P1036-TH1675

EFFECT OF SOIL EXCHANGEABLE SODIUM AND SALINITY ON THE GROWTH AND CHEMICAL COMPOSITION OF CASHEW, COCONUT, MARKINGNUT, SOAPNUT, PHALSA, KARONDA, PASSION FRUIT AND DRUMSTICK

BY

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M.Sc. (Agri.)

T 1675



DISSERTATION

SUBMITTED TO THE MARATHWADA AGRICULTURAL UNIVERSITY

IN PARTIAL FULFILMENT OF THE REQUIREMENT

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

HORTICULTURE

DEPARTMENT OF HORTICULTURE

MARATHWADA AGRICULTURAL UNIVERSITY

PARBHANI

1989

GRATEFULLY

DEDICATED

TO

MY BELOVED GURUJI



HIS SUPREME DIVINE HOLINESS

PRAMUKH SWAMI MAHARAJ

(NARAYANSWARUPDASJI)

CANDIDATE'S DECLARATION

I hereby declare that the thesis or part thereof has not been previously submitted by me to any other university or institution for a degree or diploma

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DATE : 18th September, 1989.

CERTIFICATE I

Shri R.Z. Valia has satisfactorily prosecuted his course of research for a period of not less than five semesters and that the dissertation entitled "EFFECT OF SOIL EXCHANGEABLE SODIUM PERCENTAGE AND SALINITY ON CASHEW, COCONUT, MARKINGNUT, SOAPNUT, PHALSA, KARONDA, PASSION FRUIT AND DRUMSTICK" submitted by him is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the dissertation or part thereof has not been previously submitted by him for a degree of any university.

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CERTIFICATE II

This is to certify that the dissertation "EFFECT OF SOIL EXCHANGEABLE SODIUM PERCENTAGE AND SALINITY ON CASHEW, COCONUT, MARKINGNUT, SOAPNUT, PHALSA, KARONDA, PASSION FRUIT AND DRUMSTICK" submitted by Shri. R.Z. Valia to Marathwada Agricultural University in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY in the subject of Horticulture has been approved by the student's advisory committee after oral examination in collaboration with the external examiner.

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ACKNOWLEDGEMENT

It is my proud privilege to place on record that this piece of work is the outcome of unfathomable love and blessings showered on me by his supreme Divine holiness of Pramukh Swami Maharaj (Narayanswarupdasji) to whom this thesis is dedicated.

I have great pleasure to express my deepest gratitude and heartfelt respect to Dr.V.K.Patil, M.Sc.(Agri)., LL.B., Ph.D., Director of Instruction and Dean, Faculty of Agriculture for his keen interest, excellent guidence, inspring and worthy suggessions throughout the course of this investigation and in the preparation of this manuscript.

It is also my personal gratefulness to the members of my advisory committee, Dr.V.R.Chakrawar, Head, Department of Horticulture, C.P.Ghonsikar, Associate Director (Research), NARP, Aurangabad, Dr.G.U.Malewar, Head, Department of Soil Science and Agricultural Chemistry, Dr.B.V.Sathe, Asst. Professor, Plant Physiology, M.A.U. Parbhani for their valuable suggessions and guidance during the course of my Ph.D. study.

I am grateful to the Associate Dean and Principal, College of Agriculture, Parbhani for rendering the required facilities.

I am highly indebted to the authority of Gujarat Agricultural University, Sardar Krishinagar for allowing me to prosecute higher studies leading to the Ph.D. degree in MAU Parbhani.

I am thankful to Dr.K.W.Anserwadekar, Professor, Dr.B.N.Shinde and Dr.B.A.Kadam, Asst. Professors and all other staff of the Department of Horticulture, for their timely help.

I am extremely thankful to Dr.V.G.Makne, Asst. Professor, Department of Genetics and Plant Breeding for his keen interest and help in preparing this thesis and Dr.U.G.Kulkarni, Reader for the help in preparing the slides of stomata.

My sincere thanks are also to Dr.T.K.Bhaktta, Campus Director, Dr.J.P.Bhatt, Dr.J.S.Katrodia, Dr.J.C.Patel, Dr.K.P.Kikani, Sarvashri, R.B.Sarvaiya, P.K.Kapadia and Z.N.Patel, Gujarat Agricultural University for their inspiration and timely help.

My sincere thanks are to Dr.B.T.Valia (M.B.B.S.) and Mrs.Sharda B.Valia for their continued encoragement and financial support.

I am very much thankful to Shri. Jani, Head, Agriculture Division and B.C. Patel, Asst. Soil Schemistry, Gujarat Narmada Valley Fertilizer Company Ltd., Bharuch, for extending facilities for soil analysis.

I am also thankful to my friends Sarvashri Kapadia, Cuchha, Bhut, Sadaria, Patil, Joshi, Dalvadia, Patel and Lawand for their valuable help.

No words are enough to express my heartiest gratitude to my mother, elder brother and Shri. Bhupat Z. Valia and Mrs. Rekha B. Valia who contributed immensely in completing my studies.

I am extremely grateful for the best wishes given by S.M.Desai, Tank Vallabhabapa, M.B.Kambad, N.K.Valia and all followers of Lord Swaminarayan from A.P.Temple of Mahuva for completion of my research project within stipulated time.

I also express my deep sense of appreciation to my wife Sow. Triveni, lovely sons, Shailesh and Parvin and sweet daughter Satabdi for keeping long patience, while I remained far awary from them for the Ph.D. studies.

Rzvalia

(R. Z. VALIA)

PARBHANI

DATE 18-9-89

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Soapnut	32 to 35	88 to 91	36	92	37, 38	93, 94
Phalsa	39 to 42	95 to 98	43	99	44, 45	100,101
Karonda	46 to 49	102 to 105	50	106	51, 52	107,108
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Chapter 1

INTRODUCTION

In arid and semi-arid regions of the world, soil salinity and sodicity are the major problems. Out of the total geographical area of 329 million ha. in India the area of wasteland is 158 million ha and saline and alkaline soil is an important component (contributing 12 million ha) of wasteland. Development of this land can be done most effectively through planting of selected trees. According to the survey made by Abhange et al. (1986) an area of 0.54 million hectares has been estimated as salt affected in Maharashtra.

After examination of the various types of works highlighting the effect of salts as mentioned in different reviews (Bernstein, 1965a and 1965b; Patil, 1983a, 1983b and Dahiya et al., 1983), it is felt necessary to differentiate between various types of salt stresses. The injurious effects on the plants may be mainly due to the effect of total salinity (salinity stress) or sodicity (exchangeable sodium percentage stress) in soil.

Besides the fact that the reclamation cost of salt-affected soils is very high and also it is a difficult task, the reclamation process is confined to the only upper horizon of the soils, while most of the tree

crops have deeper root system. Hence, the present system of reclamation may not be quite effective for the cultivation of tree crops. Under such conditions, the only possible way is the careful selection of hardy fruit crops.

Various species and varieties differ markedly among themselves to the reaction of salt stresses. Although information on the responses of major fruit crops to saline and sodic soil conditions is available on citrus, grape and major fruits (Lunt, 1966; Chapman, 1968 and Patil, 1979a, 1979b), such information is lacking in fruit crops like cashew, markingnut, soapnut, phalsa, karonda, passion fruit and drumstick. These crops are also gaining importance under the present days changing situation and concept of dryland horticulture.

Cashew (Anacardium occidentale L.) is one of the most versatile tree crops which assumes higher rank in the international trade of tree nuts. Recently cashew kernel gained importance and the crop is considered as a horticultural crop of commercial importance. The tree is hardy and the kernels are of high nutritive value. It is rich in protein, carbohydrate, fats and considered as superior to apple (Nambiar and Pillai, 1985). The use of cashew in medicine, foods and beverages in well known.

The kernel supply about 6000 calories energy per kg. Cashew nutshell liquid (CNSL) is a valuable raw material for a number of polymer based industries like paints, varnish and resin (Kamth, 1956). (The cultivation of cashew is mainly limited to coastal and hill-area which yields poorly (233 kg/ha) although the potential is very high (1000 kg/ha). The cause of low yield might be due to salinity and alkalinity problems.)

The coconut palm (Cocos nucifera Linn.) not only supplies food, drink and shelter, but also provides raw materials for number of industries intimately connected with domestic as well as economic life. On account of the uses of all parts of this wonder palm to mankind the palm has been regarded as kalpa vriksha (tree of heaven). Various yield products like oil, oil cake and coir or coconut fibre from coconut palm are commercially exploited. Coconut water is a liquid endosperm of the tender coconut and is used as a refreshing and agreeable drink and as a useful substitute for saline glucose in intravenous infusions. It is also prescribed in serious cases of diarrhoea and vomiting, against dehydration of the body tissues. The kernel or endosperm of the ripe coconut is an important article of food being used in culinary purposes in various forms in

all the coconut growing countries. Coconut is one of the excellent media for tissue culture technique. Palm is mainly grown along the coast line and is known for its tolerance to soil salinity, although its tolerance to salinity in black soil is yet to be investigated.

Markingnut (Semecarpus anacardium L.) tree is commonly grown in the hotter parts of India. The fleshing orange cup (hypocarp) of the fruit is eaten when quite ripe. The seed abounds in viscous juice (Bhilawan shell liquid) which is used traditionally for marking lines. Bhilawan shell liquid (BSL) is rich in phenols and is extracted from nuts. BSL is used in production of varnishes, paints, insecticides, antiseptics, wood preservatives, etc. BSL is said to have medicinal properties and is used against cancer, blood pressure, leprosy, snake bite and scorpion sting. Edible kernel present inside the seed has an almond like taste. Kernel is rich in protein (26.4 per cent), fat (36.4 per cent), minerals (3.6 per cent), thiamin (vit.B-1) and riboflavin. This important crop has a great potential and can be grown under dryland conditions.

The soapnut (Sapindus trifoliatus Linn.) is commonly known as Reetha. It has been exported from India to various countries since ancient times. The wood is

light yellow, close-grained, somewhat coarse and uneven textured, moderately hard and moderately heavy. It is used as fuel and for charcoal making. The fruits are credited with expectorant and emitic properties and are used in the treatment of excessive salivation, epilepsy and chlorosis. The fruit is also valued for the saponins (10.1 per cent) present in the pericarp. Soapnuts are largely used as detergent for washing cloth before dyeing and for washing hair. The kernel contains a fixed oil (35 per cent) and protein (31 per cent). Its leaves can be used as manure. Roots and bark are employed as mild expectorant and demulcent.

Phalsa (Grewia asiatica L.) is commercially cultivated in many states of India. Phalsa is a drought resistant and some times grown without any irrigation when plants are established. Ripe phalsa fruits are sub-acidic and good source of vitamin A and C. They are fair source of phosphorus and iron. Fruits contain 50-60 per cent juice; 10-11 per cent sugar and 2.0-2.5 per cent acid (Aykroyd, 1963). The fruits are excellent for making juice and squash. However, it is mostly used as fresh fruit and has cooling effect. The shoots of the plants after pruning can be utilised either for making baskets or supporting vegetable crops. Phalsa baskets are fairly strong and

can also be used for transporting fruits and vegetables. Ropes can also be made from the bark after treating it, which yields fibre.

Karonda (Carissa corandas L.) is a hardy thorny and ever green shrub, tolerant to drought and can be successfully grown in diverse type of soils and climatic conditions. As this plant stands heavy pruning, if trained on a single stem. Since plant grows thickly with a fine dark green and shining foliage, it can be used as plant for topiary work in ornamental gardens. The ripe fruit is very rich source of iron and sweet edibles. It is useful for curing anaemia. Apart from this, it can also be used to prepare a fine quality wine. The jam, jelly and pickle from the fruits can also be made.

Passion fruit (Passiflora edulis Sims) includes several species grown for their edible fruits as well as for their ornamental flowers. The fruit juice contains about 12.4 sugar and 3.5 acid. It is a good source of ascorbic acid and carotene. The juice is preserved by canning or freezing and is largely used in blend with less acidic fruit juices and in the preparation of squashes, cordials syrups, carbonated beverages and jellies. It is used in flavouring candy, ice cream, cakefilling and forsting.

The fruit juice concentrates and powder are also prepared. The peel of the fruit, obtained as a byproduct of the juice industry, can be used for the recovery of pectin, for feeding livestock and as a manure. The oil from seeds of yellow fruits, could be used for edible purpose and it is suitable for use in the paint and varnish industry. The leaves are used in medicine along with those of P incarnate (Var.).

All parts of the drumstick (Moringa oleifera Lamk) are considered medicinal and used in the treatment of ascites, rheumatism, venomous bites and as cardiac and circulating stimulants. The root of the young tree and also root bark are rubefacient and vasicant. The leaves and flowers are rich in vitamin A and C and used for curry. Tender pods are cut and used in soups or sambar and also pickles. The leaves are rich in carotene and ascorbic acid. A paste of leaves is used as an external application for wounds. The juice of the leaves of the plant show strong antibacterial activity. This neglected tree if grown commercially on large scale may bring rich dividents.

(Specific information is lacking) The present piece of research work was aimed at assessing the behaviour of cashew, coconut, soapnut, markingnut, phalsa, karonda, passion fruit and drumstick in soils having wide range of sodicity and salinity.) In reference to these crops, the major objectives of the studies were --

i) to assess the effect of various levels of soil alkalinity and salinity on the growth.

ii) to assess the effect of various levels of soil alkalinity and salinity on the physiological parameters.

iii) to estimate the effect of various levels of alkalinity and salinity on the mineral composition.

iv) to find out the soil alkalinity and salinity tolerance indices.

Chapter 2

REVIEW OF LITERATURE

Most of the workers correlated the poor plant growth in a soil containing appreciable exchangeable sodium to poor soil structure leading to the problems of aeration, moisture movements and nutritional disorders.

Restricted drainage is the major factor that usually contributes to the salinization of soils and may involve the presence of a high ground-water table. In the process of salinization, soluble salts move towards soil surface by the capillary action along with water and accumulate on the surface after evaporation of water.

Although, knowledge of the salt tolerance of crops is quite well advanced, information is lacking on alkali tolerance in respect of multipurpose fruit crop species under study and a scanty information is available on salinity tolerance in respect of these crops.

Therefore, the literature pertaining to the effect of soil exchangeable sodium percentage and salinity on the growth and chemical composition of fruit crop species is reviewed in this cahpter.

2.1 Effect of exchangeable sodium percentage

2.1.1 ESP tolerance of fruit crop species

A limited information is available regarding tolerance of various fruit crop species to varying levels of ESP. As per Bernstein and Hyaward (1958) the toxic levels of Na would accumulate in citrus if the soil contains more than 5 per cent excahngeable sodium. Pearson (1960) reported that deciduous fruits, nuts, citrus and avocado were extremely sensitive (ESP = 2 to 10) to exchangeable sodium. Pearson (1960) also rightly classified citrus as the extemely sensitive to ESP. He pointed out that citrus showed sodium toxicity symptoms in the ESP range as low as 2 to 8 under non-saline conditions. Chapman (1961) and Allison (1964) emphasized that for good citrus growth, exchangeable sodium should not be more than 10 per cent. However, it is reported by Bhella (1966) from Hissar, Singh (1966) from Bhatinda and Chadda (1966) from Sangrur on the basis of studies of the orchard soils that well grown citrus trees can thrive fairly well under the soil having ESP upto 15. Nilangekar and Patil (1979 and 1981) related the decline of sweet orange orchards of Jalna and Parbhani districts with ESP higher than 18.

Patil and Bhambota (1978c) reported that citrus rootstocks viz., Jullunduri Khatti, Jatti Khatti and Carrizo were highly ESP tolerant, while Cleopatra and Kharna Khatta were most sensitive. Patil (1979a) reported that Poncirus trifoliata and citranges although were very sensitive to salinity showed better performance under higher ESP. The ESP tolerance indices (ESP level representing 50 per cent growth depression) were calculated to be 16.7, 9.5, 10.2, 11.7, 13.4 and 17.0 in Jatti Khatti, Cleopatra, Kharna Khatta, Rangpur lime, Carrizo and Jullunduri Khatti, respectively (Patil and Bhambota, 1978c).

The ESP tolerance of some fruit crops viz., figs, guava, citrus, sapodillas and avocados has been reviewed by Patil (1983a). Exchangeable sodium upto 40 per cent in jamun (Patil and Patil, 1983a), 25.5 per cent in pomegranate (Patil and Patil, 1982), 13 per cent in Peach (Martin et al., 1959b), 30 per cent in grapevines (Khanduja et al., 1980) and 30 per cent in bael (Tiwari, 1985) were estimated as the upper limits upto which these can be grown successfully. Patil (1980) studied the effect of soil ESP on guava, pomegranate, custardapple, ber, jamun, chiku and fig. He reported that chiku and fig were more ESP tolerant

than other fruit plants. The tolerance limits for ESP (ESP level representing 50 per cent growth depression) were calculated to be 39.20, 38.0, 45.50, 47.50, 44.50, 56.50 and 53.50 in guava, pomegranate, custardapple, ber, jamun, chiku and fig, respectively. Sadaria (1989) investigated the effect of soil ESP on eight plant species viz., tamarind, woodapple, mulberry, bael, khirni, eucalyptus, neem and persian lilac grown in pots containing varying levels of artificially developed ESP. The tolerance limits of ESP (ESP representing 50 per cent growth depression) were 48.50, 43.50, 38.50, 36.00, 51.50, 46.50, 64.00 and 52.25 in tamarind, woodapple, mulberry, bael, khirni, eucalyptus, neem and persian lilac, respectively.

2.1.2 Effect of ESP on the growth

There is a good amount of evidence that a high degree of saturation of the soil exchange complex with Na may be quite detrimental to plant growth (Ratner, 1935; Itallie, 1938; Joffe and Zimmerman, 1944; Bower and Turk, 1946; Bower and Wadleigh, 1948; El-Gabaly, 1955 and Peterson, 1961).

A general lack of vigour particularly of the root system is characteristic of fruit plants growing on sodic soils (Lilleland, 1946 and Hass, 1950). Pearson (1960) also stated that sodic soils may generally restrict root elongation.

Martin et al. (1959a) studied the effect of different exchangeable sodium levels (range from 1 to 15 per cent) on the growth of trifoliate orange seedlings. They observed reduced growth with the increase in ESP. The growth reduction was much more in the clay loam soil than sandy soil. At a normal K level, 7 per cent Na reduced the growth in the clay loam, while 15 per cent Na was required for growth reduction in sandy soil. They also observed that growth effects of exchangeable sodium and exchangeable potassium were additive. Jones et al. (1957) studied the effect of various levels of soil ESP ranging from 1 to 28 on lemon tree budded on eight different rootstocks. Marked growth reduction occurred at 13 per cent exchangeable Na for all rootstocks. The 28 per cent Na killed or nearly killed all plants. Martin et al. (1961) reported that the magnitude of growth reduction of sweet orange plants to increasing exchangeable Na levels (ESP tried 6, 12, 17 and 31) was greater in base saturated soils containing excess of lime (more than 70 per cent). Patil and Bhambota (1977) reported the decrease in fresh weight of root and top, with the increase in ESP levels. The leaf area of all the citrus rootstocks decreased with the increase in ESP. In the experiment of Patil (1980) the growth of guava, pomegranate, custardapple, ber and jamun started getting adversely affected

at the ESP of 30 and above. However, in chiku and fig the adverse effects were noted at ESP of 40 and above. Patil (1983a) in his review pointed out that tree growth of figs, guava, sapodillas, citrus and avocados decreased with increasing ESP levels. Patil and Waghmare (1984) in pot culture study reported that all growth parameters (plant height, number of leaves and stem diameter) were significantly declined after 360 days with rising ESP levels in sapota. Tewari (1983) also observed that the growth parameters viz., plant height, girth and spread in aonla seedlings showed decreasing trend with increasing ESP levels. Similarly recently Sadaria (1989) recorded progressive decrease in growth parameters with increase in soil ESP. Tamarind, woodapple, khirni, eucalyptus, neem and persian lilac started getting affected at ESP 40 in growth parameters viz., plant height and number of leaves. The stem diameter was also affected at the same ESP level in all crops except khirni and neem which were affected at ESP 30 and 20, respectively. All growth parameters of bael and all growth parameters except the stem diameter of mulberry started getting adversely affected right from ESP 30 onwards. In the case of mulberry the stem diameter started getting reduced at ESP 20. The fresh weight of whole plant, fresh and dry weight of top and root, plant spread, leaf area per plant,

root length and root volume decreased with the increase in ESP in all species. The extent of reduction was more in bael and mulberry as compared to other species. In the experiment of Sadaria (1989) the toxic limits of sodium in the leaves on dry weight basis for tamarind, woodapple, mulberry, bael, khirni, eucalyptus, neem and persian lilac were 1.14, 0.83, 1.15, 1.16, 0.94, 1.21, 0.55 and 0.49 per cent, respectively. Different species showed different Na content at the same ESP level. In general, tamarind, mulberry, bael and eucalyptus accumulated more Na content in the leaves as compared to neem and persian lilac.

Considering the vast scope that salt-affected soil offer for tree plantation, very limited work has been done on a field scale.

Yadav and Pathak (1967) and Khan and Yadav (1962) concluded that the forest species under different natural flora varied in their tolerance from place to place in different states of India, perhaps because of different soils, salt compositions and climatic conditions. Several workers in India and other countries have observed that the forest species amongst themselves differ in their tolerance to alkali condition.

Yadav and Singh (1970) in their investigation in Vrijbhumi Forest Division of Utter Pradesh found that all planted species failed to grow on the soil having pH more than 10 with a cemented bed of kankar nodules. According to Kaushik et al. (1969) Eucalyptus hybrid failed to grow on soils having pH more than 10 and soluble salt content above 0.7 per cent and possess compact indurated subsoil due to the presence of kankar. Eucalyptus hybrid has been found to do fairly well on the sodic soil with the adoption of proper planting technique (Yadav et al., 1972).

Chaturvedi et al. (1985) reported that Azadirachta indica, Terminalia arjuna, Pongamia pinnata and Acacia auriculaeformis were tolerant upto pH 10, whereas Eucalyptus hybrid was found to grow well upto pH 9.5 with an allowance of 30 per cent reduction in total biomass accumulation as compared to pH 7. Singh and Yadav (1985) studied the performance of shisham (Dalbergia sissoo) in pot culture conditions with different ESP levels in an alluvial silty clay loam soil by addition of different salts and reported that D.sissoo failed to grow above ESP 15.2 plant height, girth, fresh weight and dry weight of uprooted plants decreased with increase in ESP.

Singh et al. (1987) conducted greenhouse experiment under sand culture conditions to study the effect of varying pH from 7 to 12 and concluded, based on number of green leaves, plant height, diameter, total biomass accumulation and with an allowance of about 25 per cent reduction in total biomass production, it was hereby inferred that tree species viz., Prosopis juliflora and Acacia nilotica could be identified as tolerant upto pH 11 whereas Syzygium cuminii and Albizzia lebbeck could be listed as tolerant upto pH 10. Chhabra et al. (1987) studied three Sesbania species viz., Sesbania aegyptica, Sesbania formosa and Sesbania sesban which were grown in sodic soils having ESP ranging from 13 to 98. Though none of these species could survive at the highest ESP level of 98, Sesbania aegyptica was found to be more tolerant to sodic soil conditions.

Singh et al. (1982) observed that tindu (Diospyrus tomentosa), dhak (Butea monosperma), mahuva (Madhuca indica), jamun (Syzygium cuminii) were able to grow on Cl-HCO_3 type soils having a maximum pH value 8.0 and ESP 10 in one metre deep soil but in subsoil, tolerance of plants may go still higher i.e. pH 9.3 ESP 40.

2.2 Effect of salinity

2.2.1 Salinity tolerance of tree species

There is an approximate 10- fold range in salt tolerance of agricultural crops. In general, the relative tolerance indicated by different workers agree fairly well notwithstanding differences in climate, varieties and cultural practices. Although varietal differences are in general small for most crops, but there are exceptions for some fruit crops, which may show large differences in salt tolerances according to variety and rootstock (Patil, 1983b).

The work of Ayers and Westcot (1976) is pertinent, who presented a crop tolerance table for various crops. They incorporated older data from the crop tolerance tables of the USDA salinity lab staff (1954), data of Bernstein (1964), data from the University of California Committee of Consultants (1974) and have recently been updated based on data of Maas and Hoffman (1976). They reported maximum ECe, for complete ceasation of growth of various crops like datepalm-32, fig, olive, pomegranate-14, grape-12, grapefruit, orange, lemon, apple, pear, walnut, as 8 and almond, plum as 7 mmhos/cm at 25^{o}C. Patil (1983b) also updated the information on tolerance of fruit crops to salt in his review.

Ayers and Westcot (1976) also prepared crop tolerance table, in which yield decrements to be expected for certain crops due to salinity are given. Fifty per cent yield decrement was expected in crops when conductivity of saturation extract of soil was 17.9 in datepalm, 8.4 in fig, olive, pomegranate, 4.8 in grapefruit, orange, lemon, apple, walnut and 6.87 mmhos/cm in grape.

Crops with low salinity tolerance

According to U.S. Salinity Lab. Staff (1954) the crops which come in the range of poor salt tolerance (2 to 3 mmhos/cm) are muskmelon, pear, apple, citrus, plum, peach, almond, avocado, papaya and strawberrry. Besides these crops, loquat, persimmon, blackberry, gooseberry, prune, apricot, walnut, coffee and cocoa have also been found to be poorly tolerant (Vanderberg, 1950; Hayward, 1955; Hayward and Bernstein, 1958; Oganesjan, 1954; Ehlig and Bernstein, 1958).

Bernstein (1968 and 1965b) reported that ECe at which yields decrease by about 10 per cent was found to be 3 to 2.5 for orange, grapefruit and lemon. In citrus, lemons are more sensitive than orange and grapefruit. Raheja (1962) collected information on some of the Indian fruits. Out of the sensitive citrus crops, the order of

tolerance was stated as lemon sweet lime Nagpur orange Mosambi. A salt concentration of more than 0.11 per cent was highly detrimental to orange plant growth (Bhambota and Kanwar, 1970). Kanwar and Randhawa (1960), Singh (1966) and Bhella (1966) studies the orchard soils of Punjab and found a correlation between citrus decline and higher ECe values. The sweet orange plants budded on rough lemon were reported to be highly sensitive to salinity i.e., 6 mmhos/cm (Bhambota, 1965). Amongst six rootstocks evaluated, Rangpur lime and Cleopatra were reported to be tolerant upto 4.8 mmhos/cm while Bhadri lemon and Jatti Khatti were the most susceptible even at 3.8 mmhos/cm (Joolka and Singh, 1979).

