RESULT AND DISCUSSION

I. Salt Exudation by Lippia (Phyla)

Number of salt tolerance mechanisms in plants growing in varied, salt rich environment have been studied for more than a century. Today the salt tolerance mechanism have been broadly classified by Waisel (1972). The plants which have salt or are able to grow in salt rich environment - often salt is used mainly as an attribute to NaCl - are called halophytes. Waisel while classifying the halophytes has mainly recognised (1) Euhalophytes (2) Pseudo halophytes. Under the Euhalophytes he has made an subclass of salt requiring halophytes and salt resisting halophytes. And further they are classified under salt requiring halophytes obligatory halophytes and preferential halophytes. Under salt resisting halophytes he made three categories (a) salt enduring (b) salt excluding (c) salt evading. Salt enduring halophytes have high protoplasmatic salt contents whereas salt excluding types do not have high protoplasmatic salt content but special systems such as hairs, as we find in the Atriplex to store salt, or secretary glands as we find in Aeluropus etc. are provided with. Phyla (Lippia) appears to be falling in the category of salt excluding type by virtue of a fact that it has a distinct salt glands on both the epidermis (Plate I-1-1). These glands are not much discernible when it grows in salt free environment, nevertheless has all the essential "accessories" so as to fit into a typical description of salt gland i.e. secretary cell, basal collecting cell (Plate I-2).

The earliest record of leaf gland in Lippia i.e. todays Phyla comes by Metcalf & Chalk (1957). Specifically they have described it as gland without explaining whether it is secretary in nature or excretary in nature. McClean and Cook (1962) classified glands found in plants as of two types- one is

Plates 1 - 4 :

Photographs indicating Cross Sectional veiw of salt glands of Lippia (Phyla) nodiflora.

secretary which according to their definition is known to secrete directly the substances valuable to the plant while excretary gland are involved in the superflows of deleterious substances. In other words by definition, as it is observed, *Phyla nodiflora* has glands which excrete salt which is deliterious to the plants. Moreover the excretion of salt is seen only when plant grows in the salt rich environment.

More powerful justification that the glands found on the leaf surfaces of *Phyla* is of excretary nature comes by the anatomical definition of the glands. According to McClean & Cook (1962) hydathode is a peculiar type of gland associated with excretion of water, what is commonly called guttation, and these are usually modified stomata permenantly open, supplied beneath with a strand of vascular cells ending in a group of epithem cells. Such glands are often to be found at leaf margins. This anatomical description of hydathode rules out the possibility of mistaking the glands of *Phyla nodiflora* to hydathode by virtue of the fact that (1) it does not have any vascular connection (2) these are not modified stomata by the fact that they lack subsidary cells which essentially found with differentiation of stomata but are encircled by the ring of epidermal cells (Plate-1-4) (3) these are distributed throughout the leaf surface both upper as well as lower epidermis and not at the leaf margin.

According to Waisel (1972) most species with salt glands are able to tolerate the high salinity and as a rule their distribution is limited to salines of various types. Not in keeping with the original definition offered by anatomists he has loosely used the term secretary gland though they are throwing out unwanted salt, which is excretion.

The well defined salt glands either to known and describe are located or sunken into the epidermis as could be seen in Spartina townsendii. Or as in Aeluropus, which are two celled hair like glands with a basel thin walled cells. Such hair like glands are considered as simplest types. The three celled gland is found in Chloris gyana. In Avicinnia the glands are comprised of indefinite number of cells arranged in a group of four or more cells located on top of one stalk and 2-4 collecting cells. A similar gland is also found in Acanthus illicifoleous. In Aegilitis, Limonium and Tamarix the basal cells are cutinised. And the basal cells in Avicennia function as an endodermal cells. According to Waisel (1972) the impermeable walls of endodermal cells as well as impermeable cuticular layer in salt glands serve as a barrier to leakage of secreted salt solution back to the tissue. Although salt glands in Phyla nodiflora does not have a complicated structure as that of Limonium which is made up of complex of sixteen cells, nor it is as simple as that of Aeluropus, Spartina which is regarded as simplest type (2 celled hair like gland) no doubt the gland is sunken with two lateral basal cells at early differentiating cells and slowly it gets differentiated into ring of 6 to 8 cells (Plate-2). They are cutinised so as to check the back flow or provide a barrier to leakage of secreted salt solution back to the tissue. The secretary cell slowly grows into large size but remains unicellular with a basal stalk cell. There is no vacuolization in the secretary cell but is full of dense granular substances. When plants are exposed to salts the 2 armed trichome like structure develop on the lateral sides.

Extensive work on salt gland structure and the mechanism of secretion has been studied by number of workers in various plants, hither to known and unknown for salt excretion. Peter (1980) carried out the ultra structural observations on the cuticular envelope of salt gland Frankenia pauciflora during five developmental stages during differentiation of salt glands in leaves. A noteworthy observation is the cuticular envelope was seen under the electron microscope. Around each transfusion area in cuticular envelope a conspicuous Lameller ring structure was also found. The gland cell had a very dense material being accumulated in the transfusion zone. Barnabas et.al. (1981) described the fine structure of cavities in the wall of leaf blade epidermal cells of Zostera capensis, a marine angiospemus plant. They found the cavities located underneath the cuticle and are generally spherical to ovoidal in shape. The ultra structural study did not reveal any complex organisation but only lack of membrane around the cell but containing electrondense amorphous or crystalline material within the cavities. They observed structural similarities between the subarticular cavities and subcuticular spaces in the outermost secretary cells of salt glands on leaves of certain halophytes. This makes it clear that it can be classified as salt gland structure. Bosabalidis and Thomson (1984), Thomson and Kathryn (1985) made extensive study both light microscopic and ultrastructure of salt glands of Tamarix aphylla. Even ontogenetic differentiation of the gland has also been studied and during the developmental stages the vacuolization of two inner parenchyma cells adjscent and adherant to inner secretary cells getting transformed into collecting cells of the gland have been noticed. Numerous plasmodeomata in the walls between the secretary cells of glands have also been noted during transmission electron microscopic study at the maturity. The noteworthy point here is the salt glands of Tamarix aphylla which originates from a single protodermal cell and in the progress of the gland development no remarkable ultrastructural alteration occurs upto the stage of secretion.

