7 (Continued)

2. Warham populations.

Population and plant number	Spots colour in U.V. + NH_3 and number	O.Y. 1	Y.G. 2	O.Y. 3	O.Y. 4	BL. 5	O.Y. 6	F.YG. 7	F.YG. 8	BL. 9	BL. 10	BL. 11	BL. 12	BL. 13	BL/YG. 14	BL/YG. 15	BL/F.BL. 16	BL. 17	YG. 18	YG. 19	YG. 20	O.Y. 21	O.Y. 22	BL. 23	BL/YG. 24	Chlo. 25	F.YG 26	Y. 27	BL/YG. 28	BL. 29	D.O.Y. 30	BL. 31	D.O.Y. 32
4	$B_2 1$	+	−	−	−	−	−	−	+	−	+	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−
	$B_2 2$	+	−	+	−	−	−	+	+	−	+	−	−	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−
	$B_2 3$	+	−	+	−	−	−	+	+	−	+	−	−	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
4	$C_1 1$	+	−	−	−	−	−	+	+	−	+	−	−	+	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−
	$C_1 2$	+	−	−	−	−	+	+	+	−	+	−	−	+	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−
	$C_1 3$	+	−	−	−	−	+	+	+	−	+	−	−	−	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−
4	$C_2 1$	+	−	−	−	−	+	+	−	−	+	−	−	+	−	+	+	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−
	$C_2 3$	+	−	−	−	−	+	+	−	−	+	−	−	+	−	+	+	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−
	$C_2 4$	+	−	−	−	−	+	+	−	−	+	−	−	−	−	+	+	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−
4	D_1	+	−	−	+	−	+	+	+	−	+	−	−	+	+	+	+	+	+	−	+	+	−	−	−	−	+	−	−	−	−	−
	D_2	+	+	−	+	−	+	+	+	−	+	−	−	+	−	+	+	+	+	−	+	+	−	−	−	−	+	−	−	−	−	−
	D_3	+	+	−	−	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

Table A 7. 7 (Continued)

3. Pagham.

Population and plant number	Spots colour in U.V. + NH_3 and number	1 O.Y.	2 Y.G.	3 O.Y.	4 O.Y.	5 BL.	6 O.Y.	7 F.YG.	8 F.YG.	9 BL.	10 BL.	11 BL.	12 BL.	13 BL/YG.	14 BL/YG.	15 BL/F.BL.	16 BL.	17 YG.	18 YG.	19 YG.	20 O.Y.	21 O.Y.	22 BL.	23 BL/YG.	24 Chlo.	25 F.YG	26 Y.	27 BL/YG.	28 BL.	29 D.O.Y.	30 BL.	31 D.O.Y.	32
II	2	+	+	+	−	−	+	+	+	−	+	−	−	+	−	−	−	+	+	−	−	+	−	+	−	−	+	−	−	−	−	−	−
	3	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	+	−	−	+	−	−	−	−	−	−
	4	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	+	−	−	+	−	−	−	−	−	−
III	1	+	+	+	+	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−
	2	+	+	+	+	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−
	3	+	+	+	+	−	−	+	−	−	+	−	−	−	+	+	−	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−
IV	1	+	+	+	+	−	−	+	+	−	+	−	−	+	−	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	3	+	+	+	+	−	−	+	−	−	+	−	−	+	−	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	5	+	+	+	+	−	−	+	+	−	+	−	−	+	−	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−
V	1	+	+	−	−	−	−	+	+	−	+	−	−	+	+	+	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−
	2	+	+	−	−	−	−	+	+	−	+	−	−	+	−	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	3	+	+	−	−	−	−	+	+	−	−	−	−	+	+	+	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−

Table A 7. 7 (Continued)

3. Pagham.

Population and plant number	Spots colour in U.V. + NH_3 and number	O.Y.	Y.G.	O.Y.	O.Y.	BL.	O.Y.	F.YG.	F.YG.	BL.	BL.	BL.	BL.	BL/YG.	BL/YG.	BL/F.BL.	BL.	YG.	YG.	YG.	O.Y.	O.Y.	BL.	BL/YG.	Chlo.	F.YG	Y.	BL/YG.	BL.	D.O.Y.	BL.	D.O.Y.	Y
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
VI	1	+	+	+	−	−	−	+	+	−	+	−	−	+	−	+	−	+	+	+	+	−	−	+	−	−	−	−	−	−	−	−	+
	3	+	+	+	−	−	−	+	+	−	+	−	−	+	−	+	−	+	+	+	+	−	−	+	−	−	−	−	−	−	−	−	+
	5	+	+	+	−	−	−	+	+	−	+	−	−	+	−	+	−	+	+	+	+	−	−	+	−	−	−	−	−	−	−	−	+
VII	1	+	+	+	−	−	−	+	+	−	+	−	−	+	−	+	−	+	+	+	+	−	−	+	−	−	−	−	−	−	−	−	+
	2	+	+	+	−	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−
	3	+	+	+	−	−	−	+	+	−	+	−	−	+	+	+	−	+	−	+	+	−	−	+	−	−	−	−	−	−	−	−	+
VIII	1	+	+	+	+	−	−	+	+	−	+	−	−	+	+	+	−	+	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−
	2	+	+	+	+	−	−	+	+	−	+	−	−	+	−	+	−	+	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−
	3	+	+	+	+	−	−	+	+	−	+	−	−	+	+	+	−	+	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−