Bielorai et al. (1978) conducted long term experiment with 7 to 17 me Cl/l ($NaCl + CaCl_2$) as treatments on adult grapefruit trees. There was 1.45 per cent yield reduction for each 1 me/l increase in chloride concentration above 4.5 me/l. This corresponded to a 13.5 per cent decrease per 1 mmhos/cm increase in the electrical conductivity of the saturation extract above 1.2 mmhos/cm. The results indicated mainly the osmotic effect.

Patil and Bhambota (1978a) reported that Jullunduri Khatti, Jatti Khatti and Cleopatra seedling rootstocks were relatively resistant to salinity, while

Carrizo and Kharna Khatta were very sensitive. The salinity tolerance indices (salinity level representing 50 per cent growth depression) were 2.7, 2.5, 2.0, 2.1, 2.0 and 3.0 in seedlings of Jatti Khatti, Cleopatra, Kharna Khatta, Rangpur lime, Carrizo and Jullunduri Khatti, respectively. Patil (1979b) further reported that larger differences exist among different species used as rootstocks for citrus in their inherent abilities to withstand saline or alkali soil conditions. Severina buxifolia, Cleopatra mandarin, Rangpur lime in most of the investigations have been rated as salinity resistant. Different strains of rough lemon have also been found to withstand good amount of salts in substrate. Bhatti et al. (1986) tried six levels of salinity (1.1 to 20 mmhos/cm at 25°C) and reported that none of citrus rootstocks (Jatti Khatti, Gadha Dahi, Jamberi, Ceylon and Sylhet lime) was found suitable for planting in saline conditions exceeding 4 mmhos/cm.

Stone fruit trees, citrus, strawberry and papaya are sensitive even to 2-3 mmhos/cm ECe (Hayward, 1955). Concentration of total soluble salts which proved fatal were 2 and 1.2 per cent for apricot and apples, respectively (Oganesjan, 1954), while Ivanov (1970) decided upper limit for apricot to

be only 0.15 per cent and Ivanov and Ivanov (1972) for peaches to 3.7 me/l. The salt concentration range of 0.7 to 0.9 per cent for apples and 1.1 to 1.2 per cent for pear were detrimental (Beeftink, 1955).

Crops with medium salinity tolerance

According to the U.S. Salinity Lab. Staff (1954) the crops categorised into moderate salt tolerance range (4 to 10 mmhos/cm) are pomegranate, guava, fig, mango, olive, jackfruit, grapes, cantaloup etc. Vanderberg (1950), Hayward (1955) and Raheja (1962) also found that these crops are moderate salt tolerant.

According to Allision (1964) the relative limit of salt tolerance for grapes was 3 to 6 mmhos/cm. Pal (1971) observed that the salt concentrations of 3500 ppm and 4500 ppm resulted into the death of all grapevines. Nauriyal and Gupta (1967) found Anab-e-Shahi grape more susceptible to salt injury than Bangalore Purple and Selection-7. Gupta (1965) also reported Perlette and Khalili grape varieties to be highly susceptible for salt injury and Himrod as medium salt tolerant, while Almwick, Thompson Seedless and Beauty Seedless as comparatively resistant. Pal (1971) reported Bhokri and Gold varieties to be tolerant to salt as compared to Anab - e - Shahi and Gulabi. Pandey and Divate (1976) reported Anab - e - Shahi

as most salt tolerant followed by Pusa Seedless and Beauty seedless. Seeded varieties of grape were more tolerant to soil salinity compared to the seedless ones (Raheja, 1962).

Gupta (1963) concluded that Dasheri mango was more hardy to soil salinity than Langra. Jindal et al. (1975) reported that some of the mango seedlings from heterogenous population showed greater ability to tolerate salinity. Such germplasm if multiplied asexually can be used as rootstock for mango in saline areas. According to Raheja (1962) grafted varieties of mango were more sensitive to soil salinity than ungrafted ones.

Guava plants can survive well under sulphate type of salinity up to 0.525 per cent salt and under chloride and carbonate type of salinity up to 0.35 per cent salt concentration (Desai and Singh, 1980). Makhija et al. (1980) reported that 6 months old guava seedlings could survive well up to 7.5 mmhos/cm ECe, while Patil and Patil (1980) reported that the guava plants can be grown successfully up to 8 mmhos/cm ECe. Transplanted guava seedlings could not survive beyond 9 mmhos/cm ECe (Kaul, 1981). However, he further pointed out that type of salinity was more important in guava, chloride salinization was more injurious than sulphate salinization.

Gupta (1963) reported that Allahabad seedlings of guava were superior to seedless grafted in regard to soil salinity tolerance. Raheja (1962) reported that grafted guava plants were more salinity sensitive than ungrafted ones.

In the greenhouse studies made by Patil (1980) the adverse growth effects of salinity were seen right from ECe of 8 mmhos/cm of saturation extract in guava, pomegranate and custardapple. The salinity tolerance indices (salinity level representing 50 per cent growth depression) were calculated to be 9.70, 9.00 and 9.50 for guava, pomegranate and custardapple, respectively.

Crop with high salinity tolerance

Dahiya (1979) reported that ber seedlings could be grown satisfactory upto 9.75 mmhos/cm. Once established ber plants can successfully be grown up to 21 mmhos/cm ECe (Dhankhar et al., 1978). However, lateron, Dahiya and Dhankhar (1982) reported that the growth of ber seedling was adversely affected beyond 14 mmhos/cm ECe. In the pot culture study with black vertisol, Patil (1980) found 50 per cent growth depression of Umran ber grafts at ECe value of 9.64. According to Oganesjan (1954) Ziziphus jujube and pomegranate were resistant to soil salinity.

In jamun, chiku and fig grown in pots, the adverse growth effects were noticed at 12 mmhos/cm and above by Patil (1980). Thus they were found to have good salinity tolerance. The salinity level (ECe) representing 50 per cent growth depression was 18.80, 17.85 and 15.64 in chiku, fig and jamun, respectively. In the work of Sadaria (1989) the salinity tolerance indices (salinity level mmhos/cm representing 20 per cent growth depression) were calculated to be 13.25, 12.50, 8.00, 7.50, 12.75, 9.75, 15.00 and 16.50 for tamarind, woodapple, mulberry, bael, khirni, eucalyptus, neem and persian lilac, respectively.

The datepalm is reported to have highest salinity tolerance and is included in the range of salt tolerance upto 16 mmhos/cm by Hayward and Bernstein (1958), Hayward (1955), USDA salinity lab staff (1954) and Vanderberg (1950). However, the recent work on fruits in relation to salt tolerance has added a few more fruits in the list of tolerant crops such as ber, guava, aonla and phalsa (Yamdagni, 1983).

2.2.2 Effect of salinity on growth

The injurious effects to the plants may be either due to the total soil salinity (salt stress) or due to the toxic concentrations of individual ions (Ion stress)

like chloride, sodium, sulphate, etc. Even if the chloride and sodium concentrations are not excessive, high concentration of other salts may impair growth of plant and this may be due to total soil salinity.

Salinity retards all growth processes of plants including cell division and cell enlargement (Strogonov, 1962) which results in inhibition of plant growth. The inhibitory effect of salts on plant growth may probably be due to the osmotic effect on plant roots and thus causing low water availability, toxic accumulation of salinity ions (Cl^- and Na^+) in plant tissue and nutritional imbalance due to excess of salinity ions in soil and plant tissues.

Citrus plants have shown various adverse effects due to excess salts. Cooper and Peynado (1959) reported that salt treatments decreased growth in both young and old citrus trees. Patil and Bhambota (1978a and 1980) reported the adverse effects of salinity on the growth i.e. plant height, stem diameter, number of leaves and plant spread of various citrus species right from the conductivity level of 2 mmhos/cm of saturation extract. As the conductivity increased, the adverse effects on different growth parameters were also accentuated. Bhambota and Kanwar (1970) reported that salt concentration more than 100 ppm proved highly detrimental to

the growth of sweet orange. Allison (1964) also reported that ECe values from 1.5 to 3.0 mmhos/cm were safe for the growth of citrus. However, Harding and Chapman (1950) found that citrus could tolerate salinity levels up to 4 mmhos/cm. Joolka (1976) reported reduced growth, leaf number, leaf area and dry weight of roots in citrus with increasing level of soil salinity. Pearson et al. (1985) reported that 10 per cent yield reduction was associated with electrical conductivity of the soil saturation extract ECe of 2.3 dS/m, and 50 per cent reduction for citrus was associated with an ECe of 4.8 dS/m.

Makhija and Jindal (1983) found that seedlings of papaya could not survive beyond 4 mmhos/cm and those at 6 and 8 mmhos/cm died within 7 months from sowing.

Nasir et al. (1977a) while evaluating the effects of salinity on growth of plum and peach found that the growth of the trunk, length of shoot and root, the increase in shoot length and the fresh weight of top, root and total plant were reduced with increasing salinity of the irrigation water. They further pointed out that plum is more tolerant than peach.

Krylotov (1962) observed decrease in growth of grapes when total salt concentration was more than 0.3 per cent. Nauriyal and Gupta (1967) found that the growth of vines may be adversely affected by the presence of salt up to 0.1 per cent in the soil and serious injury occurred when the salt concentration exceeded 0.3 per cent.

In grapevines, dry weight of roots and shoots was reduced due to chloride, sulphate and carbonate salinization (Nauriyal and Gupta, 1967 and Gupta and Nauriyal, 1973). Joolka et al. (1977) reported that an increased salt concentration, delayed the bud sprouting and also reduced the per cent of sprouting in grapevine. Most of the vines could not survive at 12 and 16 mmhos/cm ECe level. Various growth parameters viz., number of bud sprouted, shoot length, number of leaves, leaf area and dry weight of vines decreased due to high salt concentration in the soil. Similar results were reported by Pandey and Divate (1976) in grapes. Makhija and Jindal (1984) reported that berry set remained unaffected up to 6 mmhos/cm ECe, while at 8 mmhos/cm there was reduction in berry set in grape cv. Perlette. Kishore et al. (1985) studied one year old rooted cuttings of Perlette grapevines, treated with chlorides, sulphates and carbonates of sodium, calcium

magnesium and potassium in the concentration of 0.15, 0.23 and 0.30 per cent each in pot culture experiments and they concluded that the reduced photosynthesis could be the cause of reduced vegetative growth.

Guar (1966), while studying the performance of grape varieties in relation to saline water in arid zone observed that concentration 1000-2000 ppm were initially tolerated but became progressively harmful and concentration of 2000 ppm was detrimental even in the early stage of growth.

Growth of guava seedlings decreased significantly with increasing levels of salinity i.e. above 7.5 mmhos/cm ECe (Makhija et al., 1980). However, Patil and Patil (1980) reported that up to 8 mmhos/cm ECe, there was no appreciable reduction in whole plant fresh and dry weight. Similarly, reduction in various growth parameters at and beyond 9 mmhos/cm ECe were reported by Kaul (1981) in guava plants. Desai and Singh (1980) reported that in guava, growth attributes like plant height, leaf number, leaf area, fresh and dry weight were suppressed by all salinity treatments.

Dahiya and Dhankhar (1982) studied the effects of five levels of salinity on the growth of ber seedlings. Soil salinity at and above 14.2 mmhos/cm ECe, decreased the plant height, stem diameter, leaf area and shoot and root dry matter yield. Once established, ber plants can successfully be grown up to 21 mmhos/cm ECe (Dhankar et al., 1978).

In the experiments conducted by Sadaria (1989) the adverse effects of salinity were seen right from the conductivity level of 8 mmhos/cm of saturation extract in mulberry, bael and eucalyptus, while in tamarind, woodapple, khirni, neem and persian lilac the adverse effects were noticed at and above 16 mmhos/cm.

As the salinity increased, the adverse effects on different growth parameters i.e. plant height, number of leaves, stem diameter, fresh weight of whole plant, fresh and dry weight of top and root, plant spread, root length, root volume and leaf area per plant were also accentuated.

Mortality symptoms in bael, mulberry and eucalyptus were noted from salinity level 8 mmhos/cm, while in tamarind, woodapple, khirni, neem and persian lilac they were noticed from 12 mmhos/cm. Highest mortality symptom was observed in bael and the least in neem.

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Irrigation water containing excessive dissolved salts depresses the growth of fruit plants. The growth rate of young datepalm irrigated with water containing 6000 ppm salt was about 50 per cent to that of untreated control (Furr et al., 1966).

Pomier and Branin (1974) studied the effect of irrigation on coconut with saline water and observed that the saline irrigation increased foliage, however, the stomatal openings were reduced. Nagarajan et al. (1975) observed maximum yield response from saline water with 1:2.5 ratio of sea water : fresh water, however, palm irrigated with sea water did not exhibit salinity injury.

In sapota cultivar Kallipatti, a slight decrease in root and top fresh weight was noted at ECe values 4-12 mmhos/cm with a rapid reduction at 16-20 mmhos/cm ECe level (Patil and Patil, 1983b). The tree growth in mango cultivars langra and dashehari was adversely affected at soil salinity level 10 mmhos/cm (Jindal et al., 1976).

Certain forest species have been found to show greater tolerance to the saline conditions as compared to the agricultural crops.

Raheja (1962) drew a comprehensive list of trees and shrubs together with their growth habit, which were tolerant to saline and drought conditions. Dalbergia sissoo (sisum) was said to be salt-tolerant, more so once the seedlings are established. Among the fuel trees, Tamarix articulata and Butea monosperma (dhak) had high salt-tolerance. Azadirachta indica had only medium to low salt-tolerance capacity and needed to be initially established before it can make good growth. Salvadora persica and Prosopis juliflora were adapted well to the salty dry land of western Rajasthan. Zizyphus spp. and Acacia arabica (babul) had medium salt-tolerance, but Acacia spirocarpa introduced from Israel is highly resistant to salinity. Uppal et al. (1962) included babul, dhak, khejri, khair, neem, lasora, sisum, siris and bahera as those that can be planted on saline-alkali lands. Trees of fuel value do better than those of timber value on salty lands.

Yadav and Singh (1970) in their investigation in Vrijbhumi Forest Division of Uttar Pradesh found that all planted species failed to grow on the soil having soluble salt content above 3.42 per cent in the top soil and above 1.14 per cent in the subsoil. Safe limits for Prosopis juliflora were found to be up to 0.54 per cent soluble salt

with pH up to 9.5, though the species could tolerate soluble salt content up to 1 per cent and pH up to 10. Acacia nilotica could grow satisfactorily on the soils having pH value below 9 and soluble salt content below 0.3 per cent. Azadirachta indica, Dalbergia sissoo and Terminalia arjuna were found to grow on soils which were almost free of salts in the top 60 cm depth, but had pH values up to 9.8 and soluble salts up to 0.45 per cent in the subsoil.

According to Kaushik et al. (1969) Eucalyptus hybrid was able to grow satisfactorily on the soil having pH less than 9 and soluble salts up to 0.3 per cent in Haryana and Punjab. Shaybany and Kashirad (1978) studied Acacia saligna grown in sand culture and irrigated with nutrient solution containing 0, 48, 96, 144, 192 and 240 me/l NaCl, and found that growth of the plants was reduced after 3 months in greenhouse. Salt concentrations of 96 and 144 me/l caused 50 per cent growth reduction.

Tomar and Yadav (1982) reported that the growth of Albizzia lebbeck can be expected to be quite satisfactory on the soil having ECe of about 7.0 mmhos/cm and SAR of about 40. Singh and Yadav (1985) studied the performance of Shisham (Dalbergia sissoo) in pot culture conditions with different salinity levels in an alluvial silty clay

loam soil by addition of different salts and found that D. sissoo failed to grow above ECe 8.1 dS/m. Growth parameters decreased with increase in salinity. Gupta et al. (1986) studied in pot culture, with different levels of salinity in clay, loam and sand textured soils. Based on growth parameters they concluded that Acacia nilotica and E. camaldulensis could be grown with less than 50 per cent growth reduction up to 5 dS/m salinity. Acacia nilotica withstood salinity as high as 15 dS/m. Casuarina equisetifolia was moderate in salt tolerance. Ceiba pentandra was highly sensitive tree species and did not survive beyond 2.5 dS/m.

Sharma (1973) reported that the water having EC, SAR and RSC range from 385 to 1430 mmhos/cm, 0.62 to 5.58 and 1.0 to 5.9 me/l, respectively when used on highly saline sodic soil with very low permeability supported the growth of Dalbergia sissoo, Eucalyptus hybrid and Acacia arabica.

Tomar and Yadav (1977) recorded appreciable decrease in the growth of species with increasing level of salinity in irrigation water. The adverse effect of saline water was more pronounced on Albizzia lebbeck than on Eucalyptus hybrid. Tomar and Yadav (1980) also found that

the water having EC 8-10 mmhos/cm and SAR 30 can be used for Acacia nilotica, Pongamia pinnata and Prosopis juliflora, while water of EC 4-6 mmhos/cm and SAR up to 15 for Acacia tortilis, Albizzia lebbeck, Azadirachta indica, Lawsonia gluca and Parkinsonia aculeata and the water of EC $<$ 2 mmhos/cm could be used for Eucalyptus hybrid.

Ahmad et al. (1985) studied Azadirachta indica (neem) and Melia azedarach (Persian lilac) being grown on coastal sand receiving 10-30 per cent dilutions of saline water (ECiw 4.5 - 14.0 dS/m^{-1}) for irrigation. Plant height and diameter decreased compared to control which received non-saline water. Under saline water irrigation, persian lilac showed more rapid growth than neem.

2.3 Effect of ESP on the chemical composition of tree species

The nature and extent of Na present in the soil affect the chemical composition of plants to a great extent. The plants takes up Na with the water and it is concentrated in the leaves as water gets lost by transpiration. Toxicity can result if Na accumulates to concentration that exceed the tolerance limit of the plants. Leaf burn, scorch and dead tissue along the outside edges of leaves are the typical symptoms.

Bernstein (1968) was of the opinion that concentration in excess of 0.5 per cent Na in the citrus leaves may be regarded as hazardous. Sodium injured leaves will generally have excess of 1 per cent Na on a dry weight basis. However, Bhambota (1965) argued that critical limit of Na under Punjab condition should be above 0.6 per cent in the leaves of sweet orange.

Bernstein and Pearson (1956) noted that ratio of Na in the plant tops to Na in the roots appeared to be a good criterion for estimating resistance to exchangeable sodium. The sodium sensitive plants viz., peach, citrus, avocado, kidney beans had the ratio of less than 1, while the plants having resistance to sodium had the ratios of 2 to 4. These authors also noted that this ratio tended to increase with increasing Na percentage. Martin and Bingham (1954) and Martin et al. (1953) have also reported similar observations.

El Gabaly (1955) and Peterson (1961) also stated that the high Na in the growth medium would depress the growth due among other things to (a) Na^+ toxicities because of the increased concentration of Na^+ in plants, (b) induced K^+ deficiency as a result of increase in Na^+ uptake, (c) inadequate supply of Ca^{++} and Mg^{++} (d) imbalance

among nutrients. In the plants having high Na resistance, a large part of Na^{+} absorbed by their roots is retained and accumulated in the vacuoles of root-cells. Thorne (1944) reported instances of very low availability of Ca^{++} and Mg^{++} in the alkali soil. Calcium starvation was one of the most important features in the alkali soils thereby leading injury to the plants. Many times, harmful effects of Na are correlated with the lack of Ca^{++} in soil solution (Lilleland, 1946 and Hass, 1950). Jones et al. (1957) also reported similar results in young lemon plants budded on different rootstocks. Under the influence of higher amounts of exchangeable Na, they observed total concentration of cations decreased in leaves than in tap roots. Page and Martin (1964) studied the effects of graded levels of exchangeable Na in K deficient soils on citrus and observed that increased Na levels in the soil resulted in accumulating Na in the roots with its least translocation to the tops. They further concluded that Na addition was not capable of increasing the availability of K to citrus seedlings grown under K deficient soils. Martin et al. (1959a) investigated the effects of different ESP levels (from 1 to 15 per cent) on the composition of trifoliate orange seedlings. As the ESP was increased they found

decreased absorption of Ca and slightly increased absorption of K. Decreased absorption of Mn under high ESP was also observed. In sodic non-saline soils the decrease in exchangeable Ca + Mg may cause Ca and Mg deficiency (Bernstein, 1974). Wahid et al. (1974) studied the inter-relationship among root CEC, yield and cations in coconut and observed a significant correlation between K : Na, K : (Ca + Mg) and K : Mg ratios in the soil and leaves. Oseni (1985) also observed significant differences in root CEC and root weight of tree citrus seedlings.

Plants which can absorb sufficient calcium or have low calcium requirement are expected to have greater tolerance to exchangeable sodium (Pearson and Bernstein, 1958). Exchangeable sodium generally caused an increase in the absorption of sodium, nitrogen and molybdenum and decrease in the absorption of calcium, potassium, phosphorus, sulphur, manganese, copper, zinc, boron and chloride (Bains and Fireman, 1964).

Jindal et al. (1976) and Joolka (1976) observed decrease in potassium content of mango and citrus, respectively with increasing sodium content in the foliage. In mango root-stocks, sodicity caused an increase in the content of nitrogen and sodium in the leaves, whereas

phosphorus, potassium, calcium and magnesium content decreased with increasing ESP levels (Thakur et al., 1982). Under increased ESP conditions, Patil (1976) reported that Kharna Khatta and Cleopatra were adversely affected in respect of nutrition of N, P, Ca, Mg, Zn, Mn and Cu, while Jatti Khatti, Jullunduri Khatti and Carrizo were relatively less affected. A general decrease in P, K, Ca, Mg, Zn and Mn due to high ESP was recorded by Patil (1980) in leaves and roots of guava, custardapple, pomegranate, ber, jamun, chiku and fig. The Cu content of leaves did not differ significantly except in leaves of ber. A general increase in Na in leaves and roots due to ESP was evident in all crops. Sadaria (1989) found that with the increase in ESP, sodium content and mortality of different species were also increased. The highest mortality was recorded in bael followed by mulberry and eucalyptus at ESP 50. Further, he also reported that the N content in leaves of bael, khirni and neem increased with the increase in ESP up to certain level, but it was not consistent. The same, however decreased at highest ESP level. In tamarind and eucalyptus, N content increased consistently with the increase in ESP, while there was no effect in woodapple, mulberry and persian lilac. Root N of all species except persian lilac decreased with the increase in ESP.

The P content in leaves and roots of all species decreased with the increase in ESP except root-P in woodapple.

In general, decrease in K, Ca and Mg content in leaves and roots due to high ESP was recorded in all plant species. Under increasing ESP the Ca : Na and Ca + Mg + K : Na ratio of leaves and roots decreased in all species. It was the lowest in the leaves of bael followed by mulberry at ESP 50.

Increasing levels of ESP significantly decreased Zn, Fe and Mn contents in leaves and roots of all species. The Ca content in leaves significantly decreased with the increase in ESP in all species except tamarind. Root-Cu also decreased with the increase in ESP in all species except woodapple.

Tewari (1983) and Pandey et al. (1985) observed that nitrogen, phosphorus, potassium, calcium and magnesium content in the foliage of aonla and bael, respectively decreased, whereas sodium increased with the increasing sodicity. Singh et al. (1983) also reported that rise in soil ESP increased plant Na and Fe, and decreased Ca and Mn in both jujube and guava and decreased K and P in guava only, while Zn and Cu contents were unaffected in both species.

Singh and Yadav (1985) studied the performance of Shisham in pot culture and concluded that uptake of Na^+ and Mg^+ by plant increased progressively with increase in ESP levels, while the uptake of Ca^{++} decreased and K^+ did not exhibit any definite relationship with increase in ESP. The values of Na:k, Na:Ca and Na:Mg ratios in plants increased with increase in ESP.

Leon and George (1956) in the studies of influence of exchangeable sodium on green beans, garden beets, clover and alfalfa plant and reported that with the exception of beans total sulphur and nitrogen showed consistent trends or large variations in relation to ESP levels, whereas in beans both sulphur and nitrogen increased consistently and markedly with increase in ESP. Bains and Fireman (1964) in studies of effect of ESP on five crop plants reported that there was only increased sulphur content in safflower and tomato and not in corn, sorghum and Ryegrass with increase in ESP.

2.4 Effect of ESP on Physiological Parameters

2.4.1 Chlorophyll

Leaf chlorophyll content decreased with the increase in soil exchangeable sodium in citrus rootstocks (Patil, 1976; Patil and Bhambota, 1978c; Kadam, 1984).

They attributed the decrease in chlorophyll content to the reduction in the uptake of essential nutrient elements like Mg, Ca, N and Fe. There was also the decrease in chlorophyll content of leaves in pomegranate (Patil and Patil, 1982), in ber (Patil et al., 1981; Pandey, 1984), in bael (Pandey et al., 1985; Tewari, 1985) and in rose rootstocks (Singh and Chitkara, 1984) with increasing ESP in soil.

Gill (1987) studied the effect of soil alkalinity on growth, yield and some biochemical parameters in cowpea and dhaincha. He noticed that the chlorophyll content decreased significantly with increased sodium in various parts of the cowpea plants, effects being more pronounced on pods and leaves on branches rather than leaves on main stem. In dencha, chlorophyll content increased in leaves as well as in pod.

The total chlorophyll content in leaves of all species decreased with the increase in soil ESP. In general, plant species showing more tolerance indices had greater chlorophyll content in leaves (Sadaria, 1989).

2.5 Effect of salinity on the chemical composition of tree species

Pearson et al. (1957) after using saline water (original salt concentration of NaCl and $CaCl_2$ 200 ppm) found a direct relationship between the conductivity of saturation extract and the concentration of sodium and chloride in the leaves of young grapefruit trees. Sodium accumulation in the wood, bark, branches and twigs was lower than in the roots. In all these fractions, the accumulation of salinity in irrigation water caused a decrease in the concentration of Ca, Mg and K in leaves. P concentrations in plant tissue were unaffected by the either salinity. In general, Mg in all fractions was inversely related to salinity. The accumulation of K in the fine roots was directly related to the salinity status of the soil.