Oross and Thomson (1982) carried out the ultrastructural studies of salt glands of Cynadon dactylon and Distichilis (Poaceae). According to them the salt glands of this Bermuda grass is similar to those of many dicot plant with respect to accumulation of large quantity of chloride in some cuticular chamber in secretary cells, but the salt glands of grass lack the suberized or cutinized zone that is present in walls of dicot plants, which is known to present apoplastic back flow of accumulated salts from collecting chamber and the leaf mesophyll. The epidermal salt glands of Cynadon and Distichilis consists of smaller outer cap cell and a larger flask shaped basel cell. The wall of basal cell is contigous with those adjacent epidermal cells and underlying cells. The basal cell consists of smaller outer capcell and a larger flask shaped basal cell. The wall of basal cell is contigous with those adjascent epidermal cells and underlying cells. The basal cell is connected symplastically with all adjoining cells via plasmodesmata. The outer protruding portion of gland is covered by cuticle continuous with that of adjoining epidermal cells.

Strking observation of salt gland structure in eleven species belonging to six different genera of Plumbaginaceae had been made by Faraday and Thomson (1986). The gland ultrastructure was considered with respect of species secretary activity and secretary products. They showed that all the mature gland have similar ultrastructure with dense cytoplasm. Secretary cells contained a full compliment of organelles and structure which include numerous mitochondria and few plastids but what is striking here is section through entire gland revealed that each gland cell contained one or two vacuoles with a convoluted tonoplast in both secretary and non secretary states. The absence of numerous vacuoles and vesicle during the secretary activity suggested that ion secretion was by transmembrane pattern rather than viside mediated pathway.

A. Salt Exudation Study :

The rate of salt exudation by the leaf glands of *Phyla nodiflora* has been studied under different culture conditions.

(1) after culturing the plants in salt in the soil in earthern pots with increasing concentration of NaCl.

(2) after culturing the plants in sand on Hoagland and then treated with increasing concentration of NaCl.

(3) in the liquid of Hoagland and then treated with increasing concentration of NaCl.

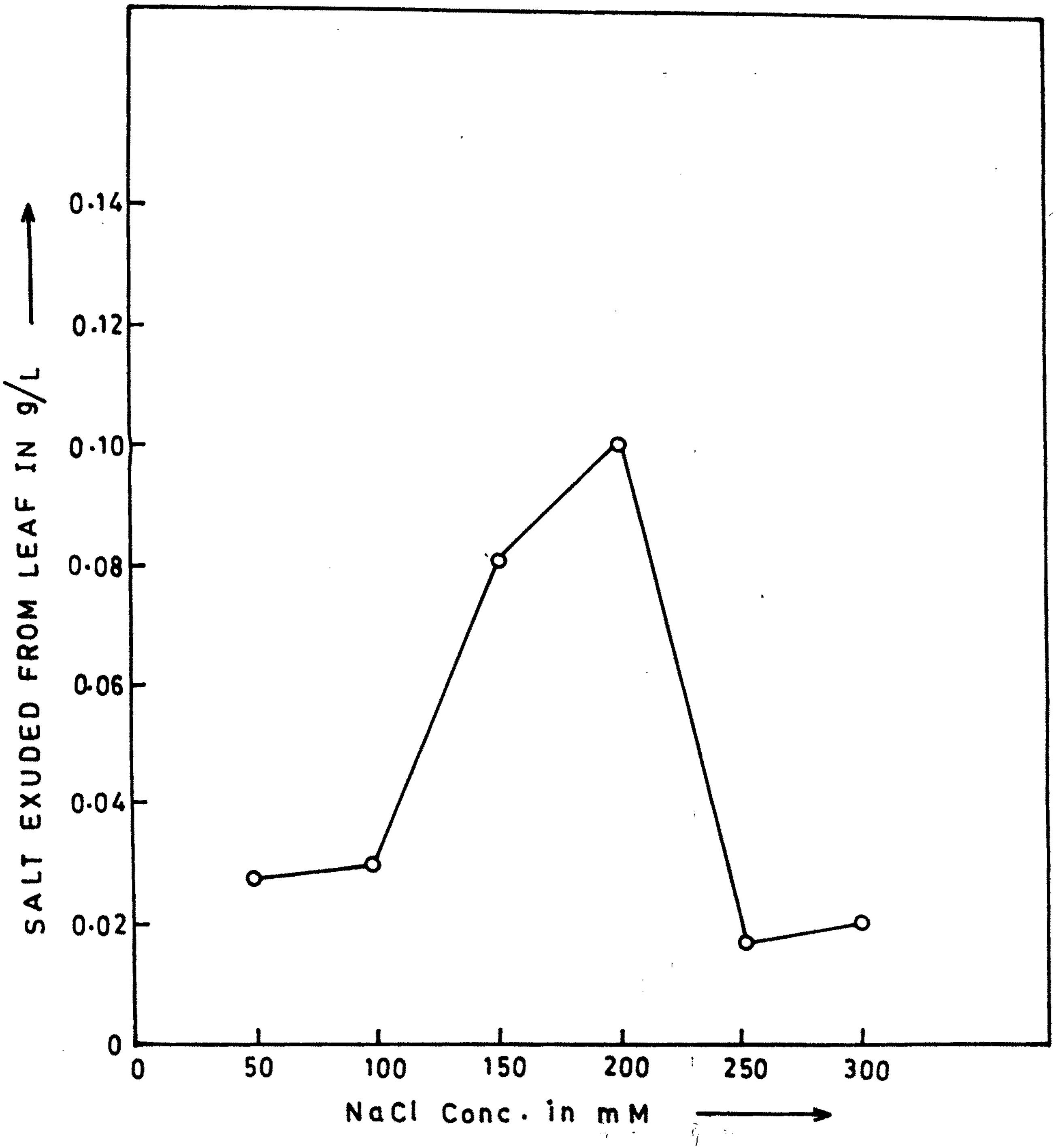
Amount of salt exuded by leaf per Se per day (12 hours) are given in the Table-1, . In all the three conditions treatment of NaCl was received by the plants only after they establish in respective conditions. The NaCl conc. to which the plants were exposed ranged from 50 mM to 300 mM with a difference of 50 mM.