Table A 7.7 (Continued)

4. Hayling Island.

Population and plant number	Spots colour in U.V. + NH_3 and number	O.Y. 1	Y.G. 2	O.Y. 3	O.Y. 4	BL. 5	O.Y. 6	F.YG. 7	F.YG. 8	BL. 9	BL. 10	BL. 11	BL. 12	BL. 13	BL/YG. 14	BL/YG. 15	BL/F.BL. 16	BL. 17	YG. 18	YG. 19	YG. 20	O.Y. 21	O.Y. 22	BL. 23	BL/YG. 24	Chlo. 25	F.YG 26	Y. 27	BL/YG. 28	BL. 29	D.O.Y. 30	BL. 31	D.O.Y. 32
1	A_1	+	−	+	+	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−
	A_2	+	−	+	+	−	−	+	+	−	+	−	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−
	A_3	+	−	+	+	−	+	+	+	−	+	−	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−
1	B_2	+	+	+	−	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	−	−	−	+	−	−	−	−	−
	B_3	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	−	+	−	−	−	−	+	−	−	−	−	−
	B_4	+	+	+	+	−	+	+	+	−	+	−	−	+	+	+	−	+	+	−	+	+	−	−	−	−	+	−	−	−	−	−
1	D_1	+	−	+	+	−	−	+	−	−	+	−	−	+	+	+	−	−	−	−	+	−	−	−	−	−	−	−	+	−	−	−
	D_2	+	−	+	+	−	−	+	−	−	+	−	−	+	+	+	−	−	−	−	+	−	−	−	−	−	−	−	+	−	−	−
	D_3	+	−	+	+	−	−	+	−	−	+	−	−	+	+	+	−	−	−	−	+	−	−	−	−	−	−	−	+	−	−	−
1	$E_1 1$	+	+	+	+	−	−	+	−	−	+	−	−	+	+	+	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	+
	$E_1 2$	+	+	+	+	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	+
	$E_1 3$	+	+	+	+	−	−	+	+	−	+	−	−	+	+	+	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	+
1	$E_2 1$	+	−	+	+	−	−	+	−	−	+	−	−	+	−	+	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	−
	$E_2 2$	+	−	+	+	−	−	+	−	−	+	−	−	+	−	+	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	−
	$E_2 3$	+	−	+	+	−	−	+	−	−	+	−	−	+	−	+	−	+	+	−	−	−	−	−	−	−	−	−	+	−	−	−

Table A7.8 Shows the table of the latent vectors values of the variable phenolic glycosides spots and the axes values (axis 1 and 2) for each of the 52 *Salicornia* populations analysed by Principal Component Analysis.

LATENT VECTORS	1	2
1	.431	.032
2	.114	.326
3	.014	.373
4	.092	-.222
5	.084	.247
6	.202	.078
7	.225	.056
8	.022	-.034
9	.093	-.075
10	.285	.099
11	-.128	.058
12	.414	-.116
13	.414	-.116
14	.234	-.243
15	.263	.095
16	.157	.363
17	.218	.032
18	.148	-.054
19	-.052	.407
20	-.011	.138
21	-.009	.302
22	.018	.165
23	.116	.161
24	.098	-.233

PRINCIPAL COMPONENTS	1	2
1	2.812	.136
2	2.603	.614
3	2.836	.371
4	2.617	.987
5	3.024	.062
6	3.338	-.127
7	2.693	.705
8	2.805	.682
9	2.893	.132
10	2.941	.077
11	2.722	.845
12	2.814	-.177
13	2.119	.155
14	2.709	.745
15	2.616	.821
16	1.306	.122
17	3.037	1.907
18	3.037	1.907
19	2.585	2.118
20	1.757	2.349
21	2.585	2.118
22	2.713	2.059
23	2.765	1.652
24	1.728	1.928
25	3.017	1.591
26	2.713	2.059
27	3.066	2.417
28	3.281	2.019
29	2.792	2.288
30	1.943	2.160
31	1.959	1.456
32	1.651	2.036
33	1.545	2.349
34	2.077	2.004
35	.582	.758
36	.584	.436
37	.502	.758
38	.389	.313
39	.929	1.172
40	.673	1.606
41	2.926	1.415
42	2.767	1.078
43	2.826	1.322
44	2.593	-.265
45	2.673	-.581
46	2.959	-.403
47	2.721	-.160
48	1.086	1.394
49	2.722	1.757
50	1.040	1.186
51	2.354	.715
52	1.604	.859

PERCENTAGE VARIANCES

17.045 16.106