The excess of Cl in the orange leaves produced leaf bronzing. Injured leaves usually contained more than 1.10 per cent Cl on a dry weight basis and concentrations in excess of 0.5 per cent were regarded as hazardous (Bernstein, 1965).

Bhambota (1965) investigated the effects of salinity levels on sweet orange budded on rough lemon and reported that the potassium content in the leaves were markedly depressed by higher ECe levels of 4 and 6 mmhos/cm. However, Ca showed the opposite trend. The Cu and B contents were depressed whereas Zn and Fe status were increased by the high levels of salinity. Joolka and Singh (1977) studied the effects of soil salinity on the mineral composition of citrus rootstocks and found that N, P, K, Ca, Mg, Zn contents in the leaves decreased whereas Na, Cl and S contents increased under all salinity levels. The rootstocks also differed with regard to their chemical composition.

Patil and Bhambota (1978a and 1980) undertook greenhouse studies and reported that N and P content in citrus rootstocks namely kharna khatta and Carrizo citrange decreased at higher soil salinity levels. A general, decrease of K and Ca in the leaves of all rootstocks was also observed. Mg in leaves and roots of Kharna Khatta was reduced and leaf-Na increased at higher salinity in all rootstocks. Under higher salinity Na/Ca + Mg in leaves and roots was low and this ratio was high in Carrizo and Kharna Khatta. Among micronutrients, upta^ke of Zn was particularly reduced under high salinity (Patil and Bhambota, 1978b). Abdel-Messih et al. (1979) added salt

($NaCl + CaCl_2$) up to 6000 mg/g to irrigation water and grew different citrus rootstock seedlings. The Na, Ca and to a lesser extent the K levels increased in leaves of all rootstocks. Leaf Mg, N and Fe fell and P was unaffected. Individual cation contents varied between rootstocks regardless of treatment, Na and Ca were high in sour orange. N contents varied little.

Studies were made by Hernansaez et al. (1979) on 12 year old trees of Verna lemon on sour orange rootstocks in saline soil. The ratio Na + K + Ca + Mg/N + P decreased in the roots and rose in the leaves, in the first 24 to 90 days, respectively. The ratios Fe + Mn/N and Fe + Mn/P also increased in the leaves but reached a peak in the roots in about 12-16 days and then declined. Khelil (1979) observed Clementine on Troyer citrange, sour orange and Poncirus trifoliata in complete nutrient solution with added NaCl at 2 g/l. Toxicity symptoms appeared after 3 months which was most marked on citrange rootstock and least on sour orange. After 3 months, salt treatments had increased leaf Cl and Na and reduced K, Ca, Mg, Fe and P.

Petrosjan et al. (1977) studied the effect of excessive soil salinity on nitrogen metabolism in apple leaves and found that total nitrogen increased whereas non-protein N decreased with increasing levels of salinity. Ivanov (1971) found that in apple leaves, nitrogen, potassium, sodium, iron and manganese contents increased but calcium and magnesium were not affected. Whereas in apricot leaves, potassium, calcium and iron increased and phosphorus decreased (Ivanova, 1971). Further, Ivanov and Ivanova (1976) reported that in peach, apricot, sweet cherry and pear tree, leaf-N, Fe and Na contents increased and P, K and S decreased with increasing salinity. In plum and apricot, salinity caused a disruption in nutrient translocation between roots and aerial parts and resulted in metabolic imbalances (Morozovskii and Kandina, 1974).

Naor et al. (1977b) reported that Cl content in the leaves and roots of plum and in the leaves of peach increased with salinity, whereas Cl in peach roots was not affected. Sodium content increased with salinity in plum, whereas in peach it was not affected. The effect of salinity on Ca content was not consistent in plum and peaches. Potassium content in the leaves of plum and peaches decreased with salinity, whereas in the roots

it was not affected. Leaf-P in plum and Balady peach decreased with salinity, while in Mit Ghamre peach it was not consistently affected.

Investigation done by USDA salinity lab staff (1954) showed that the leaf burn was associated with 0.6, 0.6, 0.5 to 0.9, 0.5 to 1.2, 1.0, 1.0 to 1.5 and 2.0 per cent Cl in the leaves of plum, pecan, avocado, grape, peaches, grapefruit and Valencia orange, respectively.

Ehlig (1960) reported that the per cent of Cl was 0.04 in grape healthy leaves and reached 1.5 per cent in the leaves of deteriorated vines and 1.69 per cent in case of dead vines. He also observed marginal leaf burn of vines grown under controlled large sand beds when the Cl content in leaves ranged from 1.93 to 2.27 per cent. Black Rose and Cardinal were much more sensitive to chloride than Perlette and Thompson Seedless, because they accumulated Cl two to three times faster. In the experiments consisting of various salinity treatments Divate and Pandey (1981) found that salinity treatments increased N, P, Na and Cl and decreased, K, Mg (except for Mg salt) and Ca (except for Ca salt) in the leaves of all three

grape varieties tried. The chloride type of salinity caused an increase in Ca and decrease in P content of grapes (Joolka et al., 1977).

Desai and Singh (1979) reported the effect of salinity on the nutritional imbalance in guava leaves and they found that various salinity treatments increased N, Na and Cl content in leaves and decreased K, P, Ca, Mg and S (except salts containing sulphate ions) content. The increase or decrease was proportional to the concentration of salt studied. Salinity caused a significant increase in Cl, Na, Ca and Mg content in guava foliage and decreased N and K above 7.5 mmhos/cm ECe (Makhija et al., 1980). Similar results were also obtained by Dhankhar et al. (1981) in guava and phalsa. Patil et al. (1984) also reported that in guava leaf-N increased with increasing salinity levels but root-N decreased, whereas leaf and root P, K, Ca, Mg, Zn, Fe, Mn and Cu contents decreased with higher salinity levels.

Salinity caused a considerable increase in the contents of Na, Ca, Mg, and Cl in ber leaves whereas K and B decreased with increasing levels of salinity (Dhankhar and Dahiya, 1980; Dahiya and Dhankhar, 1982).

Patil (1980) recorded lower contents of K, Ca and Mg in the leaves of seven fruit crops with increase in soil salinity. Increase in Na due to higher salinity was observed in all crops. Under high salinity the zinc and iron content of leaves decreased in guava, pomegranate, custardapple, ber, jamun and fig but not in chiku. The copper content of leaves and roots of guava and pomegranate decreased at high levels of salinity, while in other fruit-crops there was no decrease. Doring and Dudders (1986) studied rooted pomegranate cutting (cv. Mytelinis) in sand culture for 3 months with different salts (NaCl, Na_2SO_4, $CaCl_2$, $MgCl_2$ or $MgSO_4$) at different concentrations (40, 60 or 80 meg/l). With all rates, Na was concentrated mainly in the root tissue, whereas the higher application rates of Ca and Mg resulted in high concentrations of these minerals in leaf rather than root.

Jindal et al. (1979) reported that all the concentrations of salts (2-10 mmhos/cm) reduced N, P, K and Mg levels in the leaves of mango seedlings as compared to control. P and Mg deficiencies were caused to a greater extent by Na_2SO_4 than by other salts. The seedlings absorbed the constituent ions of salinity (Na^+, Cl^- and SO_4^-) in toxic amounts. The accumulation of these ions increased with an increase in concentration of salt in the substrate

Singh and Yadav (1985) studied the performance of shisham in pot culture and concluded that uptake of Na^{+} and Mg^{+} by plant increased progressively with increase in salinity levels, while the uptake of Ca^{++} decreased and K^{+} did not exhibit any definite relationship with increase in salinity. The values of Na/K, Na/Ca and Na/Mg ratios in plants increased with increase in salinity. Under saline conditions decrease in sugar and protein content was associated with an increase in proline in the foliage of neem and persian lilac (Ahmad et al., 1985).

In the experiments conducted by Sadaria (1989) the nitrogen content in leaves increased up to certain level with the increase in salinity levels in tamarind, mulberry, khirni and persian lilac but it was not consistent. It again decreased at highest salinity level (i.e. at 20 mmhos/cm). In bael, eucalyptus and neem the N content consistently increased with successive increase in salinity levels. Varying salinity levels had no effect on the N content in the leaves of woodapple. Root-N gradually decreased with the increasing salinity levels in all species. The P content in the leaves of tamarind, mulberry, bael, khirni and persian lilac decreased significantly with the increase in salinity. Root-P in all species except khirni also decreased due to high salinity level. The K content

in the leaves and roots depleted with the increase in salinity level in all species except tamarind roots. The leaf and root-Ca decreased with the increase in salinity level in all species. A decline in Mg content in leaves and roots with successive increase in salinity level in all species except eucalyptus leaves was recorded. Increase in sodium content in the leaves and roots due to higher salinity was observed in all species except woodapple. The Zn content in the leaves and roots of all species except in leaves of khirni decreased with the increase in salinity level. Successive increase in salinity level the leaf and root-Fe in all species. The Mn and Cu contents in the leaves and roots decreased with the increase in salinity level in all species.

The studies of Desai and Singh (1979) on the nutritional imbalance in guava indicated that various salinity treatments increased nitrogen, sodium and chloride in leaves and decreased potassium, phosphorus, calcium, magnesium and sulphate (except the salts containing sulphate anions) content.

Gupta and Nauriyal (1973) studied salt tolerance in grape. They found that in comparison to control, the chloride and sulphate content of leaves in

all the treatments viz., high level of chloride, sulphate and carbonate, were abnormally high. The accumulation of chloride in high chloride treatments and of sulphate in high sulphate treatments was nearly 100 and 400 times respectively that of control.

Joolka et al. (1977) also reported the mineral composition of grape as affected by chloride and sulphate salts of sodium in soils. They found that the Cl and SO_4 salts influenced the uptake of Ca, and P differently so that the Ca content was high and the P content was low in Cl salinity and the Ca content was low and P content was high in SO_4 salinity. The uptake behaviour of other elements did not seem to vary much with the type of salinity. The varieties differed in their performance to a certain type of ion. Thompson seedless variety of grape contained more SO_4 than rest of the varieties at the same level of salinity. In the studies of salinity on mineral nutrients in mango seedlings reported by Jindal et al. (1979) it was seen that the Na, Cl and SO_4 accumulations in toxic amounts in the leaves of young seedlings as a consequence of high salt concentration. But the accumulation of Cl was consistent with the concentration of NaCl and that of SO_4 with the concentration of Na_2SO_4. Robinson and Smith (1970) observed that sulphate accumulation under NaCl treatments

and Cl accumulation under Na_2SO_4 treatments were almost on par with the accumulation in the control. But SO_4 was in toxic amount in seedlings treated even with the mixture that contained very low amount of Na_2SO_4.

David et al (1958) noticed that the chloride content in cherry leaves and grape petiole was directly proportional to supply and when the chloride level was supplied with medium level, the chloride level in leaves of apple and peach was more, whereas increasing the sulphate level apparently reduced chloride absorption for all crops. It was also reported by them that sulphur content in all plants increased with supply in the absence of chloride, whereas high chloride levels depressed sulphate absorption with all crops.

Walter and Ballinger (1962) found that an increase in sulphate and decrease in chloride content of leaves was generally accompanied by a decrease in Ca and an increase in P content.

2.6 Effect of salinity on physiological parameters

2.6.1 Chlorophyll

The specific ions of salts contribute a lot in changing the pigment concentration of plants. Bleaching of chlorophyll is more severe in sensitive plants whereas the tolerant crops have a mechanism to retard chlorophyll degradation (Gupta, 1977).

A decreasing trend of chlorophyll content has been reported with increasing salinity by Bhambota and Kanwar (1970) in the leaves of Malta Blood Red grafted on rough lemon. Further Joolka (1976) and Patil (1976) reported decreased levels of chlorophyll in leaves of citrus rootstocks under the increasing salinity treatments. The loss of dark green colour of grape leaves was reported to be due to excess of carbonate (Gupta and Nauriyal, 1973). Divate and Pandey (1981) reported proportional decrease in chlorophyll content with higher salt concentration in grape cultivars. Higher reduction in chlorophyll content was also observed in guava leaves under sulphate type of salinity as compared to chloride type of salinity (Kaul, 1981). Divate and Pandey (1981) studied the effect of salt tolerance of chemical composition of three grape cultivars. They observed that the chlorophyll content and the rate of photosynthesis decreased with the increased salt concentrations. However, the rate of respiration was stimulated by various salinity treatments. Patil (1980) also recorded lower chlorophyll content in leaves as soil salinity increased in all the seven fruit crops studied.

Sadaria (1989) reported that the total chlorophyll content in the leaves decreased with the increase in salinity levels in all species except woodapple.

2.6.2 Stomatal behaviour

There is limited experimental evidence to show the effects of different levels of salinity on stomatal structure in halophytes. However, according to Waisel (1972) it was clear that frequency of stomata in different species has no relation to the plant habit. Joshi (1976) observed that mangroves which also grow in saline habitats show markedly higher number of stomata. Joshi *et al.* (1980) studied the effect of salinity on structure and frequency of stomata in salt marsh halophytes. They found that the halophytes viz., *Salicornia brachiata* and *Suaeda nudiflora* exhibited reduction in number of stomata per unit area, suggesting that higher salinity does not alter structure but reduces their number.

The stomatal behaviour was also studied by Joshi and Rao (1986) in halophytes from the mediterranean coast. They reported that succulent halophytes have lower stomatal index than the non-succulent species. Similarly they reported different types of stomata.

In groundnut the influence of salinity on stomatal behaviour was studied by Sarada Devi and Rao (1980). They observed that NaCl salinity treatment caused alterations in the stomatal characteristics and behaviour. The salinity treatment also resulted in changes of per cent distribution of stomatal type, its frequency and index. A common effect of salinity is said to be the decrease in the number of stomata (Strogonov, 1964; Waisel, 1972). Similarly Strogonov (1964) reported the inhibition of cell division but not cell expansion with the sodium chloride salinity.

2.6.3 Rate of transpiration

The upset in water balance and other metabolic variations caused by salinity are very often accompanied by structural adaptations (Waisel, 1972). The decreased rate of transpiration and other related processes under saline conditions may be partly due to the structural and physiological modifications of stomata (Strogonov, 1962; Gale and Poljakoff, 1975). Sarada Devi and Rao (1980) in the studies on stomatal behaviour observed that the stomatal rhythm was altered, pore width having remained maximum during early hours of the day as against later hours in the

control plants. They attributed such alterations of rhythm as a measure of physiological adaptability to saline environment meant for the reduction in the transpiration rates. Similarly during 1978 these authors reported the same type of shift in rhythm in their studies in safflower grown under saline conditions.

Chapter 3

MATERIALS AND METHODS

The present investigations were carried out to study the effect of different levels of exchangeable sodium percentage and salinity levels in soil on the growth, physiological parameter and chemical composition of eight fruit crops during 1987 and 1988 in the Department of Horticulture, Central Nursery Scheme, Marathwada Agricultural University, Parbhani.

Separate experiments were laid out for each fruit crops to study--

i) the effect of different levels of exchangeable sodium percentage (ESP) in the soil

ii) the effect of different levels of salinity in soil.

3.1 Soil used

Pot culture experiments were conducted using medium black soil classified as inceptisol (Malewar, 1976). The soil was passed through 2 mm sieve. The physico-chemical properties of soil are given in Table 1.

Table 1: Physico- chemical properties of the soil used

Particulars		Results of analysis (normal soil)
A) Mechanical composition		
Coarse sand	(Per cent)	9.4
Fine sand	(Per cent)	15.5
Silt	(Per cent)	28.6
Clay	(Per cent)	46.5
Textural class		Clayey
Saturation percentage		55.00
B) Chemical composition		
Organic carbon	(Per cent)	0.562
Total nitrogen	(Per cent)	0.058
Available phosphorus	(kg/ha)	22.80
Available potassium	(kg/ha)	308.0
pH (1:25 soil water suspension)		8.00
EC (1:25 mmhos/cm at 25°C)		0.40
ECe (mmhos/cm at 25°C)		1.20
Exchangeable sodium (per cent)		3.82
Cation exchange capacity (me/100g)		40.60

3.2 Exchangeable sodium per centage

The soil was treated with the solution of sodium bicarbonate ($NaHCO_3$) for building five levels of ESP namely, 12, 24, 36, 48 and 60 by following the procedure described

by Bains and Fireman (1964). The characteristics of the soil after $NaHCO_3$ treatment were as given in Table 2.

Table 2: Characteristics of the soil after sodium bicarbonate treatment

ESP		pH 1:2 soil water suspension	ECe mmhos/cm at 25°C
Desired	Obtained		
12	12.10	8.70	0.80
24	23.70	8.85	1.50
36	35.60	9.36	1.65
48	46.50	9.65	1.75
60	59.00	9.86	1.90

In addition to the six artificially created ESP levels, additional treatment of natural problematic soil was included. A representative sodic soil from the Purna Command area comprising, Aral, Pimpalgaon and Limbgaon villages formed additional treatment. The physio-chemical characteristics of this soil are given in Table 3.

Table 3: Physico-chemical properties of the soil used

Particulars		Results of analysis of problematic soil (Saline sodic soil)
A) Mechanical composition		
Coarse sand	(per cent)	7.5
Fine sand	(per cent)	16.8
Silt	(per cent)	25.7
Clay	(per cent)	50.0
Textural class		Clayey
Saturation percentage		45.00
B) Chemical composition		
Organic carbon (per cent)		0.410
Total nitrogen (per cent)		0.035
Available phosphorus (kg/ha)		24.70
Available potassium (kg/ha)		334.0
pH (1:25 soil water suspension)		8.70
EC (1:25 mmhos/cm at 25°C)		1.20
ECe (mmhos/cm at 25°C)		4.70
Exchangeable sodium (per cent)		41.40
Cation exchange capacity (me/100g)		46.00

The earthen pots (40 cm height with 35 cm upper diameter) of 12 kg soil capacity were used for experimentation of all fruit crops except coconut. A big size cement pots of 30 kg capacity were used for coconut seedlings. Ten and twentyfive kg of sodic soil, already prepared under each treatment was filled in the 12 and 30 kg capacity pots, respectively. The soil was pressed firmly. Two litres of water was added to each pot to settle down the soil. Uniform four months old saplings of following eight fruit crops were planted, one in each pot on 15-9-1987.

Name	Botanical Name	Pedigree
Cashew	(Anacardium occidentale L.)	Local selection from Goa.
Coconut	(Cocos nucifera Linn.)	TxD hybrid, P.C.R.S., Mahuva, Gujarat.
Markingnut	(Semecarpus anacardium L.)	Selection from Nanded District (M.A.U.)
Soapnut	(Sapindus trifoliatus L.)	Social Forestry, Parbhani.
Phalsa	(Grewia asiatica L.)	G.A.U., Navsari.
Karonda	(Carissa corandus L.)	M.A.U., Parbhani.
Passion fruit	(Passiflora edulis Sims)	Agril.College, Poona.
Drumstick	(Moringa oleifera Lamk)	Agril.College, Poona.

Out of the eight plant species, drumstick and passion fruits were rooted cuttings and remaining six were seedlings.

The trial was laid out in completely randomized design. One plant in one pot was constituted a plant unit, like this each plant was repeated three times making three replications for each fruit crop.

3.3 Salinity levels

The same medium black soil from normal field which was used for the studies of ESP was used. The cement pots of 50 litres capacity (height 45 cm and diameter of upper face 40 cm) were used for the coconut seedlings. Earthen pots of same size were used for remaining fruit crops. Each pot was provided with a false bottom having 5 cm layer of gravel to facilitate drainage. The inner side and bottom of each pot were covered over with a polythene sheet (300 guage) in order to avoid the loss of soluble salts and also to check root growth outside the pots. Ten kg soil was filled in the pots of 12 kg soil capacity for cashew nut, marking nut, soapnut, phalsa, passion fruit, karonda and drumsticks wereas in coconut 25 kg soil was used.

3.3.1 Treatments

Salt concentrations @ 40, 80, 120, 160 and 200 ml/l of saturation extract were considered to raise the

conductivity to 4, 8, 12, 16 and 20 mmhos/cm, respectively (U.S. Salinity Staff, 1954), which formed the five levels of salinity.

The relative proportion of various ions and amount of salts used to achieve the desired salinity levels are given in Tables 4 and 5, respectively.

Table 4: Relative proportion of various ions (me/l) under different salinity treatments

Electrical conductivity of saturation extracts (mmhos/cm)	Na^+	Ca^{++}	Mg^{++}	Cl^-	SO_4^{--}	HCO_3^-
4 mmhos/cm	16	12	12	31	7	2
8 mmhos/cm	32	24	24	62	14	4
12 mmhos/cm	48	36	36	93	21	6
16 mmhos/cm	64	48	48	124	28	8
20 mmhos/cm	80	60	60	155	35	10

The above proportion of cations and anions used in the experiment represented roughly the soil profile characteristics of the salt affected area in the Purna command.

Table 5 : Relative proportion of salts (me/l) under different salinity treatments

Conductivity mmhos/cm	Salts				
	NaCl	$NaHCO_3$	Na_2SO_4	$CaCl_2$	$MgCl_2$
4 mmhos/cm	7	2	7	12	12
8 mmhos/cm	14	4	14	24	24
12 mmhos/cm	21	6	21	36	36
16 mmhos/cm	28	8	28	48	48
20 mmhos/cm	35	10	35	60	60

Weighed amounts of above salts were dissolved in enough quantity of water so as to bring the soil in the pots to saturation point.

A representative saline soil of Purna Command area comprising Aral, Pimpalgaon and Limbgaon villages formed additional salinity treatment. The physico-chemical characteristics of such soil are presented in Table 6.

The pots were then ready to receive the experimental plants. Four months old uniform samplings of eight fruit crops as mentioned in the ESP studies were planted on 25-9-1987. These experiments were also laid out in completely randomized design. Plant unit was one and there were three replications.

Table 6 : Physico-chemical properties of the soil used

Particulars		Results of analysis of problematic soil (Highly saline soil)
A) Mechanical composition		
Coarse sand	(Per cent)	8.5
Fine sand	(Per cent)	14.7
Silt	(Per cent)	38.7
Clay	(Per cent)	48.1
Taxtural class		Clayey
Saturation percentage		53.00
B) Chemical composition		
Organic carbon	(Per cent)	0.558
Total nitrogen	(Per cent)	0.047
Available phosphorus	(kg/ha)	20.70
Available potassium	(kg/ha)	325.0
pH (1:25 soil water suspension)		8.30
ECe (mmhos/cm at 25°C)		13.62
Exchangeable sodium	(Per cent)	24.56
Cation exchange capacity	(me/100g)	42.50

3.4 Irrigation and other cultural operations

The pots were kept in greenhouse and were protected from rains. The passion fruit plants were supported with bamboo stick. Well water was used for irrigating the pots as and when required. Pots containing saline soil were irrigated carefully each time so as to avoid leaching and obtain uniform distribution of salts. The well water used had the following composition (Table 7).

Table 7: The chemical analysis of well water

Particulars	Results of analysis
CO_3^{--}	0.20 me/l
HCO_3^{-}	2.43 me/l
Cl^{-}	0.55 me/l
Ca^{++} Plus Mg^{++}	6.10 me/l
Na^{+}	0.62 me/l
Electrical conductivity	0.53 mmhos/cm at 25°C

The soil in the pots was raked as and when required. The nitrogen in the form of urea (2% spray) was applied three times at an interval of 20 days after planting for each fruit crop.

As and when required, the cultural practices were undertaken. The plants were protected from insect pests and diseases by adopting appropriate control measures.

3.5 Observations recorded

The observations on growth parameters in the following way were undertaken.

3.5.1 Plant height

The height of individual plant was measured in cm in last week at every month and the per cent increase over the initial reading was calculated.

3.5.2 Number of leaves

The total leaves were counted on each plant at an interval of one month and the per cent increase over the initial reading was calculated.

3.5.3 Stem diameter

Stem diameter of the plant was measured in mm at 10 cm above ground level uniformly in all fruit crops at an interval of one month with the help of vernier caliper. The per cent increase over the initial readings was work out.

3.5.4 Plant spread

Maximum plant spread both in east-west and north-south directions was noted. The mean was taken as the plant spread.

3.5.5 Number of primary branches

The total number of primary branches were counted on each plant of fruit crop like phalsa and karonda at an interval of one month.

3.6 Leaf area

For calculation of leaf area representative leaves were taken from each plant in each treatment. This was repeated for every fruit crop. The number of leaves taken from each fruit crop are given in Table 8.

Table 8: Number of leaves taken from each fruit crop for leaf area

S.No.	Name of species	Number of leaves
1	Cashew	21
2	Coconut	3
3	Markingnut	21
4	Soapnut	12
5	Phalsa	21
6	Karonda	60
7	Passion fruit	15
8	Drumstick	15

The area of the leaves, was measured on automatic leaf area meter. The average leaf area and total leaf area per plant was calculated.

3.7 Mortality

The adverse effect of exchangeable sodium percentage and salinity in soil was evident from the various types of symptoms on the plants. The following key was used to assess the extent of mortality (Table 9). The per cent mortality was transformed into arcsine values as per Fisher and Yates (1963).

Table 9 : Key used to count the extent of mortality

Sr.No.	Symptoms	Per cent mortality
1	Leaf burning from margin	25
2	Severe defoliation and drying of shoot tip	50
3	Drying back from main stem	75
4	Complete death of plant	100

3.8 Fresh and dry weight of plant

In the first week of November 1988, plants were uprooted, taking due care to avoid damage to the root system. The roots were cleaned by washing with water

and immediately fresh weight of the whole plant was recorded. The root portion of the plants was cut at the root collar and fresh weight of root and top was separately recorded. Dry weight of the root and top was also recorded after drying the samples to a constant weight in an electric oven at 60°C temperature. In case of coconut, the fruit was cut down and the roots were separated and recorded fresh and dry weight. Similarly the top fresh and dry weight was recorded.

3.9 Root study

3.9.1 Root length

Maximum length of root of each plant was recorded in cm.

3.9.2 Root volume

Root volume was measured by liquid displacement method in ml with the help of measuring cylinder.

3.9.3 Root diameter

Root diameter of the drumstick plant was measured in mm at the middle point of the root, with the help of Vernier caliper.

3.9.4 Number of primary and secondary roots

At the end of experimentation the plant was uprooted and thoroughly washed with tap water. The total number of primary roots were counted. On each primary root, the total number of secondary roots were also counted with the help of magnifying lens.