The salt exudation per day per leaf when cultured in pots in soil has been recorded and given in the Table-1, Fig. 1. The rate of exudation from 50 mM to 300 mM of NaCl conc. at the root zone has been expressed in terms of gm/litre and mol/litre. At 50 mM of NaCl it is 0.68 mMol/L per day but at 100 mM it decreased marginally and at 150 mM it improved to shoot upto 4 times and at 200 mM it is 1.71 mMol/L^{-1} per day. The maximum exudation is recorded when the plants received 300 mM NaCl at root zone which is 1.28 mMol/L^{-1} per day.

TABLE - 1

Salt exuded by leaves after exposing Phyla nodiflora to increasing concentration of NaCl under pot culture condition in soil.

Conc. ofNaCl dose in mM	E.C. of soil ds/m	NaCl exuded by leaf	
		g/L	mMol/L
50	0.408	0.04	0.68
100	0.501	0.028	0.48
150	0.642	0.087	1.51
200	0.806	0.100	1.71
250	1.076	0.07	1.21
300	1.194	0.106	1.82



GRAPH SHOWING SALT EXUDED BY LEAF GLANDS OF *Phyla nodiflora* AFTER EXPOSING THEM TO INCREASING CONC. OF NaCl UNDER POT CULTURE CONDITION.

FIG. 1

In gross sense of the term under soil culture conditions the rate of salt exudation went on increasing with increase in ambient salt conc. at root zone upto 300 mM. It is noteworthy to point out here that one can see the white encrustation on the surface of the leaf.

B. Concentration of NaCl at Root Zone :

Salt exudation also increased. This increase is only upto 150 mM ambient as in the case of sand culture experiment and beyond this concentration the amount of salt pumped out of gland went on declining. At 50 mM of NaCl the salt exuded is 0.83 mM/L^{-1} per day which increased to 1.39 to 1.51 mMol/L^{-1} per day with a respective increase in NaCl concentration at the root zone region from 100-150 mM. At 200 mM of NaCl it started declining and the decrease from there onwards, has more or less the same rate as that of increase.

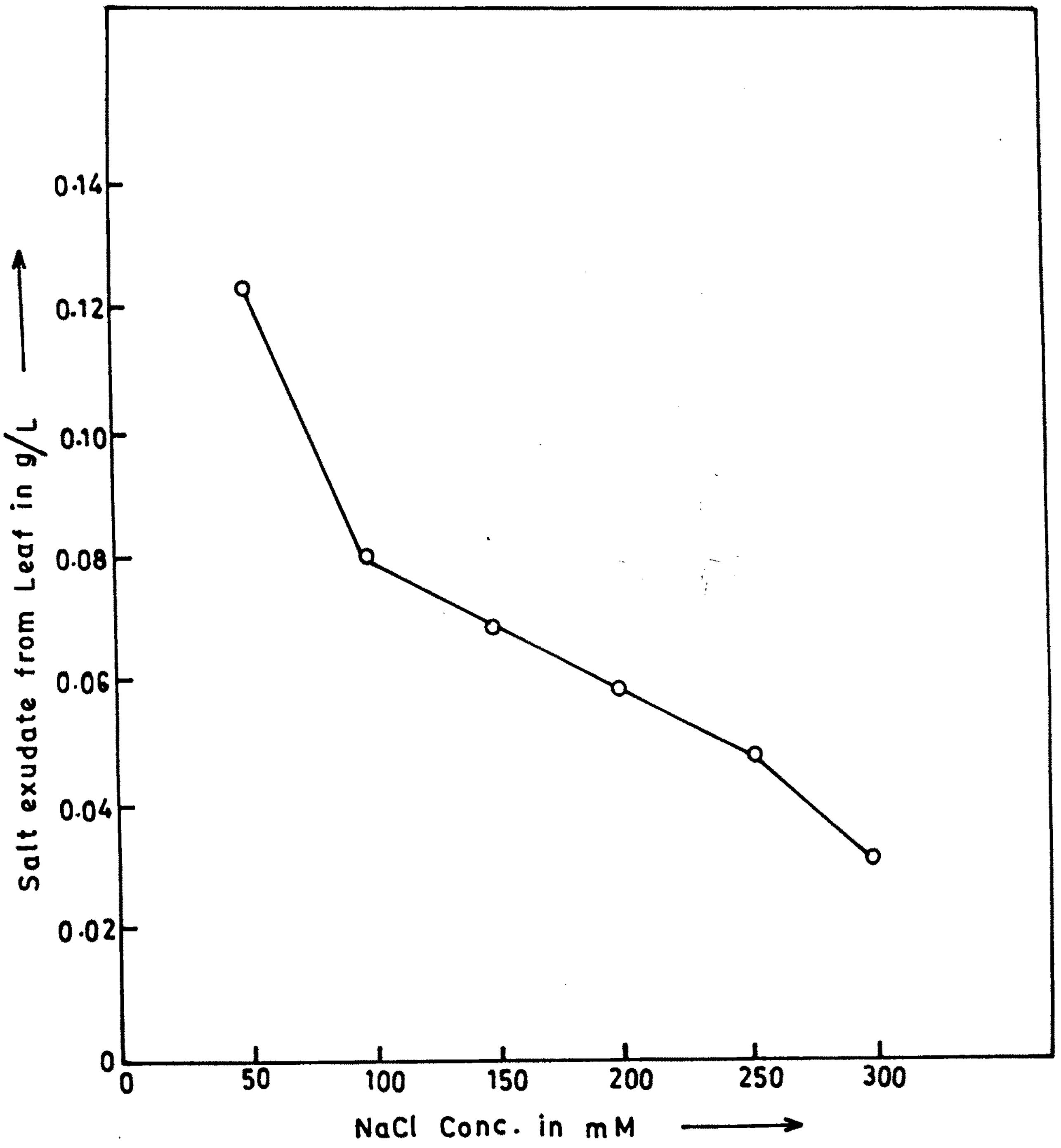
The salt exudation rate when plants were raised in liquid culture condition and treated with increasing conc. of salt through Hoagland has also been monitered and results are given in the Table- 2, Fig. 2.