3.9.5 Number of total roots

The total number of roots were counted and recorded.

3.10 Physiological studies

3.10.1 Chlorophyll estimation

Chlorophyll was estimated by the method suggested by Singh (1977).

3.10.2 Rate of transpiration

The rate of transpiration was measured when the toxicity symptoms of ESP and ECe levels were observed on the leaves. The rate of transpiration was measured by using Cobalt chloride method (Amersingh, 1977). The cobalt chloride paper was fixed on the respective leaves at 7.00 hours in the morning. The colour change observed and time in seconds was noted and finally the rate of transpiration was estimated by the formula g H_2O/Sq.cm/hr for each crop under study.

3.10.3 Stomata count

The leaves used for transpiration studies were utilized for estimating the stomata number. Two methods were followed. In fruit crops like markingnut, karonda, passion fruit and drumstick, a small peice of epidermis of the lower leaf surface was peeled off and the number of stomata was counted [illegible] per unit area using simple microscope (40 X). In fruit crops like Cashew, coconut, soapnut and phalsa, the fevicol was spread on the lower surface of the leaves and the print of lower surface formed by the film of fevicol was separated and stomata number was counted as mentioned above (Amersingh, 1977). The specific leaf selected from the top for measuring rate of trnaspiration and counting stomata number in each fruit crop was mentioned in Table 10.

Table 10 : Position of leaf selected from the top of each fruit crop

Sr.No.	Name of fruit crops	Leaf position
1	Cashew	4th
2	Coconut	3rd
3	Markingnut	3rd
4	Soapnut	4th
5	Phalsa	5th
6	Karonda	25th
7	Passion fruit	20th
8	Drumstick	10th

3.11 Collection of the samples for chemical analysis

At the time of termination (end of September, 1988) of experiments in ESP and salinity on each fruit crop for detail chemical analysis the leaves, stem and root samples were used. The fresh leaves from each plant were collected. The sheded leaves from each plant were also collected and preserved for chemical analysis. The above ground stem portion of each plant was cut down into small pieces. The underground portion including root system of each plant was takenout for this purpose. The leaves, stem and roots were washed thoroughly first with tap water, then with 0.1 N HCl and finally with distilled water. The leaves, roots and stem were dried in an electric oven at 60°C temperature till the constant weight. Then they were grinded separately and a representative sample from leaves, roots and stem was taken for chemical analysis.

3.12 Chemical analysis

In order to carry out chemical analysis of the leaves, roots and stem known quantities of the samples were digested as per the method described by Piper (1950). The acid extracts were used for determination of P, K, Ca, Mg, S, Na, Zn, Fe, Mn and Cu. Nitrogen was estimated by

micro-Kjeldehl's method as described in A.O.A.C. (1970). The methods followed for the analysis were as given below :

Macronutrient Analysed	Method used
Nitrogen	Micro-Kjeldahl's method (A.O.A.C., 1970)
Phosphorus	Vanadomolybdo phosphoric yellow colour method (Jackson, 1967).
Calcium and Magnesium	Versenate titration method (Cheng and Bray, 1951)
Sodium and Potassium	Flame photometer (Jackson, 1967)
Sulphur	Chaudhury and Cornfield (1966)
Micronutrients Analysed	
Zinc, Iron, Manganese and Copper	Automic absorption Spectrophotometer (Bradfield and Spencer, 1965)

3.13 Statistical analysis

The statistical analysis was carried out according to the method given by Panse and Sukhatme (1967) for completely randomized design. Results were tested at 5 per cent probability level of significance and standard error was estimated.

3.14 Response analysis

The response analysis of various ESP and salinity levels were estimated by fitting linear ($Y = a + bx$) and

quadratic curves in respect of dry weight of whole plant. The appropriate response curve was selected for explanation on the basis of significance of R^2 and significance of regression coefficient (Snedecor and Cochran, 1967).

3.15 Correlation and path analysis

Simple correlations were worked out between 10 independent and one dependent characters (dry matter) in all the fruit crops except Karonda and drumstick. In these crops 11 independent variables were considered (Johnson et al., 1955).

The correlation matrix of these variables was subjected to path analysis and direct and indirect effects of different variables on dry matter production were estimated as per the procedure given by Dewey and Lu (1959).

Chapter 4

RESULTS

The results obtained through the studies on the effects of different levels of exchangeable sodium percentage and salinity levels on different morphological plant attributes, physiological parameters and chemical composition of various fruit crops are presented in this chapter. The results also include the interrelationship of the important characters and path coefficient analysis.

4.1 Effect of exchangeable sodium percentage on growth

4.1.1 Cashew

4.1.1.1 Effect on plant height

Data on the periodic plant height of cashew expressed in per cent increase over the initial readings under different ESP are presented in Table 11.

The results indicated that the percent increase in the height decreased with the increase in ESP, in general. Adverse effect was recorded right from 60 days after the planting when the ESP was raised to 12. The height was reduced further

Table 11: Effect of ESP on per cent increase in plant height, number of leaves and stem diameter of cashew

Treatments	Days after planting					
	60	120	180	240	300	360
			Plant height			
Control	57.26	83.63	120.69	172.77	226.67	266.67
ESP 12	41.37	55.86	86.68	122.64	147.10	173.33
ESP 24	26.55	44.13	80.66	113.85	136.36	151.52
ESP 36	25.25	38.37	52.78	88.49	83.22	-
ESP 41	23.61	36.33	46.00	70.17	-	-
ESP 48	21.51	34.35	41.81	51.87	-	-
ESP 60	18.56	32.26	38.78	41.99	-	-
S.E.±	1.201	1.674	3.481	5.268	13.070	12.815
C.D. at 5%	3.644	5.079	7.527	15.981	42.625	44.347
			Number of leaves			
Control	100.86	212.83	340.81	407.88	475.88	581.17
ESP 12	83.33	166.18	266.91	384.41	348.12	375.47
ESP 24	50.18	133.69	228.39	247.39	263.45	283.45
ESP 36	42.28	100.19	189.17	204.17	219.27	-
ESP 41	37.50	50.51	90.43	102.45	-	-
ESP 48	25.10	45.38	75.13	81.12	-	-
ESP 60	20.19	38.43	62.67	67.67	-	-
S.E.±	2.984	11.840	9.30	14.90	13.64	20.54
C.D.at 5%	9.052	33.52	28.23	45.21	31.45	57.26
			Stem diameter			
Control	57.47	114.29	157.14	200.10	214.49	241.29
ESP 12	52.12	100.30	142.86	171.50	220.50	225.50
ESP 24	43.85	88.43	127.57	162.40	171.43	177.50
ESP 36	42.73	71.40	108.12	142.86	155.73	-
ESP 41	25.30	61.50	100.27	114.30	-	-
ESP 48	14.69	57.14	71.47	87.50	-	-
ESP 60	12.50	37.50	59.83	71.43	-	-
S.E.±	1.743	8.391	5.247	4.200	4.083	4.582
C.D.at 5%	5.287	25.452	15.917	12.740	13.315	15.858

on further increase in ESP (24). The data further revealed that the effects of ESP 48 and 60 were similar. Similarly the height of the plant was similar under ESP 36, 41 (problematic soil) and 48 in general, although the significance was absent at 240 days after planting.

4.1.1.2 Effect on number of leaves

The results showed that the number of leaves decreased when the ESP was increased artificially during the entire course of the investigation. Adverse effects were noted in greater amount when the ESP was increased. The highest level of exchangeable sodium (60) showed lowest number of leaves although the same was not statistically different from the next highest ESP treatment (48). The problematic soil had 41 ESP and showed low number of leaves, compared to that of ESP 36 right from 120 days after planting (Table 11).

4.1.1.3 Effect on stem diameter

The data indicated that the stem diameter in control and ESP 12 was similar at various growth stages except at 240 days after planting. Similarly the stem diameter in ESP 12 and 24 was similar at growth stages of 120 and 180 days after planting. Although lowest stem diameter was recorded in the highest ESP, the same was not different under ESP 48 and 60 at 60, 120 and 180 days after planting (Table 11).

4.1.1.4 Effect on plant spread

The data on plant spread are presented in Table 12. Control recorded maximum spread which decreased when the ESP was increased. Minimum plant spread was recorded in highest ESP level which was similar to that recorded in ESP 48.

4.1.1.5 Effect on leaf area

It is evident from the data in Table 12 that leaf area decreased with the increase in ESP.

4.1.1.6 Effect on plant mortality

The data regarding mortality are presented in table 12 and fig. 1. The plants under control and ESP 12 did not show any kind of mortality. Mortality was noticed under ESP 24 and 100 per cent mortality was recorded in ESP 36 and all above treatments. The mortality symptoms were noted in ESP 36 from 180 days after planting and the plant death occurred at 360 days after planting. In the case of ESP 41, 48 and 60 the mortality symptoms started appearing 150 days after planting and the complete mortality occurred 300 days after planting.

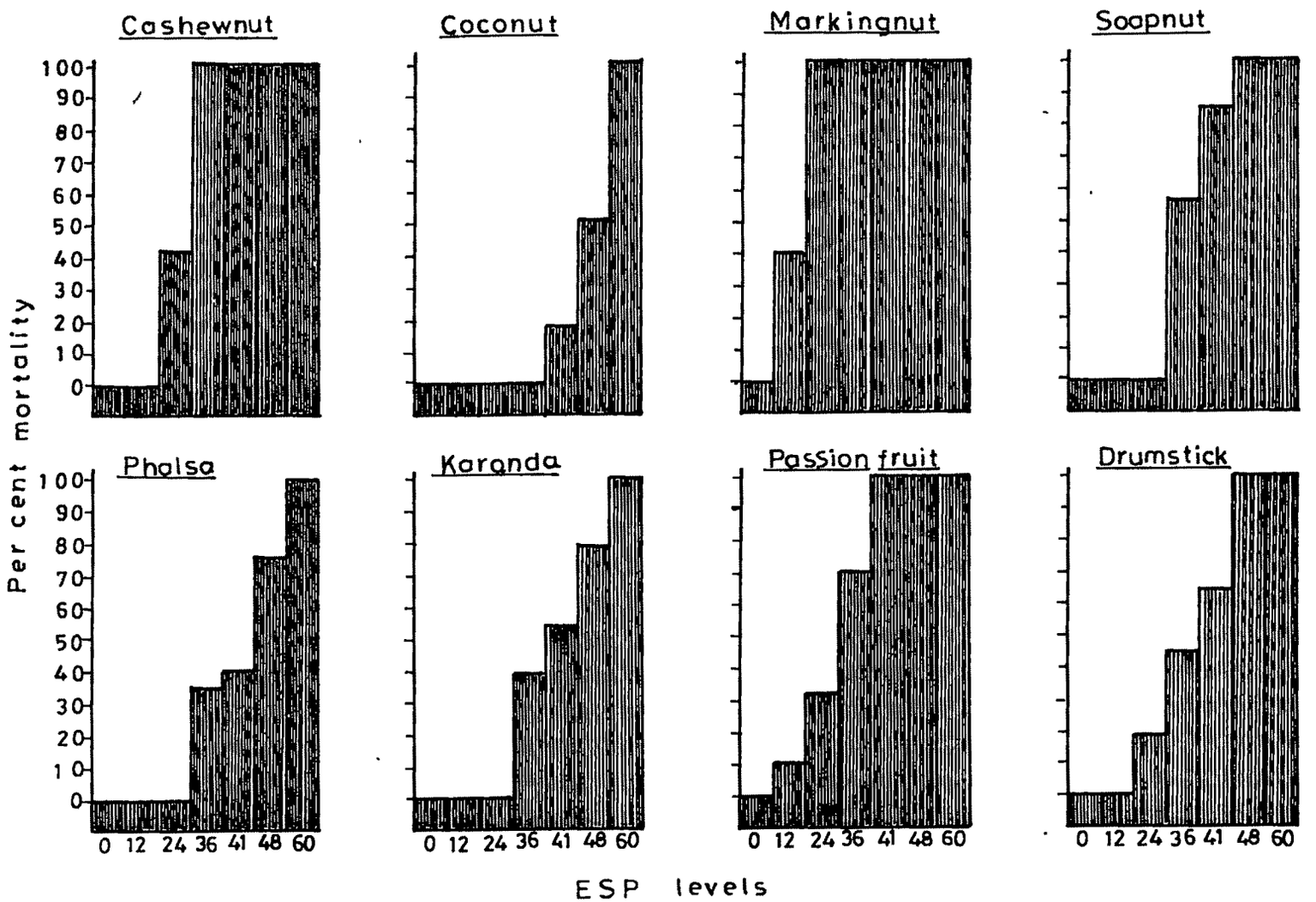


Fig 1. Effect of different levels of ESP on mortality at the time of termination of experiment



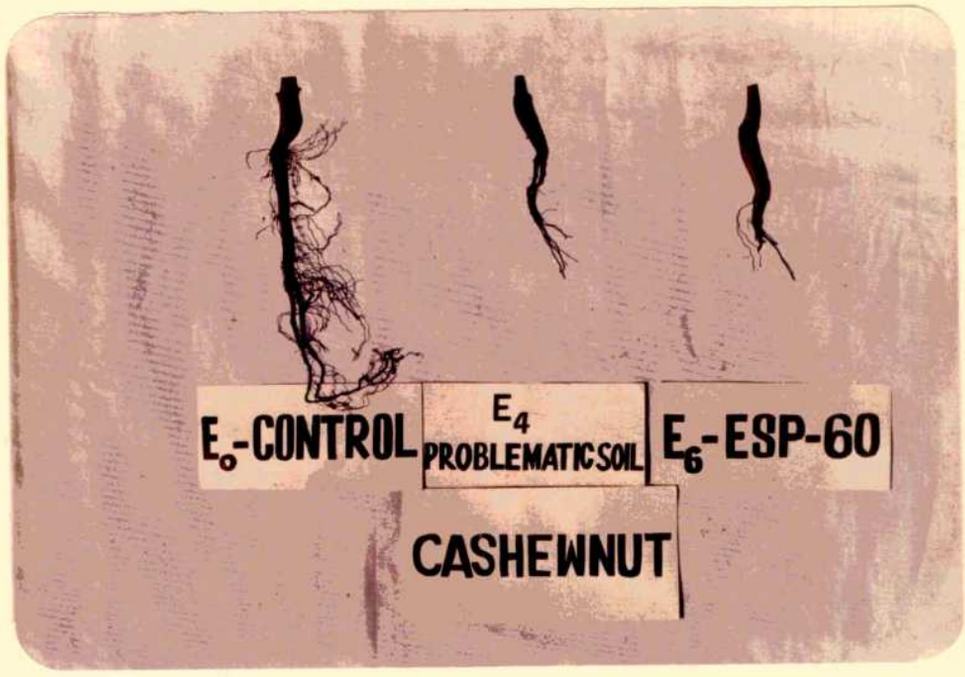


Photo Plate No. 1 : Effect of ESP 60 as evidence in complete death of plant with severely depressed primaries and secondaries of root 300 days after planting

Table 12: Effect of ESP on plant spread, total leaf area per plant and mortality of cashew

Treatments	Plant spread (cm)	Total leaf area (sq.cm)	Mortality (per cent)
Control	25.40	2353.93	00.00 (00.57)
ESP 12	22.10	2107.22	00.00 (00.57)
ESP 24	19.33	1831.10	42.00 (40.40)
ESP 36	17.60	1181.14	100.00 (90.00)
ESP 41	14.10	887.46	100.00 (90.00)
ESP 48	11.50	720.63	100.00 (90.00)
ESP 60	10.00	601.17	100.00 (90.00)
S.E. ±	0.693	35.072	- 2.40
C.D. at 5%	2.102	106.268	- 7.286

The figures in paranthoses indicate transformed percentage value in to aresine value.

4.1.1.7 Effect on root length

The root length was least in ESP 60 which was similar to that in ESP 48. The root length decreased on increase in the ESP 12. There was no difference in root length in treatments ESP 12 and 24. The problematic soil had 41 ESP and its effect was not different from ESP 36 and 48 (Table 13).

Table 13: Effect of ESP on root length, root volume, number of primary roots, number of secondary roots and total number of roots of cashew.

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots
Control	23.70	11.10	15.00	35.10	50.10
ESP 12	20.00	9.00	11.70	27.10	38.80
ESP 24	20.22	9.50	8.10	17.50	25.60
ESP 36	17.10	8.00	5.10	10.20	15.30
ESP 41	15.50	6.50	3.50	6.10	9.60
ESP 48	13.10	5.00	3.00	4.40	7.40
ESP 60	13.00	4.10	2.70	3.00	5.70
S.E. ±	0.780	0.531	0.471	1.007	2.530
C.D. at 5%	2.381	1.623	1.427	3.051	7.691

4.1.1.8 Effect on root volume

The data presented in Table 13 showed that the root volume decreased markedly when the ESP was increased. The lowest volume was recorded under highest ESP level which was not different to that recorded in next highest ESP level (48).

4.1.1.9 Effect on number of primary roots

The primary roots decreased when the ESP level was increased upto 41. The primary roots were similar in ESP 41 and ESP 48. Similarly they were similar in ESP 48 and 60 (Table 13).

4.1.1.10 Effect on number of secondary roots

The secondary roots decreased with the increase in ESP up to 41. There was no difference in the secondary roots under ESP 41 and 48. Similarly there was no difference in secondary roots recorded at ESP 41 and ESP 60 (Table 13).

4.1.1.11 Effect on total number of roots

The total number of roots decreased with increase in ESP level up to 36. The number of roots were similar under ESP 36 and 41, ESP 41 and 48, ESP 48 and 60 (Table 13).

4.1.1.12 Effect on fresh weight of whole plant

The data in table 14 indicated that up to ESP 12 there was no adverse effect. The adverse effect was noted when the ESP level was increased to 24. Lowest fresh weight was recorded under ESP 60.

4.1.1.13 Effect on fresh weight of root

The data in table 14 indicated that up to ESP 12 there was no adverse effect. The adverse effect was noted at 24 ESP. Lowest fresh weight of root was recorded under ESP 60 which was similar to that recorded under ESP 48.

4.1.1.14 Effect on fresh weight of top

The adverse effect was seen when the ESP was increased to 24. The lowest fresh weight was recorded under ESP 60. The problematic soil which contained 41 ESP showed the same effect as that of ESP 48 (Table 14).

4.1.1.15 Effect on dry weight of whole plant

Dry weight of whole plant increased only on increase in the ESP level up to 36. There was no difference in the dry weight of whole plant recorded under ESP 36 and ESP 41 (problematic soil). Lowest dry weight of whole plant was recorded under ESP 60(Table 14 and Fig. 2).

4.1.1.16 Effect on dry weight of root

Lowest dry weight of root was recorded under ESP 60. Similar effect was also recorded under ESP 48, ESP 41 and ESP 36 (Table 14).

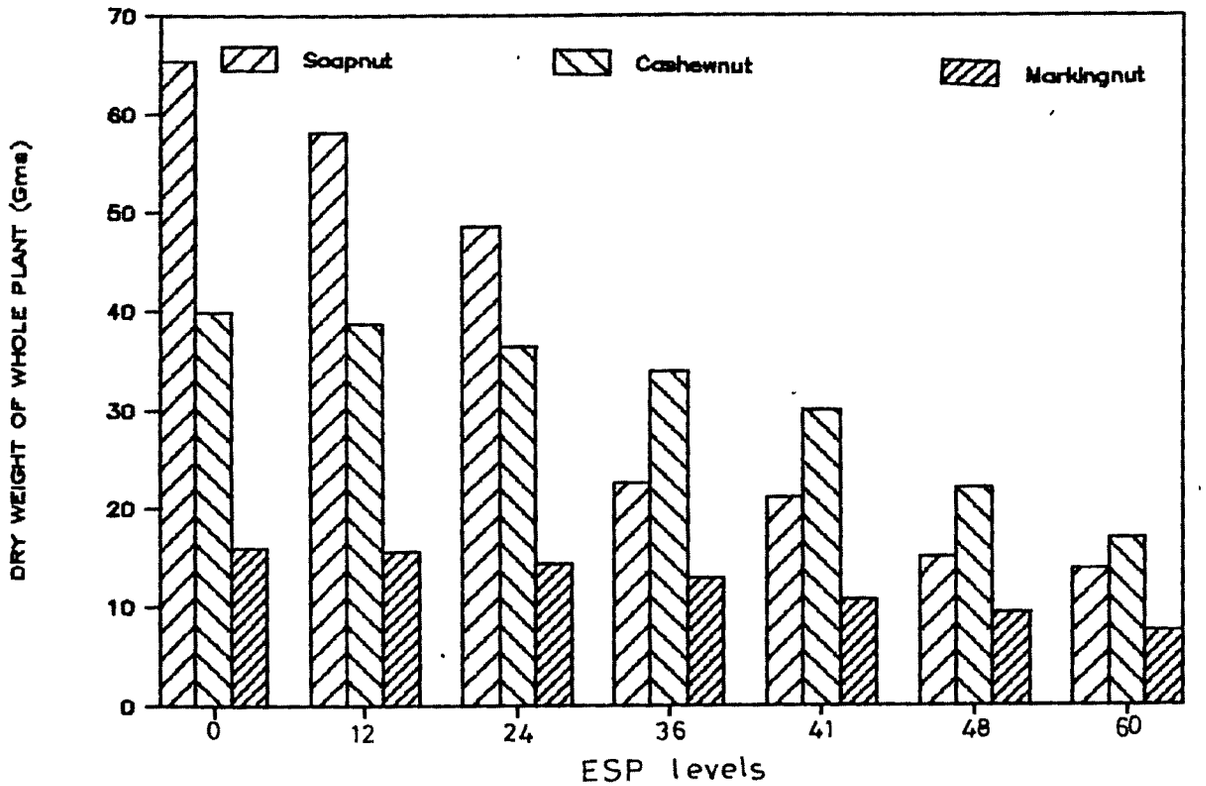


Fig 2. Effect of different levels of ESP on dry matter accumulation in Cashewnut, Soapnut and Markingnut at the time of harvest

4.1.1.17 Effect on dry weight of top

Dry weight of top increased at and above ESP 24. The lowest dry weight of top was recorded under ESP 60 (Table 14).

Table 14: Effect of ESP on fresh and dry weight of whole plant, root and top of Cashew

Treatments	Fresh weight of whole plant (g)	Fresh weight of root (g)	Fresh weight of top (g)	Dry weight of whole plant (g)	Dry weight of root (g)	Dry weight of top (g)
Control	99.67	21.33	78.34	39.90	6.19	33.71
ESP 12	95.33	20.33	75.00	38.72	6.10	32.62
ESP 24	86.66	16.00	70.66	36.41	5.96	30.45
ESP 36	71.00	12.00	59.00	33.83	4.92	28.91
ESP 41	54.00	10.67	43.33	29.91	4.48	25.43
ESP 48	49.00	9.00	40.00	22.00	4.41	17.59
ESP 60	29.33	7.00	22.33	16.92	3.57	13.35
S.E. ±	2.73	1.13	1.09	1.54	0.37	0.92
C.D. at 5%	8.380	3.441	5.741	4.670	1.131	2.792

4.1.1.2 Physiological parameters

4.1.1.2.1 Effect of exchangeable sodium percentage on chlorophyll content of leaves

The data in table 15 indicated that the lowest chlorophyll content was estimated under ESP 60 which was similar to that recorded under ESP 48. This was same in the case of chlorophyll 'a', 'b' and 'total'. Although chlorophyll 'a' and 'b' was not decreased with increase in the ESP 12 the total chlorophyll decreased significantly.

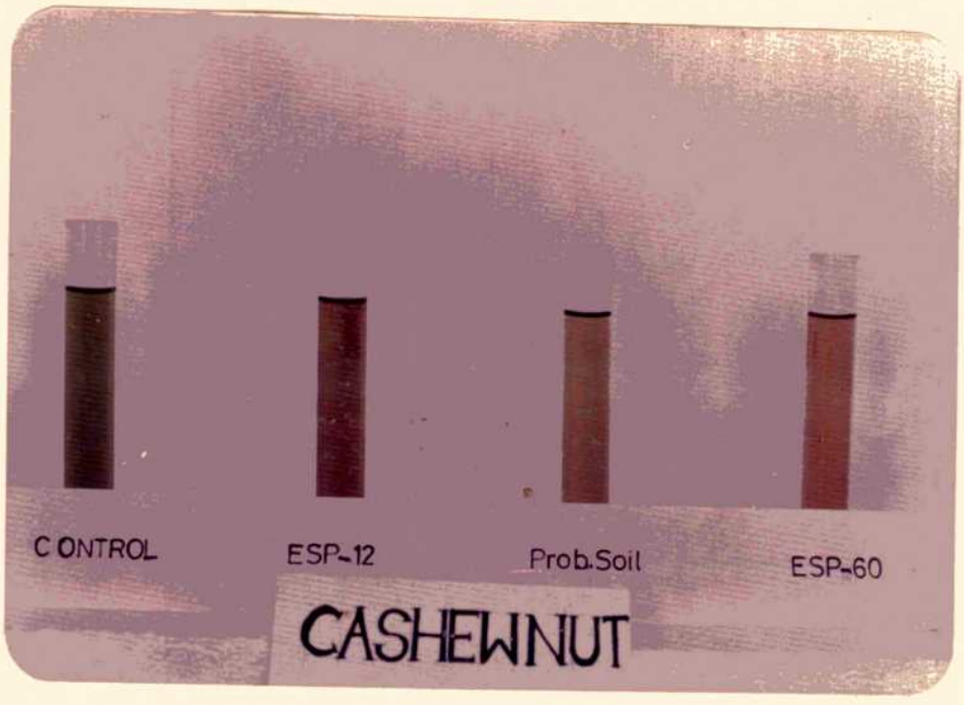


Photo plate No. 2 : Effect of ESP levels showing gradual change in chlorophyll content in cashew

4.1.1.2.2 Effect on the number of stomata

The data in table 15 and Fig. 3 indicated that there was trend of increased stomata with the increase in ESP. A significant increase in the number of stomata was observed when the ESP level was increased to 36. There was no difference in the number of stomata recorded under problematic soil and ESP 48. Similarly there was no difference in ESP 48 and ESP 60.

Table 15: Effect of ESP on chlorophyll content of leaves, number of stomata per unit area and rate of transpiration of Cashew

Treatments	Chlorophyll 'a' mg/g	Chlorophyll 'b' mg/g	Chlorophyll Total mg/g	No.of stomata (40x)	Rate of transpiration g $H_2O/cm^2/hr.$
Control	1.0383	1.0917	2.1300	10.66	0.0927
ESP 12	0.9667	0.9877	1.8943	12.00	0.0737
ESP 24	0.7640	0.7850	1.5490	13.33	0.0703
ESP 36	0.6917	0.7500	1.4417	16.66	0.0637
ESP 41	0.6193	0.7360	1.3553	20.66	0.0533
ESP 48	0.2870	0.4180	0.7050	23.00	0.0467
ESP 60	0.2000	0.3640	0.5640	25.33	0.0410
S.E. ±	0.030	0.029	0.0591	1.351	0.002 3
C.D. at 5%	0.092	0.089	0.1794	4.098	0.0071

4.1.1.2.3 Effect on rate of transpiration

Data in table 15 and Fig. 3 indicated that control plants were on highest rate of transpiration and the same was decreased when the ESP was artificially raised. The lowest rate of transpiration was recorded under ESP 60 which was similar to that in ESP 48.

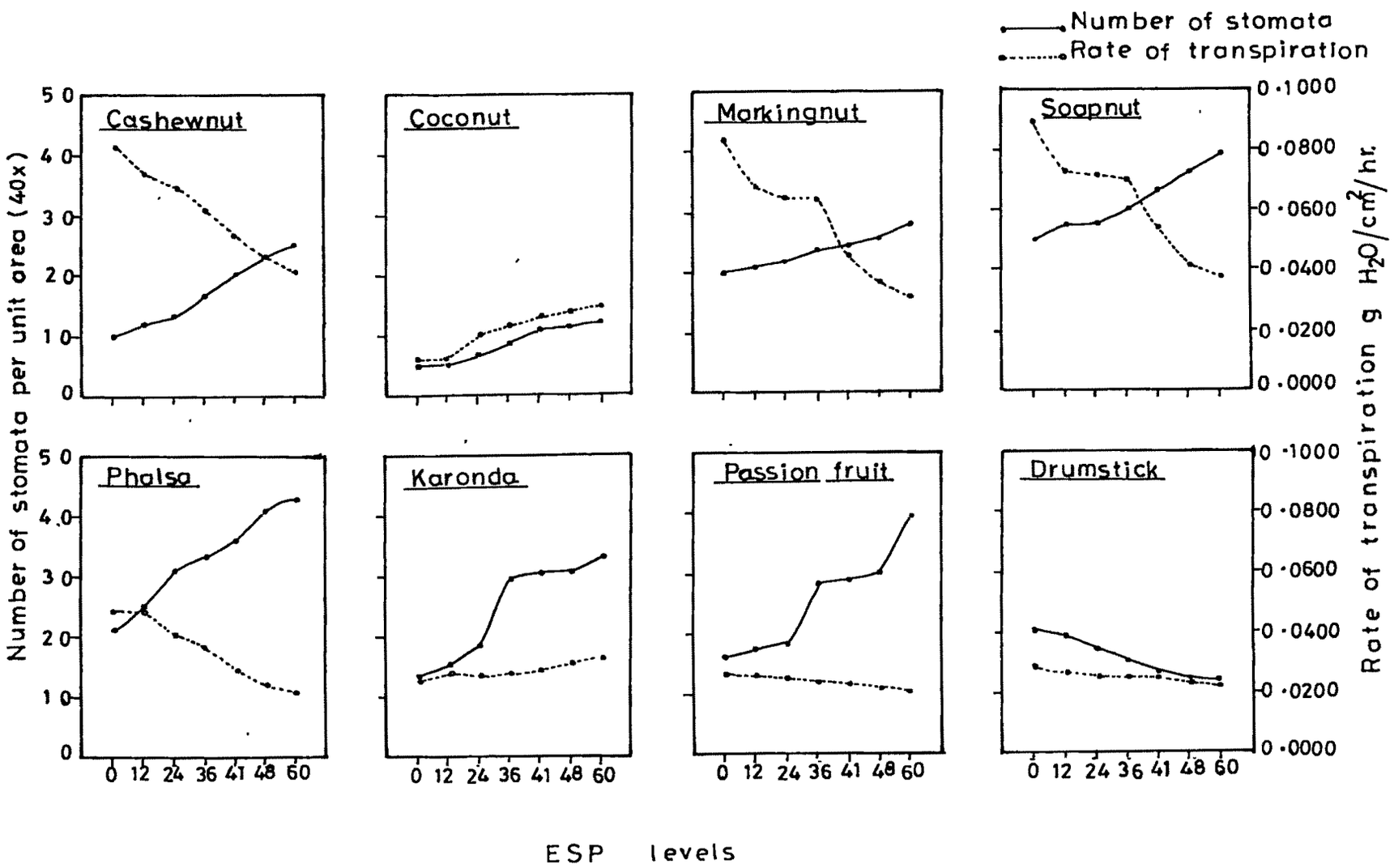


Fig 3. Effect of ESP levels on number of stomata and rate of transpiration

4.1.1.3 Effect of exchangeable sodium percentage on chemical composition

The data on the chemical composition of leaves, roots and stem as affected by various ESP levels are presented in Table 16 and 17.

4.1.1.3.1 Macronutrient content of leaves, roots and stem

4.1.1.3.1.1 Nitrogen :

Leaves : The data in Table 16 indicated that the N content of leaves increased when the ESP level was raised upto problematic soil. Next higher ESP level showed statistically significant decrease of N content. Which was significantly lower than rest of the treatments.

Roots : Roots nitrogen decreased when the ESP was artificially increased. Although control plants and ESP 12 plants showed similar N content. The lowest root nitrogen was recorded under ESP 16.

Stem : The data in Table 16 showed that the stem nitrogen content was decreased with the increase in the ESP. The lowest stem nitrogen was recorded under ESP 60.

4.1.1.3.1.2 Phosphorus

Leaves : The leaf P content decreased with an increase in ESP. The problematic soil which contained 41 ESP and the artificial treated soil having ESP 36 showed similar effect in regard to leaf P. The lowest leaf P was noted under ESP 60 (Table 16).

Table 16: Effect of ESP on macronutrient content (Percentage) of leaves, roots and stem of Cashew

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	3.20	1.47	2.08	1.88	0.84	0.79	0.76
ESP 12	3.20	1.29	1.73	1.69	0.72	0.70	0.99
ESP 24	3.57	1.05	1.68	1.53	0.65	0.63	1.18
ESP 36	3.88	0.89	1.49	1.38	0.58	0.55	1.33
ESP 41	3.90	0.76	1.06	1.21	0.50	0.48	1.58
ESP 48	3.00	0.60	0.99	1.12	0.46	0.43	1.63
ESP 60	2.40	0.39	0.76	0.92	0.28	0.32	1.70
S.E.±	0.028	0.026	0.047	0.023	0.016	0.015	0.027
C.D.at 5%	0.086	0.079	0.112	0.070	0.050	0.044	0.083
			Roots				
Control	3.00	0.80	0.53	1.60	0.58	0.51	0.48
ESP 12	2.90	0.74	0.43	1.40	0.43	0.49	0.60
ESP 24	2.79	0.67	0.40	0.96	0.35	0.48	0.69
ESP 36	2.57	0.63	0.38	0.88	0.30	0.42	0.75
ESP 41	2.23	0.37	0.31	0.85	0.28	0.35	0.84
ESP 48	1.98	0.32	0.27	0.83	0.25	0.33	0.85
ESP 60	1.61	0.19	0.28	0.75	0.21	0.25	0.90
S.E.±	0.045	0.023	0.012	0.037	0.014	0.011	0.013
C.D.at 5%	0.137	0.071	0.035	0.114	0.042	0.039	0.041
			Stem				
Control	3.08	0.65	0.68	0.88	0.72	0.68	0.72
ESP 12	3.00	0.60	0.64	0.84	0.70	0.65	0.78
ESP 24	2.66	0.55	0.55	0.80	0.65	0.56	0.90
ESP 36	2.38	0.46	0.46	0.78	0.58	0.46	0.04
ESP 41	2.14	0.43	0.40	0.72	0.50	0.36	1.14
ESP 48	1.83	0.34	0.32	0.68	0.38	0.35	1.56
ESP 60	1.54	0.19	0.16	0.49	0.10	0.21	1.80
S.E.±	0.057	0.013	0.016	0.016	0.030	0.013	0.039
C.D.at 5%	0.173	0.041	0.048	0.048	0.091	0.041	0.118

Roots : The P content of roots also decreased when the soil exchangeable sodium increased. The lowest P content was noted under ESP 60.

Stem : The stem P also decreased with increase in ESP up to 36. The problematic soil containing ESP 41 showed similar effect as that of ESP 46. Lowest P was recorded under ESP 60.

4.1.1.3.1.3 Potassium

Leaves : The K content of leaves was remarkably reduced when the ESP was raised to 12. The lowest K content was recorded under ESP 60 (Table 16).

Roots : The K content of roots also decreased with increased ESP of the soil. The lowest K content was estimated under ESP 60.

Stem : The stem K content was decreased when the ESP level was increased to ESP 24. The lowest K content of the stem was recorded on highest ESP level.

4.1.1.3.1.4 Calcium

Leaves : The Ca content of the leaves decreased on increasing the ESP. The lowest Ca content was noted under ESP 60. The problematic soil having ESP 41 showed intermediate Ca content to that of ESP 36 and ESP 48 (Table 16).

Roots : The root Ca decreased with the increase in the ESP up to 36. The root Ca was similar in ESP 36, 41 and 48. Lowest root Ca was recorded under ESP 60.

Stem : The stem Ca decreased at ESP 24. The lowest stem Ca was estimated under ESP 60.

4.1.1.3.1.5 Magnesium

Leaves : The Mg content of leaves was maximum in control. The lowest Mg content was noted in the leaves from ESP 60 (Table 16).

Roots : Roots of control plants showed highest Mg content and lowest was recorded under ESP 60. There was no difference in the effect of problematic soil of ESP 36 and 48.

Stem : The Mg content of stem decreased only when the ESP level was raised to 41 (problematic soil). The lowest stem Mg was recorded under ESP 60 which was similar to that under ESP 48.

4.1.1.3.1.6 Sulphur

Leaves : Sulphur content of leaves decreased when the ESP was raised to 24 and the sulphur content continued decreasing with the further increase of ESP (Table 16).

Roots : Sulphur content in roots decreased only when ESP was raised to 36. The lowest sulphur was estimated under ESP 60.

Stem : The stem sulphur decreased when ESP was raised to 24. Further increase in soil ESP showed further decrease in stem sulphur.

4.1.1.3.1.7 Sodium

Leaves : The Na content of leaves was increased significantly with the increase in ESP, although ESP 60 missed this slightly (Table 16).

Roots : The data showed that the root Na content increased with increase in ESP, in general. The effects of ESP 41 (problematic soil) and ESP 48 were similar.

Stem : The stem Na content increased consistently with the increase in ESP.

4.1.1.3.1.8 Ca : Na

Leaves : Ca : Na content of leaves in control was highest. This ratio was lowest under ESP 60, which was similar to that under ESP 48 and 41 (problematic soil) (Table 17).

Roots : Ca : Na content of roots decreased with the increase in ESP up to 24. The lowest ratio was recorded under ESP 60. ESP 41, 48 and 36 showed the similar resistance.

Stem : Ca : Na content of the stem decreased with increase in ESP.

4.1.1.3.1.9 Ca + Mg + K : Na

Leaves : Ca + Mg + K : Na content of leaves decreased with increase in ESP up to 41. The lowest ratio was estimated under ESP 60 which was statistically similar to that recorded under ESP 48 (Table 17).

Table 17: Effect of ESP on macronutrient ratio of Ca : Na and Ca + Mg + K : Na micronutrients content of leaves, roots and stem of Cashew

Treatments	Ca/Na	Ca+Mg+K/Na	Micronutrient (ppm) Zn	Fe	Mn	Cu
			Leaves			
Control	2.49	6.35	28.48	1644.85	124.64	56.63
ESP 12	1.69	4.16	26.87	1620.88	120.64	45.88
ESP 24	1.29	3.27	25.10	1505.63	116.37	36.38
ESP 36	1.04	2.52	24.87	1410.37	110.83	30.53
ESP 41	0.69	1.75	24.87	1283.80	100.05	25.43
ESP 48	0.54	1.57	22.15	1099.83	89.18	21.24
ESP 60	0.51	1.15	19.13	836.53	70.38	19.47
S.E.m.+	0.120	0.121	0.402	33.446	2.305	1.237
C.D.at 5%	0.363	0.368	1.220	101.456	6.991	3.752
			Roots			
Control	3.35	4.70	33.00	1710.31	125.79	100.41
ESP 12	2.35	3.77	29.38	1680.81	114.88	82.30
ESP 24	1.39	2.47	28.48	1619.22	98.22	78.76
ESP 36	1.18	2.16	20.34	1522.95	89.09	73.45
ESP 41	1.02	1.63	19.54	1412.50	87.64	60.65
ESP 48	0.94	1.55	18.92	1062.14	70.35	33.63
ESP 60	0.83	1.27	13.25	781.81	45.95	29.20
S.Em. +	0.109	0.303	0.837	76.205	3.264	4.074
C.D.at 5%	0.332	0.919	2.540	231.164	9.901	12.357
			Stem			
Control	1.22	3.17	48.73	1204.13	64.91	184.94
ESP 12	1.10	2.80	46.32	1182.93	61.37	155.39
ESP 24	0.88	2.22	42.16	1074.12	53. 99	132.19
ESP 36	0.75	1.75	36.18	901.98	45.57	102.03
ESP 41	0.63	1.43	30.89	777.58	36.84	71.68
ESP 48	0.43	0.75	24.10	658.31	29.88	45.36
ESP 60	0.27	0.42	11.83	431.58	9.16	19.46
S.Em.+	0.019	0.049	1.516	30.366	2.435	5.283
C.D.at 5%	0.058	0.149	4.598	92.114	7.387	16.027

Roots : Ca + Mg + K : Na content of roots decreased with increase in ESP up to 24. The effects of ESP 36, 41, 48, 60 were almost similar in this regard.

Stem : Ca + Mg + K : Na content of stem decreased consistently with increase in ESP.

4.1.1.3.2 Micronutrient content of leaves, roots and stem

4.1.1.3.2.1 Zinc

Leaves : The Zn content of leaves decreased with increase in ESP up to 24. Similar effects were noted in this regard with ESP 24, 36 and 41. The lowest Zn content was estimated under ESP 60 (Table 17).

Roots : Control plant showed maximum Zn content in roots. The lowest Zn content was estimated under ESP 60. The effects of ESP 12 and 24 as well as 36 and 41 were similar in this behalf.

Stem : Zn content of stem was decreased with the ESP content was raised to 24. On further increase in ESP however, there was consistent fall in Zn content.

4.1.1.3.2.2 Iron

Leaves : The Fe content of leaves was decreased when the ESP raised to 24 and on further increase in the level of ESP the Fe content of the leaves decreased (Table 17).

Roots : The Fe content of the roots was decreased only when the ESP content was raised to 41 (problematic soil). Further increase in the ESP level however brought down consistently the Fe content.

Stem : The Fe content of the stem decreased when the ESP was raised to 24. On further increase in the ESP level there was consistant fall in Fe content.

4.1.1.3.2.3 Manganese

Leaves : The Mn content of the leaves decreased when the ESP was raised to 24. The effects of ESP 24 and 36 on leaves were similar. There was consistent fall in the Mn content when the ESP was increased from 36 onwards (Table 17).

Roots : Control plants showed maximum Mn in the roots. The treatment of ESP 60 showed lowest Mn content. The ESP 41 and 36 showed similar effects in this regard.

Stem : The Mn content of the stem decreased when ESP was raised to 24. On further increase in the ESP Mn content decreased or tended to decrease.

4.1.1.3.2.4 Copper

Leaves : The Cu content of the leaves decreased consistently with the increase in ESP except at the highest level. The effect of ESP 48 and 60 was similar.

Roots : Control plants showed maximum Cu content in roots. The lowest Cu content was under ESP 60 which was similar to that under ESP 48. The effect of ESP 24 and ESP 36 was similar.

Stem : The Cu content of the stem decreased consistently with the increase in the ESP.

4.1.2 Coconut

4.1.2.1 Effect on plant height

Periodic observations on the plant height on coconut expressed in per cent increase for the initial reading are presented in Table 18. It is seen from the table that the control plants showed highest height throughout the course of investigation. The plant height measured at 360 days after planting indicated that the height decreased with the increase in ESP upto 36. The effect of ESP 36 and 41 (problematic soil) were similar. Similarly there was no difference between ESP 41 and 48 in this respect. The treatments started showing greater differences from 180 days after planting.

4.1.2.2 Effect on number of leaves

The data on number of leaves indicated that a significant reduction in the leaves was noted when the ESP was raised to 24 during the entire course of investigation. ESP 48 and 60 although showed similar effect the highest level of ESP showed significant reduction in the number of leaves compared to rest of the treatments throughout the course of investigation. Marked reduction in the number of leaves was recorded from 180 days after planting (Table 18).

Table 18: Effect of ESP on percentage increase in the plant height, number of leaves and stem diameter of Coconut

Treatment	Days after planting					
	60	120	180	240	300	360
			Plant height			
Control	70.12	225.10	400.30	699.70	765.70	900.40
ESP 12	65.20	165.30	305.10	505.30	550.47	475.40
ESP 24	63.15	142.10	242.10	426.30	489.47	552.63
ESP 36	45.37	100.00	175.70	340.10	385.00	403.19
ESP 41(PS)	38.81	89.47	144.33	305.26	347.36	384.21
ESP 48	26.31	73.68	110.52	294.73	310.52	321.05
ESP 60	25.10	55.00	103.24	265.20	280.27	-
S.E.+	1.550	6.870	9.810	14.980	16.750	21.029
C.D.at 5%	4.710	20.860	29.470	45.380	50.810	63.770
			Number of leaves			
Control	50.67	87.73	187.34	275.50	353.93	450.93
ESP 12	48.33	82.10	175.30	265.44	338.72	354.78
ESP 24	43.87	72.82	168.60	250.57	310.38	338.72
ESP 36	42.10	67.18	160.43	223.33	287.22	302.50
ESP41(PS)	38.60	58.33	152.49	198.48	231.51	275.33
ESP 48	34.89	50.58	147.45	166.43	207.20	250.27
ESP 60	33.33	48.91	142.33	150.67	192.27	-
S.E.+	2.857	1.382	1.599	3.925	5.100	6.230
C.D. at 5%	8.667	4.193	4.850	11.906	15.460	18.897
			Stem diameter			
Control	50.55	118.53	150.46	263.01	286.62	300.71
ESP 12	46.60	87.74	144.56	237.83	265.55	297.34
ESP 24	37.60	85.54	133.53	218.70	237.61	254.54
ESP 36	33.68	66.71	115.78	199.92	212.76	225.53
ESP 41(PS)	25.37	62.74	100.46	150.73	175.49	220.60
ESP 48	16.65	50.50	89.88	125.70	150.65	189.09
ESP 60	12.53	44.38	33.79	62.43	66.63	-
S.E.+	1.299	4.093	6.573	8.717	9.518	12.468
C.D. at 5%	3.939	12.416	19.940	26.443	28.872	38.421

4.1.2.3 Effect on stem diameter

Nearly throughout the period of investigation the stem diameter was seen decreased only when the ESP was raised to 24. A marked reduction in stem diameter due to ESP was observed when the plants attained 240 days after planting. The effect of ESP 36 and 41 were similar (Table 18).

4.1.2.4 Effect on plant spread

The plant spread was decreased after increase in the ESP up to 24 given in Table 19. There was no difference between ESP 24 and 36. Similarly from ESP 36 onwards a consistent decrease in plant spread was noticed with the increase in ESP.

Table 19: Effect of ESP on plant spread, total leaf area per plant and plant mortality of Coconut

Treatments	plant spread (sq.cm.)	Total leaf area (sq.cm.)	plant mortality (per cent)
Control	120.50	17469.59	00.00 (00.57)
ESP 12	107.00	15609.40	00.00 (00.57)
ESP 24	97.30	12418.68	00.00 (00.57)
ESP 36	91.50	9358.63	00.00 (00.57)
ESP 41 (P.S.)	80.00	7731.55	18.66 (25.84)
ESP 48	65.33	6429.26	51.33 (45.75)
ESP 60	52.50	3236.01	100.00 (90.00)
S.E.±	2.873	544.830	- 2.700
C.D. at 5%	8.715	1652.921	- 8.181

The figures in parentheses indicate transformed value into arcsine value.

4.1.2.5 Effect on leaf area

The total leaf area decreased with increase in ESP up to 41. The effect of ESP 41 (problematic soil) and ESP 48 was similar. ESP 60 showed minimum total leaf area (Table 19).

4.1.2.6 Effect on plant mortality

No mortality was recorded under ESP upto 36. The mortality increased with the increase in ESP from 41 to 60. In case of ESP 60 the mortality symptoms were recorded from 240 days after planting and the complete mortality occured five months after planting. The burning of young leaves was the initial symptoms and the last symptom was the complete drying of plant (Table 19 and Fig. 1).

4.1.2.7 Effect on root length

The root length decreased significantly with the increase in ESP upto 48. The effect of ESP 48 and 60 was not different from each other (Table 20).

4.1.2.8 Effect on root volume

Root volume decreased as the ESP increased up to 12. The ESP 24 and 36 produced the same effect. ESP 36 produced plants with greater root volume compared to that of ESP 41 (problematic soil). There was no difference between ESP 48 and 60 (Table 20).

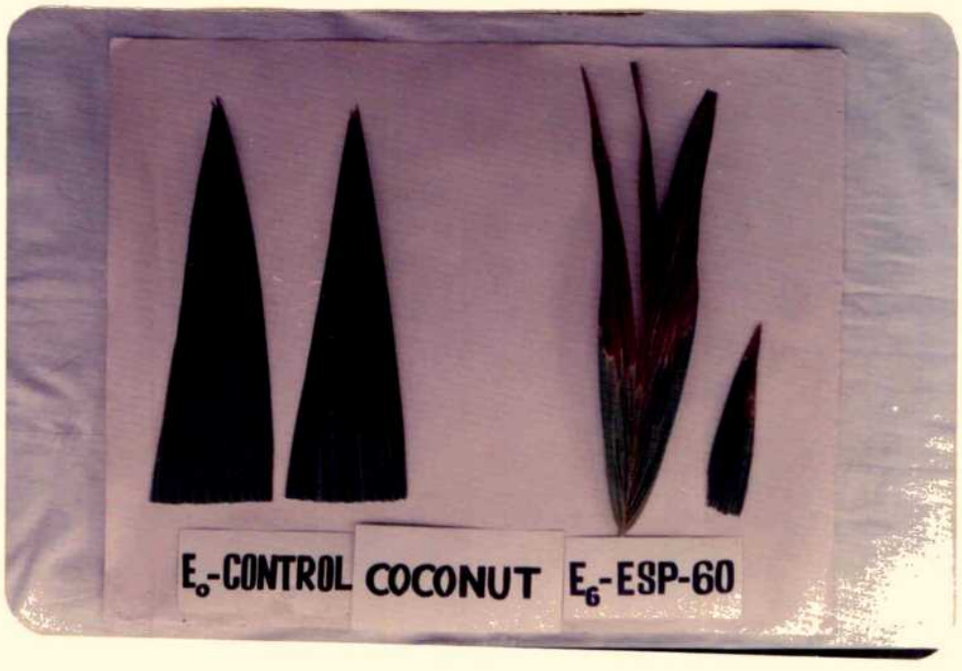


Photo plate No. 3 : Effect of 60 ESP causing leaf injury as noticed 360 days after planting

Table 20: Effect of ESP on root length, root volume, number of primary roots, number of secondary roots and total number of roots of Coconut

Treatment	Length of root (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots
Control	50.00	14.10	10.00	150.30	160.30
ESP 12	44.50	12.10	9.20	128.10	137.30
ESP 24	38.30	10.00	7.30	103.00	110.30
ESP 36	31.10	10.10	6.31	78.33	84.64
ESP 41	25.10	7.20	5.40	35.27	40.67
ESP 48	19.30	6.50	5.20	23.30	28.50
ESP 60	17.20	6.00	5.00	17.10	22.10
S.E.±	1.320	0.570	0.610	3.670	8.430
C.D. at 5%	4.010	1.750	1.870	11.150	24.660

4.1.2.9 Effect on number of primary roots

The primary roots decreased when the ESP was raised to 24. ESP 41, 48 and 60 exhibited similar effects (Table 20).

4.1.2.10 Effect on number of secondary roots

As the ESP increased the number of secondary roots decreased upto ESP 48. There was no marked difference between the effects of ESP 48 and 60 (Table 20).

4.1.2.11 Effect on total number of roots

The adverse effect of ESP was noticed with each successive increase in the ESP level upto ESP 41. The effects of ESP 41 and 48 and also of ESP 48 and 60 were similar (Table 20).

4.1.2.12 Effect on fresh weight of whole plant

The fresh weight of whole plant decreased when the ESP was raised to 24. On further increase in the ESP there was successive decrease in the weight of whole plant upto ESP 48. No marked difference was observed between the effects of ESP 48 and 60 (Table 21).

Table 21: Effect of ESP on fresh and dry weight of whole plant, root and top of Coconut

Treatment	Fresh weight of whole plant (kg)	Fresh weight of root (kg)	Fresh weight of top (kg)	Dry weight of whole plant (kg)	Dry weight of root (kg)	Dry weight of top (kg)
Control	2.370	0.680	1.690	0.733	0.175	0.558
ESP 12	2.210	0.650	1.560	0.702	0.175	0.527
ESP 24	2.130	0.610	1.520	0.692	0.160	0.532
ESP 36	1.690	0.450	1.240	0.687	0.164	0.523
ESP 41 (P.S.)	1.440	0.320	1.120	0.611	0.121	0.490
ESP 48	1.060	0.260	0.800	0.572	0.114	0.458
ESP 60	0.810	0.210	0.600	0.448	0.095	0.353
S.E. ±	0.077	0.022	0.058	0.028	0.007	0.022
C.D. at5%	0.233	0.068	0.177	0.084	0.028	0.066

4.1.2.13 Effect on fresh weight of root

The fresh weight of root was decreased when the ESP was raised to 12. It was further decreased when the ESP was raised from 24 to ESP 48, successively. The effect of ESP 48 and 60 was not different from each other (Table 21).