The striking difference in the rate of exudation can be seen from those of earlier two conditions. At 50 mM ambient salt exuded per leaf per 12 hours of duration is 2 mMol/L^{-1} which decreased from 1.39 to 1.22 to 0.99 and 0.8 mMol/L^{-1} respectively with the salt concentration at the root zone increasing from 100, 150, 200, 250 and 300 mM. In other words unlike the situation when grown under soil condition under liquid culture condition the rate of salt exudation decreased with increasing conc. of NaCl in the culture. This means the exudation rate and the increase in conc. of NaCl are antiparallel. The situation under soil culture condition is diame-

TABLE - 2

Salt exuded by leaves after exposing *Phyla nodiflora* to increasing concentration of NaCl under liquid culture condition.

Conc. of NaCl in mM	E.C. of Hoagland solution mmhos/cm.	NaCl Exuded	
		in g/L	in mmol/L
50	4.5	0.116	2.00
100	8.62	0.081	1.39
150	11.95	0.071	1.22
200	17.45	0.064	1.09
250	19.85	0.053	0.99
300	28.45	0.491	0.83



GRAPH SHOWING SALT EXUDED BY LEAF GLANDS OF *Phyla nodiflora* AFTER EXPOSING THEM TO INCREASING CONC. OF NaCl UNDER LIQUID CULTURE CONDITION.

FIG. 2

trical opposite to that of liquid culture condition whereas under sand culture condition it is in between. Table - 3, Fig.3.

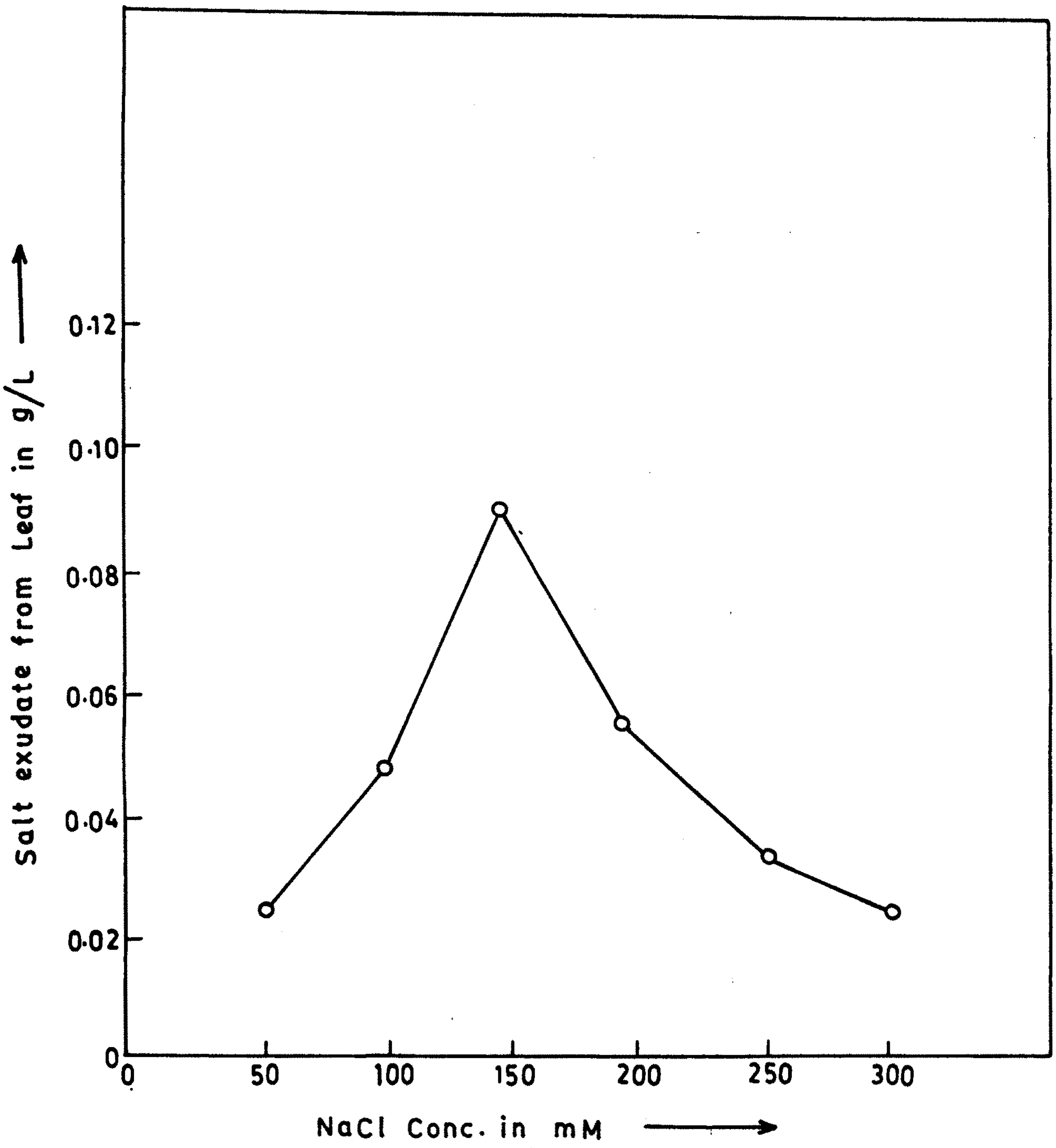
Although it is difficult to give reason as to why the rate of salt exudation changed with a change in culture condition the results are certainly striking. It is essential to mention here that the exudate had been titrated to determine the Cl^- chloride.