4.1.2.14 Effect on fresh weight of top

The fresh weight of top was decreased only when the ESP was raised to 36. Lowest fresh weight was recorded under highest ESP (Table 21).

4.1.2.15 Effect on dry weight of whole plant

Dry weight of whole plant was significantly decreased only when the ESP was raised to 41 (problematic soil). The problematic soil having ESP 41 exhibited similar effect to that exhibited by ESP 48. The ESP 60 produced minimum dry weight of whole plant (Table 21 and Fiv. 4).

4.1.2.16 Effect on dry weight of root

The dry weight of root decreased only when the ESP was 41 (problematic soil). The problematic soil and the ESP 48 showed similar effect. Similarly highest level of ESP 60 and ESP 48 showed similar effects (Table 21).

4.1.2.17 Effect on dry weight of top

The dry weight of top was not significantly affected due to ESP 12, 24 and 36. The effects of problematic soil and the ESP 48 were similar. ESP 60 showed minimum dry weight of top (Table 21).

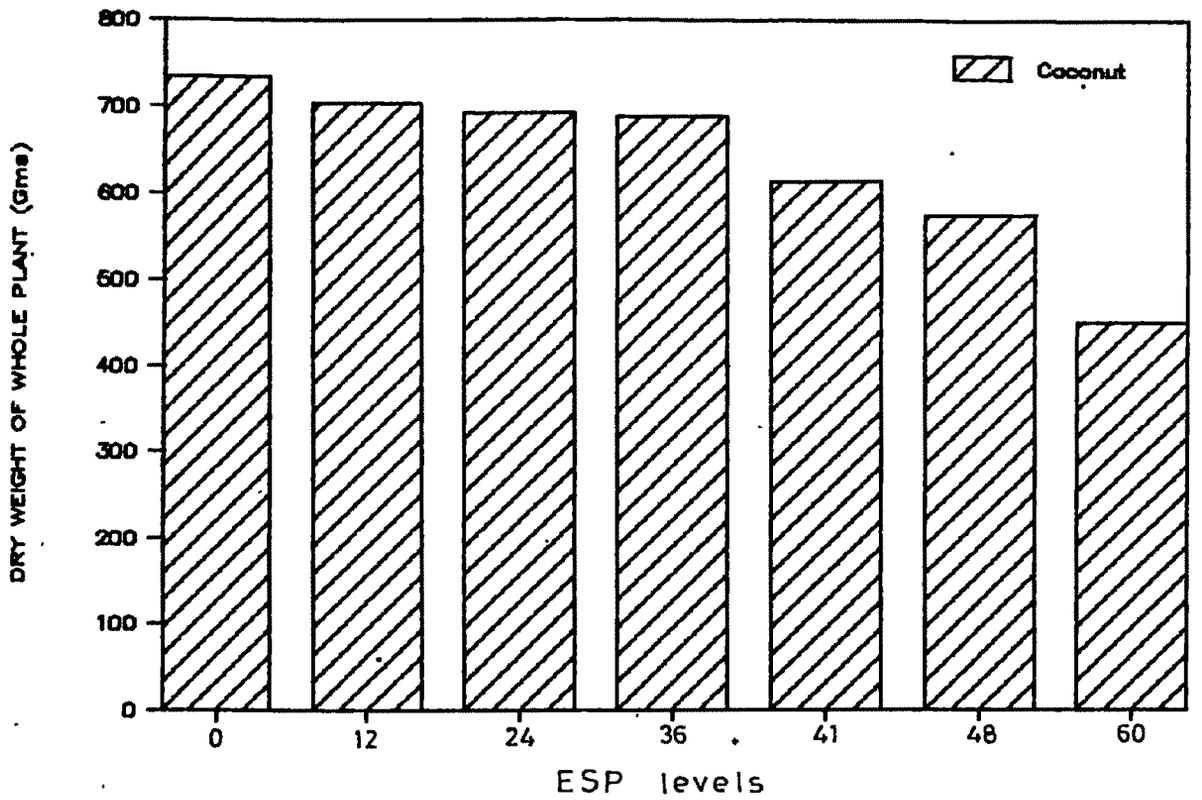


Fig 4. Effect of different levels of ESP on dry matter accumulation in Coconut at the time of harvest



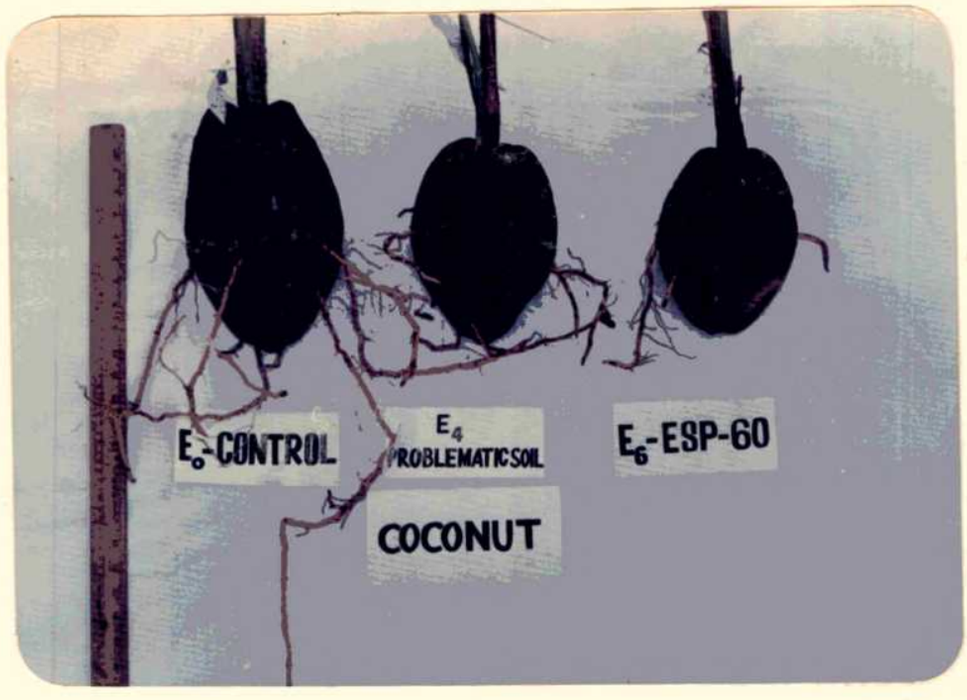


Photo plate No. 4 : Effect of highest ESP, 60 compared to problematic soil and control as noticed with drying of shoot (upper photo plate) and depressed root growth (lower photo plate) 360 days after planting

4.1.2.2 Physiological parameters

4.1.2.2.1 Effect of exchangeable sodium percentage on chlorophyll content of leaves

The chlorophyll 'a' and 'b' decreased with the increase in ESP upto 24 (Table 22). The total chlorophyll was highest in control plant. The chlorophyll 'a' and 'b' was lowest under ESP 60. The total chlorophyll although under ESP 60 was at par with that in ESP 48, it was low as compared to that in rest of the treatments.

Table 22: Effect of ESP on the chlorophyll content of leaves number of stomata per unit area and rate of transpiration of Coconut

Treatments	Chlorophyll 'a' mg/g	Chlorophyll 'b' mg/g	Chlorophyll Total mg/g	Number of stomata (40 x)	Rate of transpiration g $H_2O/cm^2/hr.$
			Leaves		
Control	1.1717	1.4273	2.7647	5.00	0.0157
ESP 12	0.8450	0.9590	1.4877	5.33	0.0169
ESP 24	0.6597	0.6770	1.3367	6.66	0.0204
ESP 36	0.6440	0.6890	1.3330	8.67	0.0235
ESP 41 (P.S.)	0.5327	0.6373	1.1700	11.00	0.0268
ESP 48	0.4060	0.4760	0.8820	11.33	0.0272
ESP 60	0.3020	0.3410	0.6430	12.67	0.0296
S.E. ±	0.023	0.029	0.1563	0.436	0.0006
C.D. at 5%	0.068	0.085	0.4730	1.323	0.0019



Photo plate No. 5 : Effect of ESP levels showing gradual change in chlorophyll content in coconut

4.1.2.2.2 Effect on number of stomata

The trend of increase in number of stomata with increase in ESP was recorded (Table 22 Fig. 3). Although number of stomata increased under ESP 24. The ESP 41 (problematic soil), 48 and 60 produced similar effect which showed greater number of stomata as compared to those in rest of the treatments.

4.1.2.2.3 Effect on rate of transpiration

Transpiration rate was increased with each successive increase in ESP (Table 22 and Fig. 3).

4.1.2.3 Effect of exchangeable sodium percentage on the chemical composition

The data regarding chemical composition of leaves and roots of Coconut as influenced by various ESP levels are presented in Table 23 and 24

4.1.2.3.1 Macronutrient content of leaves and roots

4.1.2.3.1.1 Nitrogen

Leaves : An increase in the leaf nitrogen content due to ESP was noted when the level was increased to ESP 41. The ESP 36 and 41 (problematic soils) showed significant effects. Similarly as the ESP increased from 41 to 60 there was decrease in the nitrogen content of the leaves (Table 23).

Table 23: Effect of ESP on macronutrient content (Percentage) of leaves and roots of Coconut

Treatments	N	P	K	Ca	Mg	S	Mn
			Leaves				
Control	3.07	0.81	2.60	0.48	0.60	0.44	0.13
ESP 12	3.17	0.80	2.58	0.44	0.55	0.44	0.30
ESP 24	3.20	0.72	0.48	0.40	0.48	0.40	0.41
ESP 36	3.51	0.55	0.28	0.32	0.41	0.39	0.59
ESP 41	3.61	0.42	2.08	0.28	0.36	0.24	0.68
ESP 48	3.06	0.30	1.91	0.22	0.31	0.24	0.79
ESP 60	2.70	0.12	1.68	0.10	0.16	0.11	0.80
S.E.±	0.022	0.19	0.032	0.013	0.005	0.014	0.014
C.D.at 5%	0.068	0.057	0.098	0.043	0.015	0.043	0.043
			Roots				
Control	2.80	1.36	2.18	1.02	0.54	0.76	0.18
ESP 12	2.69	1.12	2.10	0.95	0.49	0.68	0.30
ESP 24	2.45	0.92	1.93	0.83	0.41	0.61	0.42
ESP 36	2.28	0.80	1.80	0.72	0.36	0.53	0.59
ESP 41	2.20	0.67	1.58	0.65	0.30	0.41	0.71
ESP 48	1.96	0.58	1.41	0.54	0.24	0.32	0.84
ESP 60	1.57	0.49	1.20	0.37	0.12	0.22	0.98
S.E.±	0.050	0.021	0.029	0.018	0.013	0.014	0.026
C.D.at 5%	0.151	0.065	0.088	0.054	0.041	0.043	0.080

Roots : The root nitrogen decreased when the ESP was raised to 24. Highest ESP level exhibited lowest nitrogen content of the leaves. ESP 36, 41 and 48 behave similarly (Table 23).

4.1.2.3.1.2 Phosphorus

Leaves : P content of the leaves decreased at the ESP 24 level. On further increase in ESP the P content decreased successfully and the lowest P content was recorded under the highest ESP level (Table 23).

Roots : As the ESP increased the P content of the roots decreased successfully (Table 23).

4.1.2.3.1.3 Potassium

Leaves : The K content of the leaves decreased when the ESP level was increased upto 24. On further increase in ESP level there was successive decrease in the K content of the leaves (Table 23).

Roots : The root K content decreased when the ESP level was increased. On further increase in ESP level there was successive decrease in K content (Table 23).

4.1.2.3.1.4 Calcium

Leaves : The Ca content of the leaves was decreased when the ESP level was increased to 24. The highest level of ESP registered lowest Ca content and as the ESP decreased from 60 to 41 there was consistent increase in Ca content (Table 23).

Roots : The root Ca decreased when the level was increased to ESP 24. On further increase in ESP level there was consistent fall in root Ca (Table 23).

4.1.2.3.1.5 Magnesium

Leaves : A very clear cut trend of decreasing in Mg content of the leaves with the increase in ESP was noted (Table 23).

Roots : In roots also it was observed that the Mg decreased with each increase in ESP level (Table 23).

4.1.2.3.1.6 Sulphur

Leaves : Sulphur content remain same upto the ESP level of 24. The lowest sulphur content was noted under highest ESP level (Table 23).

Roots : As the ESP increased the S content of the roots decreased successfully (Table 23).

4.1.2.3.1.7 Sodium

Leaves : The Na content of the leaves increased with each increment in the ESP (Table 23).

Roots : In roots also the Na content increased with every increment in the ESP level (Table 23).

4.1.2.3.1.8 Ca : Na

Leaves : Ca : Na content of leaves was highest in control plants. The ESP 12 although was on par with ESP 24 and 36 showed next highest Ca : Na content of leaves (Table 24).

Table 24: Effect of ESP on macronutrient ratios of Ca : Na and Ca + Mg + K : Na and micronutrient content of leaves and roots of Coconut

Treatments	Ca/Na	Ca+Mg+K/Na	Micronutrient ppm Zn	Fe	Mn	Cu
			Leaves			
Control	2.98	30.25	26.22	1346.89	92.18	76.10
ESP 12	1.48	11.98	24.86	1230.17	81.10	70.83
ESP 24	0.98	8.24	23.90	1145.12	70.65	62.05
ESP 36	0.54	5.10	21.70	1081.51	58.42	54.13
ESP 41 (P.S.)	0.41	4.00	19.44	823.35	48.25	41.95
ESP 48	0.28	3.05	18.54	650.93	35.39	29.23
ESP 60	0.12	2.31	16.15	337.52	20.27	18.48
S.Em. ±	0.322	2.115	0.348	40.962	2.224	2.070
C.D.at 5%	0.975	6.415	1.056	124.256	6.747	6.279
			Roots			
Control	5.87	21.65	26.22	1346.12	118.88	51.32
ESP 12	3.21	11.94	24.84	1250.58	105.82	45.76
ESP 24	2.04	7.80	23.90	1145.12	92.18	39.73
ESP 36	1.22	4.89	21.70	1081.51	79.80	30.67
ESP 41 (P.S.)	0.91	3.57	19.44	928.35	65.75	21.31
ESP 48	0.64	2.61	18.54	650.93	50.35	14.98
ESP 60	0.36	1.71	15.82	337.45	31.27	10.00
S.E.+	0.398	1.176	0.361	41.252	2.982	1.304
C.D.at 5%	1.085	3.567	1.095	125.137	9.045	3.957

Roots : Control plant showed maximum Ca : Na content of roots and the same was decreased on each subsequent of ESP upto ESP 24. The ESP 41, 48 and 60 showed almost significant results (Table 24).

4.1.2.3.1.9 Ca + Mg + K : Na

Leaves : The control plant showed maximum on Ca + Mg + K : Na content of leaves. The ESP 12 and 24 although similar ESP 12 induced more Ca + Mg + K : Na in leaves compared to those in rest of the treatments (Table 24).

Roots : Ca + Mg + K : Na of the roots decreased with the increase in ESP upto 24. ESP 41, 48 and 60 behaved similarly (Table 24).

4.1.2.3.2 Micronutrient content of leaves and roots

4.1.2.3.2.1 Zinc

Leaves : The data indicated that clearly with each increase in the ESP level there was reduction in Zn content of the leaves (Table 24).

Roots : The Zn content of the roots was also clearly depleted with every increase in the ESP level (Table 24).

4.1.2.3.2.2 Iron

Leaves : The lowest Fe content of the leaves was noticed under highest ESP level. The Fe content of the leaves increased when the ESP was decreased from 60 to 36 (Table 24).

Roots : Lowest Fe content of the roots was noted under highest ESP level and the Fe content increased with the decrease in the ESP from 60 to 41 (Table 24).

4.1.2.3.2.3 Manganese

Leaves : Very clear cut reduction in the Mn content of the leaves was noted with each increase in the ESP level (Table 24).

Roots : As the ESP level increased, Mn content decreased significantly (Table 24).

4.1.2.3.2.4 Copper

Leaves : The control plants and those under ESP 12 behaved similarly. Both these treatments showed highest Cu content in the leaves. As the ESP was further increased there was successive decrease in Cu content (Table 24).

Roots : The Cu content of the roots decreased with every increment in the ESP level (Table 24).

4.1.3 Markingnut

4.1.3.1 Effect on plant height

The data presented in table 25 indicated that control plants were tallest throughout the period of investigation. The marked depressive effect due to ESP was

Table 25: Effect of ESP on percentage increase in plant height, number of leaves and stem diameter of markingnut

Treatment	Days after planting					
	60	120	180	240	300	360
			Plant height			
Control	18.52	28.09	52.31	77.83	87.79	89.42
ESP 12	16.17	22.22	39.75	62.30	70.76	73.83
ESP 24	13.03	21.78	37.46	52.00	-	-
ESP 36	12.52	20.92	30.72	44.21	-	-
ESP 41	12.18	18.20	30.29	40.40	-	-
ESP 48	8.94	15.38	27.31	-	-	-
ESP 60	7.99	13.08	23.49	-	-	-
S.E. ±	0.363	0.581	0.594	1.165	1.725	1.702
C.D. at 5%	1.101	1.764	1.802	5.671	6.774	6.682
			Number of leaves			
Control	75.80	110.18	250.51	300.48	463.34	566.67
ESP 12	50.87	90.87	215.50	266.67	355.50	375.81
ESP 24	40.18	75.91	189.10	235.33	-	-
ESP 36	33.36	63.33	166.67	200.10	-	-
ESP 41	28.25	51.25	130.11	150.83	-	-
ESP 48	26.10	50.20	100.34	-	-	-
ESP 60	21.81	35.22	40.35	-	-	-
S.E.±	2.120	4.791	7.633	7.798	20.034	36.731
C.D.at 5%	6.432	14.55	23.154	24.571	78.651	144.199
			Stem diameter			
Control	50.83	120.32	173.81	221.18	260.86	266.86
ESP 12	40.93	100.38	146.10	171.13	250.34	253.34
ESP 24	40.44	80.24	112.82	151.12	-	-
ESP 36	33.33	66.35	96.67	137.27	-	-
ESP 41	32.33	60.13	88.82	100.38	-	-
ESP 48	28.10	50.38	65.66	-	-	-
ESP 60	25.90	45.28	57.53	-	-	-
S.E.±	1.011	3.669	3.861	4.271	3.178	3.178
C.D.at 5%	3.066	11.129	11.721	13.271	2.477	12.477

seen right from 60 days after planting. Although plants in all treatments survived till 180 days after planting the plants under ESP 48 and 60 died at 240 days after planting. ESP 60 showed severest depressive effect which was followed by ESP 48 and ESP 41 during the course of investigation. There was hardly any difference between the ESP 24 and in this regard.

4.1.3.2 Effect on number of leaves

Control plants had maximum number of leaves which was followed by those under ESP 12. Plants under ESP 24 and above survived upto about 8 months. The plants under ESP 48 and 60 were recorded surviving only upto about 6 months. There was hardly any difference in the effect of ESP 41 and 48 till about 4 months after planting. In the case of rest of the treatments it was observed that the number of leaves decreased at various stages with the increase in the ESP (Table 25).

4.1.3.3 Effect on stem diameter

Control plant showed maximum stem diameter. Stem diameter was similar under ESP 12 and 24 and was though similar at 60 days after planting the depressive effect of ESP was observed from 120 days after planting. Most striking depressive effect was that of ESP 60 which was however not different from that of ESP 48 (Table 25).

4.1.3.4 Effect on plant spread

The control plants exhibited largest plant spread followed by that from ESP 12 and ESP 24. There was hardly any difference between the effect of ESP 36 and 41. Similarly ESP 41, 48 and 60 showed similar effects (Table 26).

Table 26: Effect of ESP on plant spread, total leaf area per plant and mortality of Markingnut

Treatments	Plant spread (cm)	Total leaf area (sq.cm.)	Mortality (per cent)
Control	24.50	647.65	00.00 (00.57)
ESP 12	20.10	419.36	40.33 (39.47)
ESP 24	12.30	309.38	100.00 (90.00)
ESP 36	11.00	245.62	100.00 (90.00)
ESP 41	10.00	219.00	100.00 (90.00)
ESP 48	8.66	178.10	100.00 (90.00)
ESP 60	8.00	155.27	100.00 (90.00)
S.E.±	0.693	12.214	- 4.836
C.D.at 5%	2.090	37.050	- 14.671

* Thr figures in parenthese indicate transformed percentage value into arcsine value.

4.1.3.5 Effect on leaf area

The depressive effect of the ESP was seen right from the ESP 12 which continued upto ESP 36. The most striking depressive effect was recorded under ESP 60 which was however on par with that under ESP 48 (Table 26).

4.1.3.6 Effect on plant mortality

Hundred per cent plant mortality was observed at and above ESP 24. ESP 48 and 60 started showing mortality symptoms right from 90 days after planting while the mortality symptoms were recorded under ESP 24, 36 and 41 from 150 days after planting. Complete mortality of the plants under ESP 48 and 60 was observed at 240 days after planting. The plants under ESP 24, 36 and 41 however, were completely dried when they attained 300 days after planting. The initial symptoms of mortality were drying of tips, which then continued upto stem and finally the plants died (Table 26 and Fig. 1).

4.1.3.7 Effect on root length

Root length started decreasing right from ESP 12 and the same went on decreasing with the increase in ESP upto 36. The problematic soil which had 41 ESP showed similar effect to that of ESP 36 and 48. Similarly there was no difference in the effect of ESP 48 and 60 (Table 27).

4.1.3.8 Effect on root volume

The root volume decreased due to the ESP levels. The ESP 12 showed greater root volume than ESP 41 and above. There was no difference between the treatments ESP 36, 41, 48 and 60 (Table 27).



Photo plate No. 6 : Effect of ESP 60 causing leaf injury 300 days after planting

Table 27: Effect of ESP on root length, root volume, number of primary roots, number of secondary roots and total number of roots of Markingnut

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots
Control	28.00	10.90	11.27	55.00	66.27
ESP 12	25.50	8.10	10.00	40.10	50.10
ESP 24	20.50	6.98	8.10	40.61	48.71
ESP 36	12.10	6.00	5.57	27.80	33.37
ESP 41	10.20	5.50	3.60	16.10	19.70.
ESP 48	8.30	4.00	3.30	10.41	13.71
ESP 60	6.10	4.00	2.00	2.25	4.25
S.E.±	0.981	0.401	0.503	1.677	2.122
C.D.at 5%	2.977	1.203	1.526	5.088	6.436

4.1.3.9 Effect on number of primary roots

The depressive effect of ESP was started from ESP 24 which continued with increase in the ESP upto 41. The most striking depressive effect was from ESP 60 which was however, not different from that of ESP 48 (Table 27).

4.1.3.10 Effect on number of secondary roots

The number of secondary roots decreased right from ESP 12. It was lowest under ESP 60 which was followed by ESP 48 (Table 27).

4.1.3.11 Effect on total number of roots

Total number of roots decreased significantly right from ESP 12. Lowest number of roots was recorded under ESP 60 which was followed by ESP 48 (Table 27).

4.1.3.12 Effect on fresh weight of whole plant

Fresh weight of whole plant was reduced from ESP 24. Lowest fresh weight was recorded under ESP 60 which was however, on par to that of ESP 48 (Table 28).

Table 28: Effect of ESP on fresh and dry weight of whole plant, root and top of Markingnut

Treatment	Fresh weight of whole plant (g)	Fresh weight of root (g)	Fresh weight of top (g)	Dry weight of whole plant (g)	Dry weight of root (g)	Dry weight of top (g)
Control	44.53	20.67	23.86	16.04	5.54	10.53
ESP 12	40.11	18.17	21.94	15.52	5.09	10.43
ESP 24	36.40	16.50	19.90	14.41	4.87	9.54
ESP 36	25.67	11.00	14.67	12.86	4.43	8.43
ESP 41	23.50	10.33	13.17	10.83	3.92	6.91
ESP 48	17.17	8.00	9.17	9.36	3.00	6.36
ESP 60	13.17	5.33	7.84	7.53	2.75	4.78
S.E.±	1.524	0.894	1.094	0.531	0.286	0.415
C.D.at 5%	4.622	2.440	3.318	1.612	0.888	1.268

4.1.3.13 Effect on fresh weight of root

Fresh weight of root was started decreasing right from ESP 12 and it continued with the decrease in ESP 36. There was no difference in the effect of ESP 36 and 41. Lowest fresh weight was recorded under ESP 60 which was followed by ESP 48 (Table 28).

4.1.3.14 Effect on fresh weight of top

Fresh weight of top was reduced at and above ESP 24. Lowest fresh weight was recorded under ESP 60 which was followed by that under ESP 48 (Table 28).

4.1.3.15 Effect on dry weight of whole plant

Dry weight of whole plant was reduced at and above ESP 24. Lowest dry weight of whole plant was recorded under ESP 60 which was followed by that under ESP 48. ESP 41 and 48 behaved similarly (Table 28 and Fig.2).

4.1.3.16 Effect on dry weight of root

The dry weight of root started decreasing only at ESP 36. Lowest dry weight was recorded under ESP 60 which was however not different from that under ESP 48 (Table 28).

4.1.3.17 Effect on dry weight of top

Dry weight of top started declining from ESP 36 onwards. Lowest dry weight was recorded under ESP 60 which was followed by ESP 48 as well as by ESP 41 (Table 28).