According to Waisel (1972) salt glands are assumed to transport the ions against the conc. gradient. Scholander et.al. (1962) have demonstrated this capacity. They found that NaCl conc. in secreted solution collected from various mangrove species exceeded the NaCl conc. in root zone medium of Aegialitis, aegiceros and avicennia. A similar case was also reported by Pollak and Waisel (1970) in Aleuropus littoralis where the conc. of the secreted fluid were always higher than conc. of the treatment solution. This observation is contrary to the one which has been demonstrated by Ruhland (1950) who floated leaf disks of Stattice gemelina over the salt solution and found them to secrete out of their salt glands fluid of the same conc. of the salt. In the case of Limonium latifolium Aristz et.al. (1955) showed that conc. of the secreted fluid exceeded that of the external solution only at the lower values of the later. In Spartina the brine secreted from the glands when irrigated with the solution is equal to that of sea water gave values of approximately 0.5 M NaCl. The ability to secrete ions against conc. gradient is not unique to halophytes. Tissue segment of Nepenthes for instance made transport of chloride against conc. gradient 100 times higher than their own (Luttge, 1976).

TABLE -3

Salt exuded by leaves of Phyla nodiflora after exposing them to increasing concentration of NaCl under sand culture condition.

Conc. of NaCl dose in mM	E.C.of soil ds/m	NaCl exuded by leaf	
		g/L	mMol/L
50	0.21	0.049	0.83
100	0.33	0.081	1.39
150	0.33	0.088	1.51
200	0.35	0.087	1.49
250	0.36	0.058	0.99
300	0.12	0.052	0.89



GRAPH SHOWING SALT EXUDED BY LEAF GLANDS OF *Phyla nodiflora* AFTER EXPOSING THEM TO INCREASING CONC. OF NaCl UNDER SAND CULTURE CONDITION.

FIG. 3

Concentration of secreted salt is often so high that under dry atmospheric conditions salt crystalization and covers the plant with either salty scales as could be seen in *Limonium* and *Spartina* or salt whiskers as could be seen in the *Tamarix* and *Aeluropus*. Such situation is especially noticeable in highly saline habitat or on detached leaves that are exposed to salty solutions. Rozema et.al. (1981) studied the relative rate of salt excretion of four halophytes *Spartina*, *Limonium*, *Armeria* and *Glaux*. All these plants were collected in the fields and grown on different concentration of NaCl, KCl and $CaCl_2$ and the type of salt secretion or exudate has been examined. It has been shown that highest rate of exudation is of Na rather than any other salt. This experiment of Rozema reflect not on the selective absorption of cations but on the selective excretion of rather less important cations that enters the plant system. Baumeister and Gunter (1981) have studied the salt secretion by salt glands of *Armeria maritima*. Their study included analysis of the dry material of stem and leaves which revealed that the uptake of Na^+ and Cl^- has increased while the contents of K^+, Ca^{++} and Mg^{++} ion and bicarbonate decreased considerably in the presence of 300 mM of NaCl at the root zone region. This reflected the selective absorption of Na^+ and Cl^- ions over others and exudation or excretion are the same.

Mallery and Teas (1984) in their study of the mineral ion relationship of two different types of mangrove salt exuder and the salt secreter namely *Rhizophora* and *Avicennia*. They studied the efflux kinetic of ^{22}Na and ^{36}Cl from 48 hour after preloading grown in low salinity conditions. They estimated percentage isotope distribution throughout the whole plant and the uptake rates. It was shown that significantly great uptake for Na^+ and

Cl^- in Aegiceros a non excluding salt secreting species while little or no ^{22}Na, ^{36}Cl absorbed or distributed to leaf tissue in red mangrove Rhizophora This led to the characterization as non-secreting salt excluding species. In the Aegiceros the typical intracellular compartation was found in leaf tissue and according to them the efflux kinetics clearly indicated that Na and Cl are handled differently by these compartments and membrane.

Drennan and Pammentar (1982) have studied the physiology of salt secretion in Avicennia marina. They examined diurnal and long term excretion by the leaves of these seedlings growing in aqueous culture with a substrate salinity. They found that excretion was greater in 100% rather than 50% sea water but the reverse was true for transpiration. The diurnal excretion pattern with excudation was found to be minimal during the day and maximal during the night. However, the total amount of salt excreted was finely correlated with a total amount of water transpired. They also found that root and xylem sap salinition are linearly related to substrate salinity but leaf Na increased to a maximum indicating that the control of leaf salt content is at the filiar rather than root level.

Work of various researchers discribed above clearly indicate that the true salt excreting types by and large excrete salt through their glands in proportion to their uptake. And these types, nevertheless also retain to certain extent salts in some compartments as shown by Mallery and Teas (1984). We certainly see increasing exudation rate with increasing salt conc. at ambient under soil grown conditions. However, this parallel increase is not more than the conc. of the salt at the root zone but under sand culture conditions it increased with increase in the concentration only to certain extent and not beyond 150 mm NaCl concentration ambient.

How [illegible]

The peculiarity of relatively high rate of exudation with low ambient salt concentration converse to that of soil grown condition could only be seen under liquid culture condition. This observation is explainable under the light of the experimental evidence putforth by Drannan and Dammentar (1982). In other words excretion increased and decreased diurnally and it is linked with transpiration rate. Possibly under liquid culture condition root absorb more water and hence more salt and their relative exudation therefore is also more.

Karadge et.al (1983) working on physiological studies on salt tolerance on Lippia nodiflora new name, Phyla nodiflora have also shown that Na^+ and Cl^- ion are accumulated in various organs. The accumulation is more in leaves than in stem or roots and there was very little effect of salinity on uptake and distribution of K^+. They concluded that this plant shows well adaptibility towards highly salinized condition. Their study however, does not take into consideration the aspect of salt excretion mechanism inherently endowed with particularly with this plant. Nonetheless the accumulation of salt especially Na^+ and Cl^- in the leaves support our observation that part of salt is secreted out and part of it is accumulated possible in the leaf cell vacuoles. This could be evidenced by the leaf flaccicity when Lippia (Phyla) exposed to salt rich environment. In brief it can be concluded that Lippia (Phyla) partly excretes the salts and partly stores in the vacuole and hence its exudation rate is not well matched with the concentration of salt in the root zone as in the case of many of the salt excreting mangroves. It is quite likely that there is some sort of diurnal fluctuation and the salt absorption or transport from leaf terminals is geared to the transpiration stream- Lippia in this respect appears to be better adopted by possessing the advantage of salt pumping in the vacuoles as well as excretion.

II. Effect of Water Logging on Lippia (Phyla) nodiflora

Wet-land problem in India is as acute as that of salt affected saline land. Often the land flooded by salty water, as could be seen in the coastal marsh or could be seen in the agricultural wet land or inland saline fields compared with the vegetation of well drained soils wet lands have a world wide similarity which over-rides climate and is imposed by common characteristics of a free water supply and the abnormally hostile chemical environ ment which plants roots must endure. The component species have morphological anatomical and physiological adaptations which allows them to cope with intermittent flooding, annoxia (lack of oxygen) and the consequent chemical reduction of the soil.

The chemical characteristics of the water logged soil are harmful to dryland species but the niche is opened to a wide range of wet land plants by adoptive modifications. Soil oxygen deficiency demands either a transport system which can supply it to underground organs form aerial structures or anaerobic metabolism, must prevail while toxic concentration of certain metal ions such as Mn^{2+}, Fe^{2+} and anion S^{2-} and H_2S and organic compounds required either as modified metabolic chemistry which continues to function this hostile environment or the plant must be armed with detoxifying mechanism (Etherington, 1983). The condition of the plant is worstened with the presence of another toxic substance in the water i.e. salt. According to Etherington (1983) wet land plants must also differ from their dry land

TABLE -4

Determination of cellulase in the root and stem of *Phyla nodiflora* under waterlogging condition.

Nature of plant organ	Time in hrs.	Cellulase activity/ gm fresh tissue
Root	18	5.3
Stem	18	7.7
Root	24	5.5
Stem	24	6.8
Root	36	8.9
Stem	36	13.4

causing not only effectively combating the adverse environmental condition described above but also in absorbing nitrogen as the ammonium NH_4^+ because dentrifying micro-organisms scavange nitrate from amaerobic coils. The answer to the above problems can be searched in the plants adopted to the varied environment. It is not amazing to get one which is able to combate not only squarely but triangularly the extreme environment of water logging salinity and the drought. Lippa (Phyla) nodiflora seems to have genetic endowment of all the three. It is one of such plants which is adopted to salinity and has an apparently very good mechanism for withstanding salinity. It has ability to withstand water logged condition too. Thirdly it has possibly an ability to withstand physical stress i.e. drought. To demonstrate another facet of this plant i.e. ability to withstand water logging besides its ability to withstand and tolerate salt rich environment, the following experiments have been carried out.

These plants were grown under pot culture conditions. They were cultured in sand with Hoagland and then under waterlogged condition i.e. in liquid Hoagland solution. After exposing these different culture conditions the plants are examined for morphological and anatomical differentiation and for the activity of enzyme cellulose which is responsible for acrenchyma formation. The resJult are tabulated in the Table-4 . The enzyme cellulase has been assayed in root stems and leaves in order to know the constitative level of enzyme as well as the enzyme induction by the environment. The activity of the enzyme has been measured spectrophotometrically which is based on the amount of substrate i.e. 3,5,carboxymethyle cellulose being degraded.

The activity of the enzyme measured in the pot cultured plant given in the Table- 6 . It can be seen from the data that the roots has maximum activity of 6.2 followed by stem which has 5.4 and then leaf which has 5.2. In other words organs have constitutive existence of enzyme cellulose in high quantity whereas the stem and the leaf have relatively low. This enzyme possibly is in the state of equilibrium with its substrate and hence does not contribute much for the cellulalytic activity.

When the plants were exposed to the waterlogged conditions and at 4 different interval of 18 hrs, 24 hrs and 36 hrs and the enzyme was assayed it revealed that the root in first 18 hours had a dip in the activity of the cellulase while the stem showed the increase (Table-4) After 24 hrs. the root showed a slight lag phase with a shooting up of its activity upto 8.9 after 36 hrs, whereas the stem showed the increased activity to almost double after 36 hrs. than what it had after 18 hrs. In other words both in the pot culture normal water conditions as well as in water logged conditions the relative activity of cellulase in stem is higher than that of roots. In evidence thereof is the active anatomical differentiation leading to aerenchyma formation which takes place first in stem rather than in roots. This clearly indicates that upon submergence of root systems in water the anaerobic condition does not provide any scope for old roots to respire any longer but send a signal to the aerial stem cells to induce cellulalytic activity. As a matter of fact the cellulalytic activity in most plants or in almost every plant first starts in stem itself so that some sort of communication between leaf and stem from the transport of O_2 is being built up. Since the oldroots are no longer capable of undergoing differentiation because of lot of conducting strands and the lignified cells the old roots die and

TABLE - 5

Determination of cellulase in root and stem of Phyla nodiflora under water stress in sand culture

Nature of plant organ	Cellulase activity gm fresh tissue
Root	5.45
Stem	8.60

TABLE - 6

Determination of cellulase in root, stem and leaf in Phyla nodiflora under pot culture condition.

Nature of plant organ	Cellulase activity/ gm fresh tissue
Root	6.2
Stem	6.54
Leaf	5.2

the new adventitious roots develoo, so that these new adventitious roots would have their aerenchyma linked up with that of the root and stem.

The enzyme cellulase assayed under sand culture condition after intermittant stress has also gave a positive result of the existence of endogenous cellulase and the activity measured is inconformity with those plants grown in the pot. Moreover, the roots have relatively low activity than that of stem in the sand culture condition. Table - 5 .