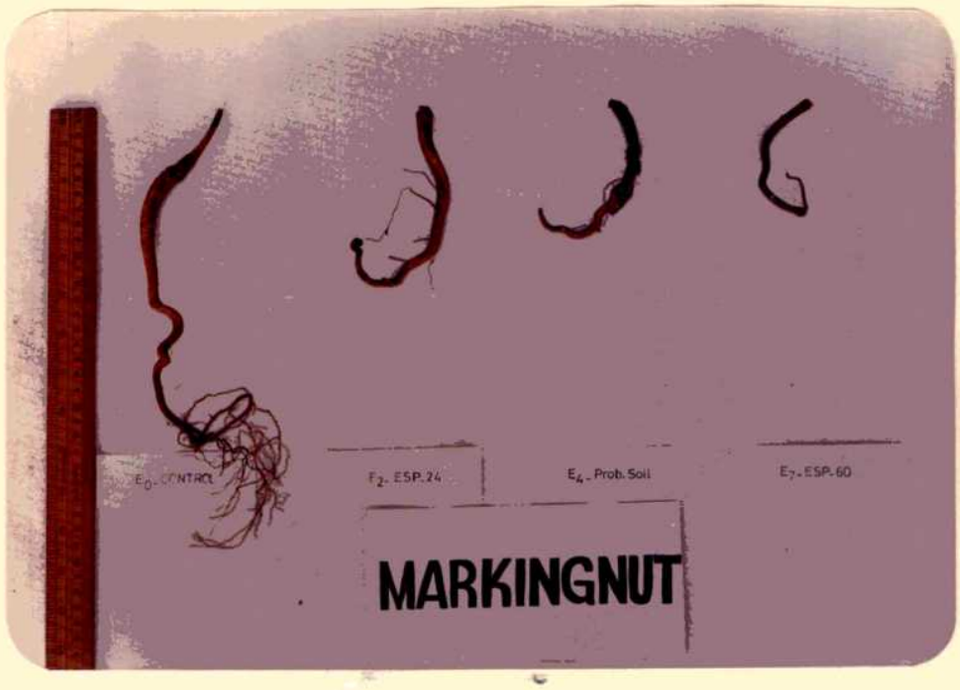


Photo plate No. 7 : Mortality symptoms as evidenced under ESP 24 and complete death of plant under ESP 60 at 340 and 240 days after planting respectively with root growth depression

4.1.3.2 Physiological parameters

4.1.3.2.1 Effect of exchangeable sodium percentage on chlorophyll content of leaves

Chlorophyll 'a' and 'b' showed stendency of decrease with the increase in ESP (Table 29). There were however exceptions between ESP 36 and ESP 41 (problematic soil). Total chlorophyll also behaved likewise.

Table 29: Effect of ESP on the chlorophyll content of leaves, number of stomata per unit area and rate of transpiration of Markingnut

Treatments	Chlorophyll 'a'	Chlorophyll 'b'	Chlorophyll Total	No.of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr.$
	mg/g				
			Leaves		
Control	1.0650	1.2713	2.3363	20.00	0.0843
ESP 12	0.9050	0.9800	1.8830	22.33	0.0683
ESP 24	0.7850	0.7623	1.5473	23.33	0.0657
ESP 36	0.6020	0.6260	1.2280	27.66	0.0657
ESP 41	0.5730	0.6227	1.1957	28.33	0.0453
ESP 48	0.4270	0.4987	0.9257	31.00	0.0370
ESP 60	0.3483	0.4070	0.7553	35.33	0.0320
S.E. ±	0.025	0.032	0.0501	1.254	0.0024
C.D.at 5%	0.077	0.097	0.1522	3.833	0.0073

4.1.3.2.2 Effect on number of stomata

Number of stomata started increasing from ESP 36 (Table 29 and Fig.3). Maximum number of stomata were recorded under ESP 60 which was however not different from that under ESP 48.

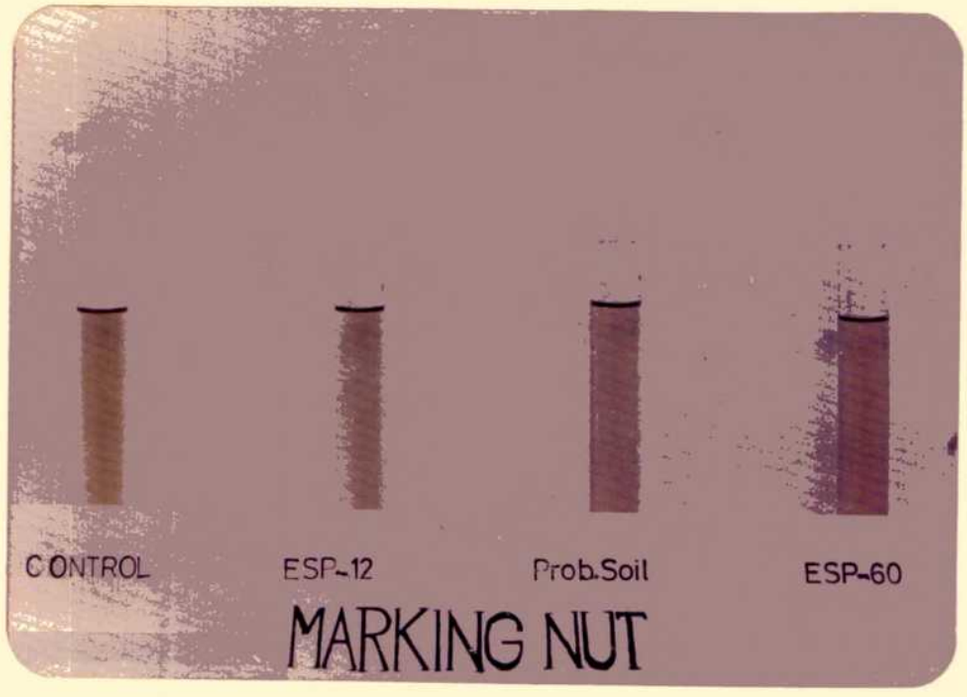
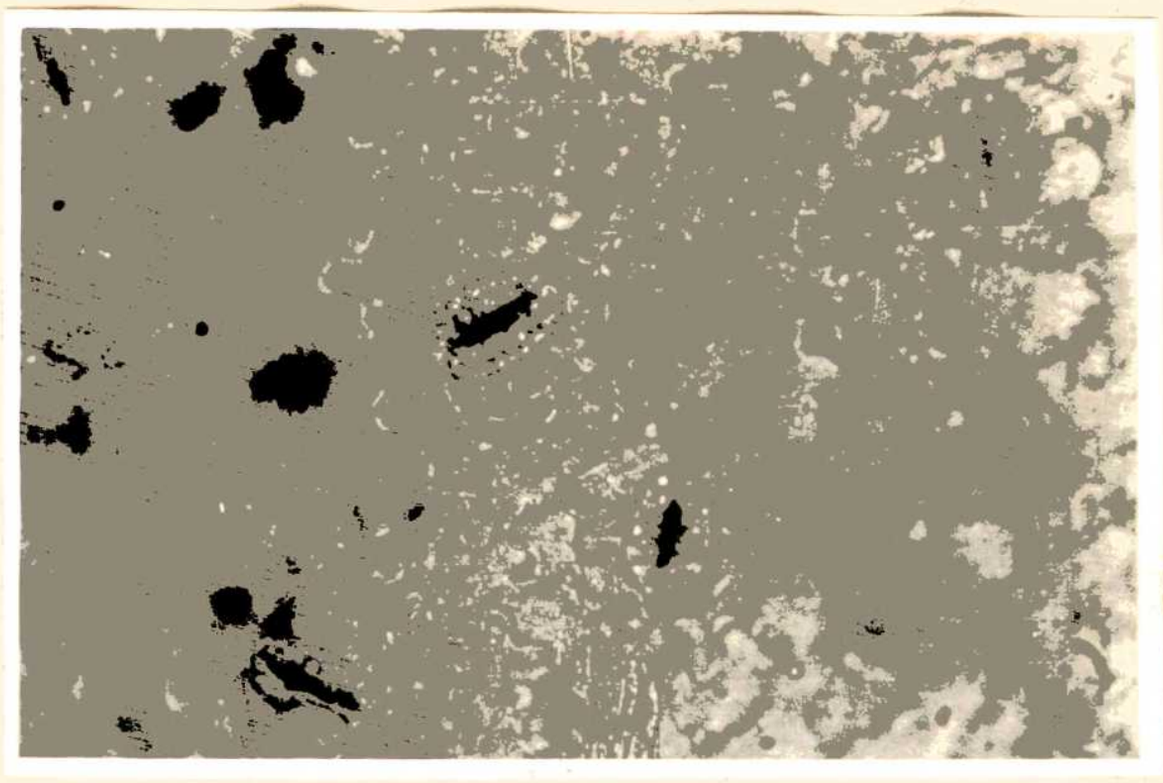


Photo plate No. 8 : Effect of ESP levels showing gradual change in chlorophyll content in Markingnut



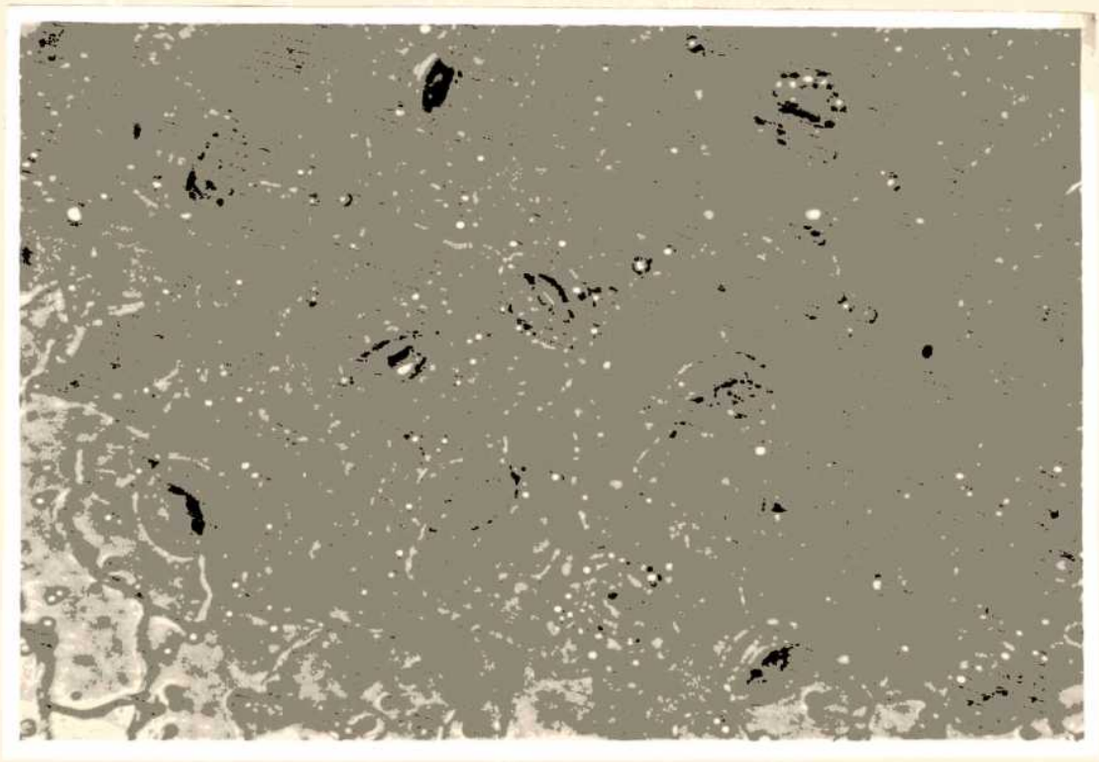


Photo plate No. 9 : Effect of ESP 60 on density of stomata number compared to control in Markingnut

4.1.3.2.3 Effect on rate of transpiration

Although there was exception between the effect of ESP 24 and 36 a general decrease in the transpiration rate was noticed with the increase in the ESP (Table 29 and Fig. 3).

4.1.3.3 Effect of exchangeable sodium percentage on chemical composition

The data regarding chemical composition of leaves and roots and stem of Markingnut as influenced by various ESP levels are resulted in Table 30 and 31.

4.1.3.3.1 Macronutrient content of leaves, roots and stem

4.1.3.3.1.1 Nitrogen

Leaves : N content of leaves started increasing with more or less similar effects when the ESP was raised to 41 (problematic soil). The lowest N was recorded under ESP 60 which was however statistically different from ESP 48 (Table 30).

Roots : In the case of roots the N declined when the ESP was raised to 24. Lowest root N content was recorded under ESP 60 which was followed by that under 48 and 41 respectively.

Stem : The stem N decreased when the ESP was raised to 24. It further decreased with the increase in ESP upto 36. The lowest stem N was recorded under highest ESP which was followed by ESP 48 and 41 respectively.

Table 30: Effect of ESP on macronutrient content (Percentage) of leaves and roots and stem or Markingnut

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	3.00	0.75	2.05	3.36	2.11	0.53	0.34
ESP 12	3.10	0.69	2.00	3.30	1.91	0.43	0.42
ESP 24	3.16	0.60	1.88	3.18	1.78	0.45	0.54
ESP 36	3.28	0.55	1.75	3.01	1.53	0.45	0.63
ESP 41	3.40	0.48	1.40	2.89	1.35	0.34	0.74
ESP 48	3.12	0.32	1.16	2.82	1.27	0.28	0.86
ESP 60	2.68	0.10	1.11	2.71	1.10	0.19	1.04
S.E.±	0.063	0.024	0.181	0.017	0.028	0.012	0.018
C.D.at 5%	0.194	0.073	0.551	0.051	0.084	0.036	0.054
			Roots				
Control	2.80	0.55	1.73	1.24	0.55	0.48	0.39
ESP 12	2.75	0.54	1.38	1.08	0.46	0.40	0.38
ESP 24	2.60	0.50	1.23	1.00	0.34	0.34	0.68
ESP 36	2.52	0.42	1.00	0.88	0.32	0.33	0.70
ESP 41	2.34	0.37	0.78	0.84	0.29	0.33	0.71
ESP 48	1.98	0.30	0.40	0.70	0.28	0.29	0.73
ESP 60	1.58	0.27	0.32	0.65	0.24	0.25	0.79
S.E.±	0.053	0.011	0.048	0.015	0.012	0.010	0.025
C.D.at 5%	0.161	0.033	0.144	0.047	0.036	0.031	0.077
			Stem				
Control	2.25	0.80	1.35	2.08	1.22	0.32	0.35
ESP 12	2.15	0.77	1.21	1.92	1.10	0.29	0.40
ESP 24	1.82	0.68	1.03	1.60	0.89	0.25	0.56
ESP 36	1.64	0.57	0.81	1.45	0.71	0.24	0.64
ESP 41	1.58	0.36	0.64	1.22	0.65	0.23	0.88
ESP 48	1.23	0.30	0.47	0.98	0.57	0.19	0.98
ESP 60	0.84	0.15	0.23	0.72	0.32	0.10	1.18
S.E.±	0.054	0.020	0.033	0.045	0.032	0.013	0.022
C.D.at 5%	0.163	0.061	0.101	0.136	0.096	0.040	0.065

4.1.3.3.1.2 Phosphorus

Leaves : The P content of the leaves under ESP_{60} was lowest which was significantly different from all other treatments. The depressive effect was started at ESP 24 (Table 30).

Roots : The depressive effect was started at ESP 24 and the root P decreased progressively with the successive increase in the ESP.

Stem : Stem P also decreased successfully with the increase in ESP.

4.1.3.3.1.3 Potassium

Leaves : Leaf K content started decreasing when ESP was raised to 24. Lowest leaf K was recorded under ESP 60 which was however not different from that under ESP 48 and 41 (Table 30).

Roots : Control plant showed maximum root K. It further decreased with increase in the ESP upto 48. The effects of ESP 48 and 60 were similar.

Stem : The stem K content decreased with increase in the ESP.

4.1.3.3.1.4 Calcium

Leaves : There was clear cut depletion in leaf Ca with each increment in the ESP (Table 30).

Roots : Similarly in roots a very positive trend of decreasing Ca was noted with the increase in the ESP.

Stem : The stem Ca was decreased significantly with the increase in the ESP.

4.1.3.3.1.5 Magnesium

Leaves : A consistent decrease in Mg content of leaves was noted with the increase in the ESP (Table 30).

Roots : The root Mg started decreasing from ESP 12 onwards which was significant upto ESP 24. Lowest root Mg was recorded under ESP 60 which was followed that under ESP 48.

Stem : The stem Mg started declining right from ESP 12 and it continued upto ESP 36. There was no difference between the effect of ESP 36 and 41. The lowest stem Mg was estimated under ESP 60 which was followed that under ESP 48.

4.1.3.3.1.6 Sulphur

Leaves : Sulphur content of the leaves was decreased from ESP 12. The effects of ESP 12, 24 and 36 were similar. The lowest leaf S was recorded under ESP 60 which was followed by that under 48 and 41 respectively (Table 30).

Roots : The root S decreased when the ESP was raised to 24. The effect of ESP 24, 36 and 41 were similar. The lowest leaf S was estimated under ESP 60 which was followed that under 48.

Stem : The depressive effect of the ESP was noticed when its level was increased to 24. The effect of 24, 36 and 41 ESP were not different from each other. The lowest S content was recorded under ESP 60 followed by that under ESP 48.

4.1.3.3.1.7 Sodium

Leaves : There was consistent increase in the Na content of the leaves with the increase in ESP (Table 30).

Roots : Although no significant at each succession, there was definite increase in the Na content of the roots with the increase in the ESP. The highest Na content was recorded under ESP 60 which was not different that under ESP 41 and 48.

Stem : The stem Na content started increasing significantly when the ESP was raised to 24 and it continued raising successfully with the further increase in ESP.

4.1.3.3.1.8 Ca : Na

Leaves : The Ca : Na content on leaves decreased successively with increase in the ESP (Table 31).

Roots : The Ca : Na content of the roots was decreased when the ESP was raised to 24. The effect of treatment ESP 24 and above were similar.

Stem : The Ca : Na content of the stem started decreasing at ESP 12 and continued same upto ESP 41. The lowest ratio was recorded under ESP 60 which was not different from that under ESP 48.

Table 31: Effect of ESP on macronutrient ratios of Ca : Na and Ca + Mg + K : Na and micronutrient content of leaves and roots and stem of Markingnut

Treatments	Ca/Na	Ca+Mg+K/Na	Micronutrient in ppm			
			Zn	Fe	Mn	Cu
			Leaves			
Control	9.91	22.25	49.73	1495.84	176.34	134.50
ESP 12	7.89	17.22	47.92	1399.37	163.17	129.23
ESP 24	5.89	12.68	45.73	1251.10	124.23	120.17
ESP 36	4.78	9.99	41.59	1153.17	108.10	103.89
ESP 41	3.91	7.88	38.81	1001.30	98.23	96.83
ESP 48	3.28	6.09	34.33	883.10	90.10	90.17
ESP 60	2.61	4.78	24.79	510.79	59.50	80.30
S.Em.±	0.225	0.398	1.139	43.347	3.417	1.873
C.D.at 5%	0.682	1.206	3.454	131.490	10.365	5.681
			Roots			
Control	3.76	10.12	143.77	1546.19	100.96	86.72
ESP 12	2.99	8.04	127.94	1373.79	83.86	69.02
ESP 24	1.47	3.27	99.40	1154.34	79.27	62.95
ESP 36	1.26	3.14	71.46	843.73	52.66	55.54
ESP 41	1.18	2.69	38.90	801.85	34.46	36.28
ESP 48	0.96	1.89	25.13	545.82	31.59	32.74
ESP 60	0.82	1.53	17.20	423.20	29.29	30.09
S.E.±	0.412	0.679	4.131	37.924	5.810	1.734
C.D.at 5%	1.250	2.061	12.531	115.041	17.625	5.260
			Stem			
Control	5.95	13.31	29.57	1725.22	81.84	99.11
ESP 12	4.85	10.64	28.82	1618.10	78.10	91.83
ESP 24	2.88	5.79	27.10	1541.58	72.82	79.13
ESP 36	2.29	4.69	26.22	1536.05	64.63	64.37
ESP 41	1.41	2.79	23.10	1389.87	53.14	49.73
ESP 48	0.99	2.07	20.86	1210.11	48.93	38.23
ESP 60	0.61	1.07	15.10	987.87	31.37	23.89
S.E.±	0.175	0.328	1.840	30.005	2.154	2.509
C.D. at %	0.532	0.994	5.578	91.019	6.533	7.612

4.1.3.3.1.9 Ca + Mg + K : Na

Leaves : The Ca + Mg + K : Na content of the leaves decreased consistently with the increase in ESP (Table 31).

Roots : The decrease in Ca + Mg + K : Na in roots was started from ESP 12 and continued upto ESP 24. There was hardly any difference between the effects of ESP 24 and above.

Stem : A consistent decrease in Ca + Mg + K : Na ratio with the increase in ESP was noted upto ESP 41. The lowest ratio was recorded under ESP 60 which was followed that under ESP 48.

4.1.3.3.2 Micronutrient content of leaves, roots and stem

4.1.3.3.2.1 Zinc

Leaves : A significant decrease in Zn content of the leaves was noticed when the ESP was increased. Lowest Zn content was recorded under ESP 60 which was followed that in ESP 41 and 48 respectively (Table 31).

Roots : A consistent decrease in Zn content of roots was estimated with each increment in the ESP level (Table 31).

Stem : The Zn content of the stem was decreased only when ESP was increased to 41. The lowest Zn content in the stem was noted under ESP 60 which was followed that under ESP 48.

4.1.3.3.2.2 Iron

Leaves : The Fe content decreased when the ESP was increased to 24. Lowest Fe content of the leaves was recorded under highest ESP which was followed by that under ESP 48 and 41 respectively (Table 31).

Roots : As the ESP increased from 12 to 36 there was consistent decrease in the Fe content of the roots. Lowest Fe content was recorded under highest ESP which was followed by that under ESP 48.

Stem : The stem Fe content decreased right from ESP 12. The lowest stem Fe content was recorded under highest ESP which was followed by that under ESP 48 and 41 respectively.

4.1.3.3.2.3 Manganese

Leaves : A consistent decrease in Mn content of the leaves with the increase in the ESP upto 36 was noted. Lowest Mn content was recorded under ESP 60 which was followed by that under ESP 48.

Roots : The depression effect of the ESP in regard to the root Mn content was noted right from ESP 12. Lowest Mn content of the roots was recorded under ESP 60, however, which was not different that under ESP 41 and 48.

Stem : The stem Mn content was decreased when the ESP was increased to 12. The lowest Mn content of the stem was recorded under ESP 60 which was followed by that under ESP 48.

4.1.3.3.2.4 Copper

Leaves : The Cu content was decreased when the ESP level was increased to 24. On further increase in the ESP level there was consistent fall in the Cu content of the leaves (Table 31).

Roots : The Cu content of the roots fell consistently with the increase in ESP upto 41. The lowest Cu content in roots was recorded under ESP 60 which was not different from that under ESP 48.

Stem : As the ESP increased the Cu content of the stem decreased consistently.

4.1.4 Soapnut

4.1.4.1 Effect on plant height

The data in Table 32 showed that the plant height was significantly reduced during the entire period of investigation when the ESP was raised upto 12. On further increasing of ESP to 24, the plant height was reduced from 120 days of sowing and the trend was consistent till the end of experimentation. This trend of decrease in plant height with increase in ESP was observed by and large upto the ESP 36. ESP 36 and problematic soil (41) although showed similar effects in the beginning the difference was noted from 240 days onward after planting. Moreover reduction was in ESP 60 which was significant at 180 and 300 days after planting.

Table 32: Effect of ESP on percentage increase in plant height, number of leaves and stem diameter of Soapnut

Treatments	Days after planting					
	60	120	180	240	300	360
			Plant height			
Control	30.81	53.76	112.53	216.64	287.50	320.58
ESP 12	25.82	45.46	86.81	190.45	231.71	245.70
ESP 24	25.13	39.62	81.52	155.39	103.80	218.43
ESP 36	22.65	38.45	72.79	109.13	166.75	172.44
ESP 41	14.27	32.38	57.77	100.25	129.17	141.81
ESP 48	14.21	32.17	53.82	76.35	83.26	-
ESP 60	12.14	30.81	38.43	62.43	-	-
S.E.±	0.595	0.900	1.411	4.622	8.974	11.454
C.D.at 5%	1.803	2.731	4.280	14.021	27.655	36.038
			Number of leaves			
Control	33.33	40.41	81.47	186.52	280.89	431.53
ESP 12	26.67	33.33	52.63	166.67	246.47	366.67
ESP 24	22.67	31.25	41.18	131.35	210.31	253.30
ESP 36	18.75	27.41	37.83	94.74	206.80	247.75
ESP 41	18.61	21.50	31.38	68.75	190.80	206.48
ESP 48	13.33	16.63	22.22	44.40	137.37	-
ESP 60	12.50	13.76	20.18	35.50	-	-
S.E.±	0.803	0.871	1.831	4.827	7.230	11.831
C.D. at 5%	2.437	2.643	5.614	14.643	22.280	37.276
			Stem diameter			
Control	60.40	160.43	133.33	183.33	186.37	250.38
ESP 12	40.54	120.70	133.33	166.67	183.33	241.81
ESP 24	40.33	114.03	116.67	150.56	166.67	240.44
ESP 36	33.30	66.67	113.67	138.68	143.73	200.18
ESP 41	32.00	66.67	100.50	125.73	133.73	166.83
ESP 48	30.45	60.45	86.67	120.35	120.49	-
ESP 60	27.53	51.31	55.92	83.06	-	-
S.E.±	1.508	4.614	3.110	4.437	4.913	5.129
C.D.at 5%	4.573	13.955	9.434	13.460	14.886	16.162

4.1.4.2 Effect on number of leaves

The number of leaves decreased when the ESP was raised to 12. The trend of decreasing number of leaves with increasing ESP, continued upto ESP 36 barring few stages of observations. Effects of ESP 36 and 41 were also on the similar lines. ESP 48 however, showed a definite depressive effect over ESP 41. There was no different effects of ESP 48 and 60 in the beginning but at the end the highest level of ESP showed conspicuous depressive over that of ESP 48 although at the earlier two stages the difference was not noted (Table 32).

4.1.4.3 Effect on stem diameter

The stem diameter decreased through out the experimentation only when the ESP was raised to 36. ESP 24 also showed depressive effect through out the trial period except at the end of the experimentation. ESP 36 and 41 although showed no varying effects in the beginning, the ESP 41 showed decreased stem diameter when plants were 180 days old from the planting and this difference continued till the end of the investigation. Although the highest ESP level showed more depressive effect compared to that of ESP 48 at the end, the trend was uneven at the earlier stages of observations (Table 32).

4.1.4.3a Effect on leaflet

The number of leaflet (Table 32a) decreased when the ESP was raised to 12. On further increasing in ESP to 24 the depressive effect was noted at all stages except the stage of 240 days after planting. Although there was no difference in the effects of ESP 24 and 36 in the earlier stages. The difference became evident from 240 days after planting and onward period. More or less similar trend was between ESP 41 (problematic soil) and 48. The depressive effect of highest level of ESP over the ESP 48 was recorded only after 180 days after planting and it was maintained till the end of investigation.