Williams and Barber (1961), Teal and Kanwisher (1966) emphasized the importance of aerenchyma for transport of oxygen leaf to root inaquatic plants. In the meanwhile Evans and Eberts (1960), Greenwood and Goodman (1971), Healy and Armstrong (1972), have shown that similar translocation of oxygen is common in mesophytic plants. One of the elegant experiment of these workers has shown that mesophytic plants when grown under low oxygen tension lysigenous acrenchyma frequently developed in their roots (Beal, 1917; Briant, 1934; McPherson, 1939). These observations have been confirmed by Kawase (1974) that the mesophytic plants herbaceous or woody produce lysigenous acrenchyma in roots as well as stem, when waterlogged. Such acrenchyma may enhance the air diffusing system in mesophytic plants from leaves to the roots.

Horton and Osborne (1967) for the first time showed that the enzyme cellulase has something to do with abscission and senescence where the radial enlargement of cortical cells, the plasticity of the cell wall must increases before the abscission takes place. In plants which are not able to withstand in waterlogged conditions the death of cortical cells occur by starvation for oxygen or annoxic condition in the event of anaerobic respiration insufficient to maintain cellular integrity.

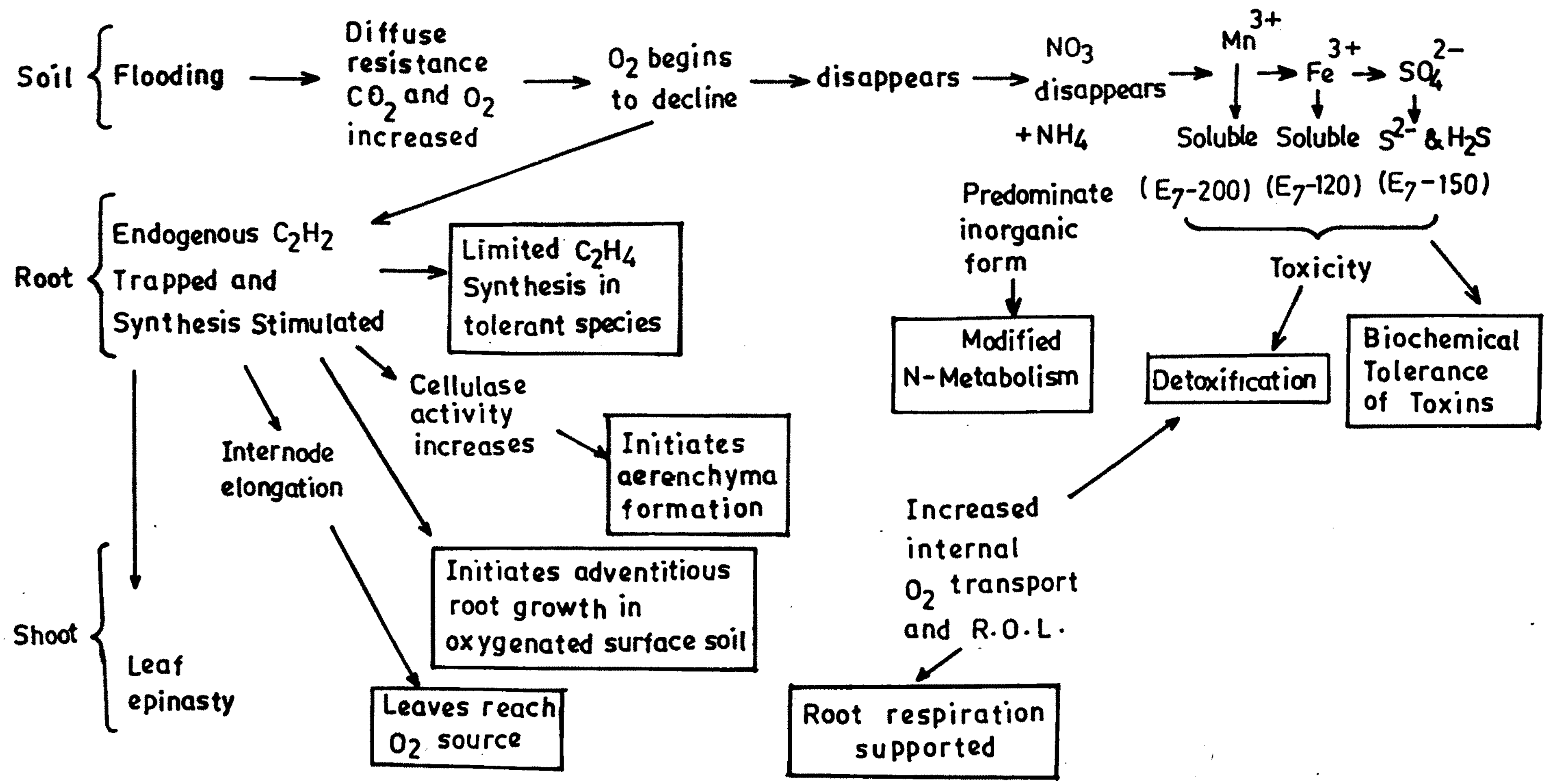
One of the best known examples of wilting that takesd place under waterloged condition is maize or even cotton which are extremely sensitive. In case of cotton the leaves start senescing as soon as water logging takes place. This may be due to failure in invoking Lysigeneous activity required for acrenchyma formation. In some plants if the existing root systems are not able to cope with the situation aerial root start developing. Waldren et.al. (1987) carried out comparative growth study of two plants in the experimentally flooded soil. When two plants *Geum rivale*, *Geum arbanum* were exposed to waterlogging and showed that waterlogging caused reduction in root biomass and changed in the distribution of roots of both species such that rooting was restricted to surface zone of flooded soil. The former plant *G. rivale* possessed rhizome like structure which was usually absent in *G. arbanum*. This rhizome structure facilitated advantitious root formation in water logged soil. Some sort of similar situation exists in *Phyla nodiflora* where new adventitious roots are formed. Neverthless *Phyla nodiflora* has inherent ability of Lysigenosity which is invoked under waterlogged condition.

Experiment of Kawase (1974) that the ethylene helps plants to withstand water logged condition has led to the systematic investigation of mechanism of its action i.e. ethylene facilitates acrenchyma formation. Even he demonstrated that application of ethepon an ethylene releasing compound was known to induce acrenchyma formation. He could clearly demonstrate that 1 ppm caused acrenchyma development in intact stems of beans, crysdenthamium, sunflower and tomato and aerenchyma development often associated with radial enlargement of cortical cells. Kawase (1979), Kawase and Whitmoyer (1980)? working on sunflower, tomato and some other plants clearly demonstrated that the localized stem treatment of an intact sunflower with

Ref ?

a water jacket increased cellulase activity in that part of cell when the lower part of sunflower water loged the cellulase activity in waterlogged stem increased. This result let them to conçlude that aerenchyma development of plant adoptation to waterlogging conditions. The deficiency of O_2 in waterlogged plant trigger the aerobic stimualtion of ethylene production which causes an increase in cellulase activity leading to aernchyma development and enhancing the transport of oxygen to the roots. Such ability does not exist in all the plants with a result that such plant are at disadvantage in waterlogged condition. In Lippia (Phyla) nodiflora possibly the genetic mechanism exists which can be invoked by waterlogging which creates anacrobic condition and ethylene formation. Ethylene trigger or activates the genes for more release of cellulase which could be evidenced by periodic monitoring of its activity in the plants after exposing them to waterloged conditions. Kawase and Whitmeyer created such waterlogged condition to sunflower and tomato plants and monitored the lysigenous aerenchyma formation in the Cortex of water logged stems. They showed that within two days the aerenchyma developed in Phyla nodiflora we find that in 36 hrs the activity of cellulase doubled indicating thereby rapid acrenchyma formation perhaps not in roots but in shoot.

Stelzer and Lauchli (1980) studied salt tolerance and flooding tolerance in Puccinellia peisonis. They investigated root respiration and the role of acrenchyma in providing atmospheric oxygen to roots. Respiration rates of roots of plants which were grown at different salinities and with varying oxygen level in the growth medium were measured. They focused that root grown in O_2 deficient medium had an increased respiration rate when 100mM



A simplified scheme for water logging tolerance. Arrows indicate sequences of events and boxes represent adaptive consequences E_7 — redox potential corrected to pH 7.0 (mV) R.O.L. — radical oxygen loss.

A.D.H. alcohol dehydrogenase.

(Adopted Chart from ETHERINGTON J.R. modified virson of J.R. ETHERINGTON)

FIG. 4

NaCl was added to growth medium. Root respiration in plant in O_2 deficient media was found to be supported by atmospheric O_2 from the acrenchyma. This experiment clearly indicated that aerenchyma formation in plants roots or shoot has an added advantage to face not only to waterlogged condition but even salt induced increased respiration which demand more O_2. Perhaps when plants are exposed both water logging and salinity the situation of O_2 demand is agrivated and aerenchyma formation facilitates O_2 supply.

Possibly Lippia being a salt tolerant plant it is inherently endowed with lysigneous activity which is also required to withstand salinity.

In conclusion it can be said that the plants which have built in genetic system to withstand varied environmental stresses such as salt and water stresses later being both types waterlogging as well as water scarcity has better ecological adoptation. Such genetic systems are rare but are more useful in transferring by way of genetic engineering to the more vulnerable and sensitive crop plants. Mechanism of water logging resistance is given in Fig.4.

A. Stomatal Frequency and Salt Gland Indices :

Stomata have pivotal role to play in many aspects of plant metabolism nutrient absorption, transport photosynthesis, respiration, etc. Many correlative study regarding stomatal frequency and index with environment in which the plant grows have been carried out time to time and it has been established that not only stomatal movement forestall the environmental fluctuation around the root zone but also the stomatal frequency whether distribution on one side or both side is able to tell something about the ecological adoptation of plants. Waisel et.al.(1972), Joshi (1976) and many workers have carried out the correlative study on this aspects. And present

TABLE -7

Stomatal index and salt gland index of leaf of

Phyla nodiflora

Leaf surface	Mean stomata	Stomatal Index	Gland Index
Upper epidermis	58 (2.3)	19.3 (0.34)	5 (0.246)
Lower epidermis	64 (4.9)	21.6 (0.68)	5.9 (0.12)

Values in parenthesis are S.E's.

investigation. Stomatal frequency per/mm^2, stomatal index and the gland index have been studied and presented in the table-7.

It can be seen from the table-7 that Phyla nodiflora has amphi stomatous leaves. The stomatal frequency per mm^2 on upper epidermis is 58 and in lower epidermis is 64 similarly. Stomatal index as expressed the stomatal frequency in relation to the frequency of epidermal cells per mm^2 area of a leaf is 19.3 on upper side and 21.6 on the lower side. Although Waisel (1972) did not give greater emphasis on stomatal index corroborated the observations of the stomatal frequency of many halophytes. According to him stomata of succelent leaves sunken into their epidermis and their numbers are usually low i.e. among the several halophytes studied only in one case namely Plantago maritima the counts exceeded 200/mm^2. Stomatal index though is in proportion to the stomatal frequency it is influenced by size and dimension of epidermal cells, and the environment in which the plant grow is known to influence profoundly. Phyla nodiflora though have stomata on both the surface like many mangrove inclining more towards halophytic habit rather than xerophytic habit.

Another parameter which has been introduced is a gland index which is calculated as number of glands in proportion to the number of epidermal cells per mm^2 of the leaf area. In other words similar to that of stomatal index. It is justified to express this parameter for the frequency of glands on the leaf surface is as dense as that of stomata. In Phyla nodiflora on both the surfaces the glands are found which has been given in the table- On upper epidermis the gland index is five and lower epidermis gland index is 5.9 which is slightly higher than that of upper epidermis. In other words, the density of plants is not as high as density of stomata. However certainly tells that high index as the lower surface means high proportion of salt exudation from the lower surface.

In conclusion it can be said that most morphological and anatomical peculiarity of Phyla categorises it as a salt tolerant species but only adopted to inland salinity. It would be interesting therefore to examine this plant to grow in salt marsh of the coast and see its behaviour.