Table 32a : Effect of ESP on percentage increase in leaflet of the Soapnut

Treatment	Days after planting					
	60	120	180	240	300	360
	Number of leaflet					
Control	75.18	150.10	366.66	575.10	933.68	1081.47
ESP 12	66.67	133.33	300.18	500.18	800.90	941.42
ESP 24	40.48	104.43	250.10	475.90	650.15	773.12
ESP 36	38.21	100.09	223.52	400.33	550.87	600.62
ESP 41	33.42	80.15	150.68	325.89	450.28	485.91
ESP 48	25.10	75.60	120.58	275.91	375.31	-
ESP 60	21.90	66.67	75.60	166.60	-	-
S.E.±	2.152	3.395	10.304	15.229	21.649	.39.882
C.D.at 5%	6.528	10.299	31.257	46.197	66.710	125.661

4.1.4.4 Effect on plant spread

The data (Table 33) showed that except between ESP 41 and 48, the plant decreased as the ESP increased. Highest depressive effect was recorded under ESP 60.

Table 33: Effect of ESP on plant spread, total leaf area per plant and mortality of Soapnut

Treatments	Plant spread (cm)	Total leaf area (sq.cm.)	Mortality per cent
Control	45.50	2428.57	00.00 (00.57)
ESP 12	41.00	2047.19	00.00 (00.57)
ESP 24	38.20	1847.43	00.00 (00.57)
ESP 36	31.30	1205.33	46.66 (49.02)
ESP 41	27.10	994.15	85.33 (67.45)
ESP 48	25.50	750.85	100.00 (90.00)
ESP 60	21.70	678.11	100.00 (90.00)
S.E. ±	0.959	40.144	- 3.051
C.D. at 5%	2.911	120.776	- 9.256

The figures in parentheses indicate transformed percentage value in to arcsine value.

4.1.4.5 Effect on leaf area

The total leaf area decreased with increase in ESP upto 48. There was no difference between ESP 48 and 60 (Table 33).

4.1.4.6 Effect on plant mortality

The data regarding plant mortality are given in Table 33 and shown graphically in Fig. 1. There was no mortality recorded upto ESP 24. As the ESP increases

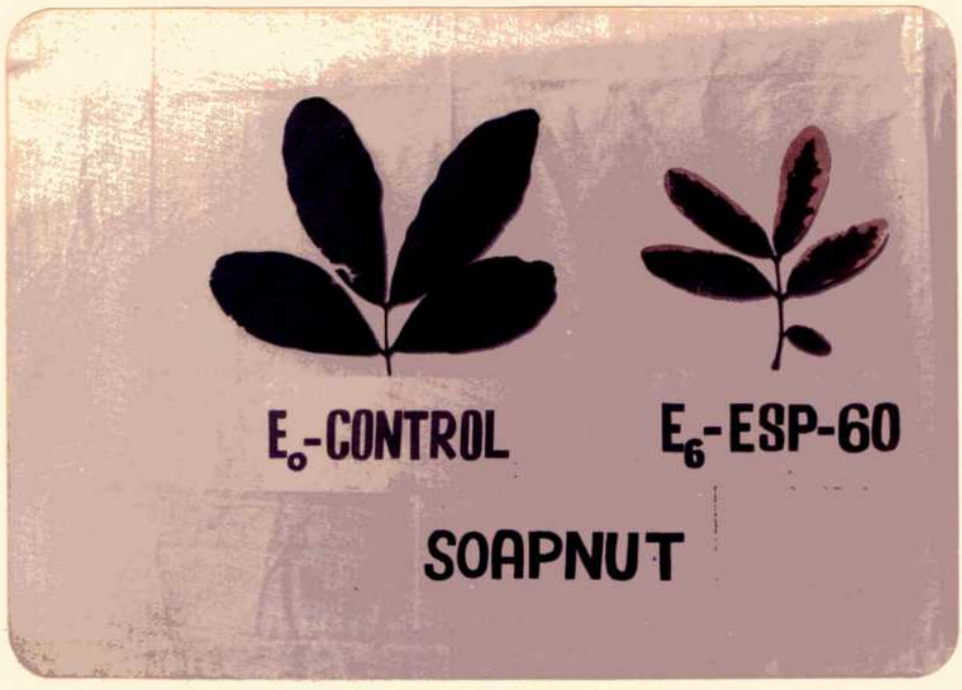


Photo plate No. 10 : Mortality symptoms as seen by burning of leaf margins under ESP 60 at 200 days after planting

from 36 to 60 the mortality increased. There was complete mortality at ESP 48 and 60. The signs of mortality were started from 210 and 248 days in ESP 60 and 48, respectively. Burning was noted from the margin and it gradually reached inner parts of the leaf. Complete death occured after 300 and 360 days of planting in ESP 60 and 48, respectively.

4.1.4.7 Effect on root length

The root length decreased only when ESP was raised to 36. There was no difference in the effects of ESP 36 and 41 (problematic soil). The effects of ESP 41, 48 and 60 were not different from each other (Table 34).

Table 34: Effect of ESP on root length, root volume, number of primary roots, number of secondary roots and total number of roots of Soapnut

Treatment	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Rotal number of roots
Control	64.50	70.70	39.40	387.10	426.50
ESP 12	61.20	65.00	32.20	270.10	302.20
ESP 24	60.00	51.12	27.10	204.50	231.60
ESP 36	30.50	38.00	21.90	66.01	87.91
ESP 41	24.10	24.30	18.60	54.11	72.71
ESP 48	22.50	20.10	13.30	40.33	53.63
ESP 60	21.30	17.00	10.27	31.62	41.89
S.E.±	2.357	3.021	0.873	10.312	14.025
C.D.at 5%	7.150	9.153	2.848	31.245	42.943

4.1.4.8 Effect on root volume

The adverse effect was recorded when the ESP was raised to 24. ESP 24, 36 and 41 showed adverse effect in descending order. Plants subjected to ESP 41. 48 and 60 showed similar root length (Table 34).

4.1.4.9 Effect on number of primary roots

The data presented in Table 34 indicated that the primary roots decreased significantly with the increasing ESP levels. However, the at the initial level of ESP, the decrease in primary roots was maximum as compared to control.

4.1.4.10 Effect on number of secondary roots

The secondary roots decreased when the ESP was raised to 24. ESP 36, 41 and 48 behaved similarly (Table 34). ESP 36 showed more pronounced reduction in secondary roots compared its preceeding levels ESP 41, 48 and 60 had similar effects.

4.1.4.11 Effect on total number of roots

The number of roots (Table 34) decreased with the increase in ESP upto 36. ESP 36 again was found to be highly effective in reduction of total number of roots as compared to its lower level of ESP. ESP 41, 48 and 60 exhibited similar effects.

4.1.4.12 Effect on fresh weight of whole plant

With the reduction in ESP upto 48 there was decrease in the fresh weight of whole plant. Plants under ESP 48 and 60 gave similar weights (Table 35).

Table 35: Effect of ESP on fresh and dry weight of whole plant, root and top of Soapnut

Treatment	Fresh weight of whole plant (g)	Fresh weight of root (g)	Fresh weight of top (g)	Dry weight of whole plant (g)	Dry weight of root (g)	Dry weight of top (g)
Control	223.00	73.33	149.67	65.34	23.42	41.92
ESP 12	158.67	53.33	105.34	58.15	17.60	40.55
ESP 24	128.67	43.00	85.67	48.55	14.62	33.93
ESP 36	64.33	18.00	46.33	22.53	7.20	15.33
ESP 41	51.00	17.00	31.67	21.09	7.02	14.07
ESP 48	30.07	11.17	18.90	14.97	5.14	9.83
ESP 60	27.17	10.33	16.84	13.84	4.84	9.00
S.E.±	3.592	1.146	2.608	3.395	0.430	1.008
C.D. at 5%	10.897	3.477	7.511	10.298	1.304	3.299

4.1.4.13 Effect on fresh weight of root

Reduction in the fresh weight of root recorded when the ESP was raised to 36. ESP 36 and 41 (problematic soil) showed similar effects which were superior to ESP 48 and 60. These two highest levels gave similar effects (Table 35).

4.1.4.14 Effect on fresh weight of top

The fresh weight of top decreased consistantly with increase in ESP upto 48, which was not different from ESP 60 (Table 35).

4.1.4.15 Effect on dry weight of whole plant

The adverse effect started right from ESP 12 (Table 35 and Fig. 2). Although ESP 12 and 24 showed similar effects both these levels gave more dry weight of whole plant compared to those in remaining all other higher ESP levels. ESP 36, 41, 48 and 60 behaved more or less similarly.

4.1.4.16 Effect on dry weight of root

The dry weight of root decreased when ESP was raised to 36. There was not difference in ESP 36 and 41 (problématic soil), but these two showed superior performance compared to remaining higher levels of ESP. The ESP 48 and 60 showed similar effects (Table 35).

4.1.4.17 Effect on dry weight of top

The dry weight of top was reduced when the ESP was increased to 24. ESP 24 showed more dry weight of top than remaining higher ESP levels. ESP 36 and 41 although similar, produced more dry weight than that in ESP 48 and 60 which were on par with each other (Table 35).



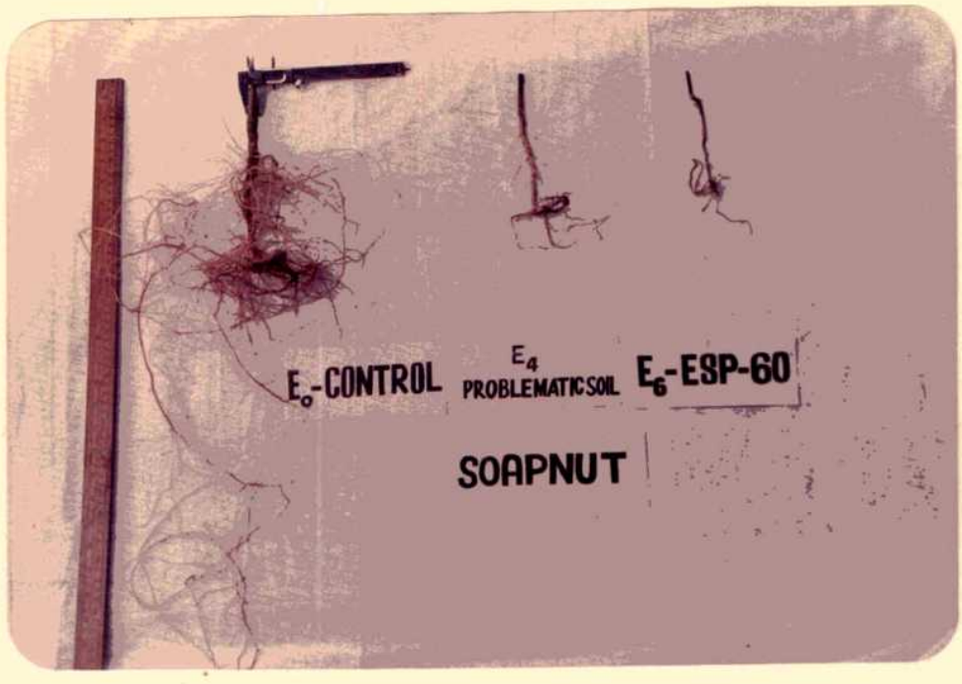


Photo plate No. 11 : Plant mortality symptoms noticed in problematic soils and complete drying of plant under ESP 60 at 300 and 360 days after planting respectively with depressive root growth

4.1.4.2 Physiological parameters

4.1.4.2.1 Effect of exchangeable sodium percentage on chlorophyll content of leaves

Chlorophyll 'a' decreased consistently upto ESP 24. There was no tendency of decrease in chlorophyll 'a' even if the ESP increased further consistently upto 41 (problematic soil). The significant decrease in chlorophyll 'a' was further recorded at ESP 48 and 60. Chlorophyll 'b' decreased at ESP 12. Total chlorophyll decreased significantly when ESP was raised upto 24. ESP 24, 36 and 41 showed similar effects.

Table 36: Effect of ESP on chlorophyll content of leaves, number of stomata per unit area and rate of transpiration of Soapnut

Treatments	Chlorophyll 'a' (mg/g)	Chlorophyll 'b' (mg/g)	Chlorophyll Total (mg/g)	Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
			Leaves		
Control	0.7500	1.5940	2.3440	25.00	0.0890
ESP 12	0.6570	1.3660	2.0230	27.33	0.0732
ESP 24	0.6447	1.1270	1.7717	27.67	0.0729
ESP 36	0.6397	1.1013	1.7410	30.33	0.0705
ESP 41	0.6250	1.0750	1.7000	33.00	0.0533
ESP 48	0.5550	0.8900	1.4450	36.00	0.0417
ESP 60	0.5107	0.8150	1.3257	39.67	0.0371
S.E.±	0.010	0.033	0.0421	1.315	0.0033
C.D.at 5%	0.031	0.100	0.1270	3.390	0.0092

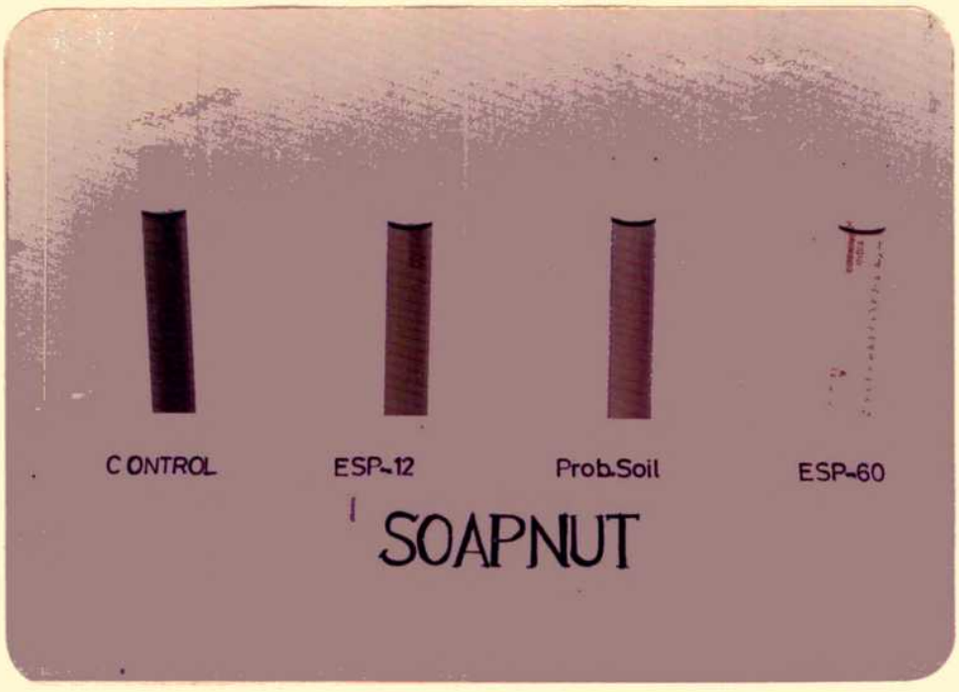


Photo plate No. 12 : Effect of ESP levels showing gradual change in chlorophyll content in Soapnut

4.1.4.2.2 Effect on number of stomata

Number of stomata decreased only when ESP raised to 36. ESP 60 produced lowest number of stomata (Table 36 and Fig. 3).

4.1.4.2.3 Effect on rate of transpiration

It was observed from Table 36 and shown graphically in Fig. 3 that ESP 12 exhibited lower rates of transpiration than control. Lowest rate of transpiration was recorded in ESP 48 and 60.

4.1.4.3 Effect of exchangeable sodium percentage on chemical composition

The data regarding chemical composition of leaves and roots of soapnut as influenced by various ESP levels are presented in Table 37 and 38.

4.1.4.3.1 Macronutrient content of leaves, roots and stem

4.1.4.3.1.1. Nitrogen

Leaves : Increase of ESP level showed higher and increasing order of N content of leaves with significant effects upto the ESP of 41 (problematic soil). However, the N content of leaves was decreased in ESP 48 to 60 (Table 37), which was lowest compared to ESP levels.

Roots : Nitrogen content in roots also decreased at ESP 24 and further increased levels of ESP also decreased in nitrogen content in roots.

Stem : Nitrogen in stem decreased at ESP 12. Further decrease in nitrogen content was noticed in highest ESP levels.

4.1.4.3.1.2 Phosphorus

Leaves : Phosphorus also decreased when the ESP was increased the significant decrease and lowest P content was recorded in ESP 60 (Table 37).

Roots : Phosphorus was decreased when the ESP was raised upto 41. Although ESP 60 was on par to ESP 48 showed lower P content than rest of the treatments.

Stem : Stem P decreased when ESP was at 24, which was on par to that of ESP 36. Further increase of ESP the P content was decreased.

4.1.4.3.1.3 Potassium

Leaves : Potassium decreased non significantly in the ESP from 12 to 36. Further increase of ESP reduced the K content significantly (Table 37).

Roots : Potassium decreased at ESP 24. The lowest K content was recorded under highest ESP level.

Stem : Potassium decreased only when the ESP was raised to 24. Further increase in ESP reduced the K content of stem.

4.1.4.3.1.4 Calcium

Leaves : Leaves Ca content decreased with the ESP increase (Table 37).

Table 37: Effect of ESP on macronutrient content (Percentage) of leaves, roots and stem of Soapnut

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	2.92	1.35	2.15	1.96	1.06	0.66	0.41
ESP 12	3.00	1.22	1.93	1.88	0.95	0.60	0.59
ESP 24	3.30	1.05	1.90	1.72	0.84	0.49	0.79
ESP 36	3.32	0.92	1.88	1.60	0.79	0.42	0.88
ESP 41	3.80	0.82	1.80	1.52	0.74	0.36	0.92
ESP 48	2.82	0.72	1.68	1.44	0.70	0.30	1.03
ESP 60	2.52	0.44	1.53	1.36	0.51	0.18	1.29
S.E.±	0.066	0.034	0.020	0.013	0.017	0.014	0.032
C.D.at 5%	0.200	0.103	0.061	0.041	0.052	0.043	0.098
			Roots				
Control	2.91	1.42	1.50	1.00	0.60	0.50	0.33
ESP 12	2.85	1.37	1.45	0.96	0.43	0.48	0.35
ESP 24	2.69	1.05	1.30	0.88	0.38	0.47	0.45
ESP 36	2.43	0.80	1.13	0.84	0.29	0.36	0.60
ESP 41	2.18	0.58	1.03	0.80	0.28	0.30	0.64
ESP 48	1.91	0.40	0.98	0.72	0.25	0.24	0.74
ESP 60	1.73	0.35	0.55	0.65	0.19	0.20	0.76
SE±	0.036	0.071	0.045	0.012	0.014	0.013	0.015
CD at 5%	0.110	0.211	0.137	0.035	0.042	0.038	0.047
			Stem				
Control	1.82	1.22	1.37	1.08	0.55	0.39	0.13
ESP 12	1.57	1.17	1.30	1.00	0.50	0.36	0.14
ESP 24	1.54	1.00	1.20	0.84	0.43	0.33	0.28
ESP 36	0.98	0.92	1.06	0.78	0.36	0.27	0.34
ESP 41	0.84	0.79	0.92	0.52	0.31	0.19	0.41
ESP48	0.77	0.53	0.68	0.43	0.25	0.13	0.47
ESP 60	0.58	0.21	0.35	0.20	0.10	0.10	0.50
S.E.±	0.042	0.038	0.032	0.030	0.013	0.015	0.112
C.D.at 5%	0.129	0.114	0.098	0.091	0.041	0.045	0.037

Roots : There was clear cut depletion in leaf Ca with the each increment of ESP.

Stem : The stem Ca decreased when ESP was raised to 24. The lowest Ca content was recorded in highest ESP levels.

4.1.4.3.1.5 Magnessium

Leaves : Magnesium decreased with increased ESP level upto 36 (Table 37). ESP 36 and 41 (problematic soil) were similar. Lowest leaf Mg was recorded in highest ESP levels. The ESP 60 showed the lowest Mg content of leaves.

Roots : The roots Mg decreased when ESP levels were increased.

Stem : The stem Mg was decreased when ESP level was increased.

4.1.4.3.1.6 Sulphur

Leaves : It is evident from the data (Table 37) that the S content decreased when the ESP levels was increased.

Roots : Sulphur decreased only when ESP was raised upto 36 but non significantly. Further increase in concentrations followed in decrease of sulphur with significant differences.

Stem : Stem S decreased non significantly when the ESP was raised to 24. The stems also again decreased upto ESP 36. ESP 48 and 60 showed lowest of sulphur. But the decreased observed from problematic soil and above was severe.

4.1.4.3.1.7 Sodium

Leaves : It is observed from the data (Table 37) that there was successive increase in Na content of leaves with increase of ESP levels. The effect of treatment ESP 24 and 36 were similar.

Roots : Root Na increased when ESP was raised upto 24. The ESP 48 and 60 showed highest Na content in roots.

Stem : Stem Na increased but non significantly when ESP was raised to 41.

4.1.4.3.1.8 Ca : Na

Leaves Ca : Na in leaves decreased at ESP 12. Although the ESP 48 and 60 were on par. The ESP 60 showed lower Ca : Na than rest of the treatments (Table 38).

Roots : Ca : Na decreased in roots when ESP was raised to 24. The lowest Ca : Na was recorded in ESP 60 which was on par to ESP 48.

Stem : Ca : Na decreased in stem at ESP 12 and 24. The lowest Ca : Na was in ESP 48 and 60.

4.1.4.3.1.9 Ca + Mg + K : Na

Leaves : Table 38 showed that the ESP increased from 24 to 36, the Ca + Mg + K : Na was decreased. The lowest Ca + Mg + K : Na was recorded in ESP 60.

Roots : The Ca + Mg + K : Na in roots decreased when ESP was increased from 36 to 60. Higher levels of ESP showed lowest Ca + Mg + K : Na.

Table 38: Effect of ESP on macronutrient ratios of Ca:Na and Ca + Mg + K : Na and micronutrient content of leaves, and roots and stem

Treatments	Ca/Na	Ca+Mg+K/Na	Micronutrient in ppm. Zn	Fe	Mn	Cu
			Leaves			
Control	4.81	12.68	46.11	1569.24	253.31	207.95
ESP 12	3.21	7.69	44.31	1365.18	227.01	183.17
ESP 24	2.16	5.64	39.33	1227.18	200.47	159.25
ESP 36	1.82	4.85	33.51	1179.38	189.27	136.27
ESP 41	1.69	4.42	32.72	1012.10	177.89	109.37
ESP 48	1.41	3.72	30.29	909.09	162.48	87.01
ESP 60	1.06	2.64	18.23	703.01	130.15	70.01
S.Em.	0.150	0.253	1.378	31.412	4.585	4.324
C.D.at 5%	0.456	0.767	4.181	95.286	13.908	13.117
			Roots			
Control	3.04	9.41	50.93	1619.03	123.54	82.30
ESP 12	2.76	8.20	48.37	1500.09	103.39	79.30
ESP 24	1.96	5.71	42.04	1423.60	101.09	44.25
ESP 36	1.40	3.77	39.78	1413.43	71.80	43.15
ESP 41	1.25	3.29	36.17	1390.38	66.06	40.71
ESP 48	0.97	2.77	24.41	1384.84	63.18	38.50
ESP 60	0.85	1.82	23.96	838.01	59.75	36.28
S.E.±	0.101	0.261	3.212	57.213	3.019	2.602
C.D.at 5%	0.307	0.793	9.744	173.554	9.159	7.892
			Stem			
Control	8.61	23.94	29.35	1294.49	66.63	130.97
ESP 12	7.32	20.56	28.17	1133.14	64.34	126.33
ESP 24	3.00	8.84	24.41	962.57	60.66	90.26
ESP 36	2.28	6.48	22.15	957.11	58.59	81.13
ESP 41	1.26	4.27	18.99	810.10	52.27	69.37
ESP 48	0.91	2.88	17.83	663.75	45.84	43.83
ESP 60	0.39	1.29	8.99	489.83	30.49	28.56
S.E.±	0.382	1.107	0.998	28.951	1.718	3.754
C.D.at 5%	1.158	3.359	3.027	87.820	5.212	11.388

Stem : In stem Ca + Mg + K : Na decrease was consistent in 46 to ESP 24. The ESP 48 and 60 showed lowest Ca+Mg+K:Na and similar effect.

4.1.4.3.2.1 Micronutrient content of leaves, roots and stem

4.1.4.3.2.1 Zinc

Leaves : The Zn content of leaves (Table 38) at the ESP 60 was significantly lower as compared to control.

Roots : The Zn decreased only at the raised ESP of 36. The Zn content of roots was high under control plant than all other ESP levels.

Stem : The Zn content of stem was decreased at 24 ESP. The low Zn was recorded under higher ESP levels.

4.1.4.3.2.2 Iron

Leaves : The data presented in Table 38 showed that the Fe content was decreased when ESP was increased.

Roots : Iron content in root decreased at ESP 24. Further increase in ESP did not significantly increase the Fe content. The higher levels of ESP showed minimum Fe content of roots.

Stem : The stem Fe decreased when ESP was at 12. The lower Fe was recorded under the higher ESP levels.

The results showed that there was decrease in plant height at the first level of ESP itself compared to control during the entire period of investigation except at 180 days after planting. The results further indicated that the problematic soil and ESP 48 were statistically equal in effect only till 120 days after planting. The highest level of ESP (60 ESP) as compared to its immediate preceeding ESP level caused highly significant decrease in plant height at all growth stages.

4.1.5.2 Effect on number of leaves

The effect of ESP on number of leaves (Table 39) revealed that the first level of ESP and control did not show any statistical difference in number of leaves upto 180 days after planting, beyond which there were significant reduction in number of leaves due to ESP 12. The striking effects on number of leaves were observed at ESP level of 60 during all growth stages except at 300 days after planting.

4.1.5.3 Effect on stem diameter

The decrease in stem diameter due to ESP at 12 was similar to that of number of leaves upto 180 days of planting, thereafter, the significant decrease was there (Table 39). It was noted that the ESP level of 24 and 36 as well as ESP 48 and 60

4.1.5.5 Effect on leaf area

The leaf area was significantly reduced at every increase of ESP (Table 40). Lowest total leaf area was associated with ESP 60 which was 4 times less as compared to control.

4.1.5.6 Effect on plant mortality

The mortality per cent shown in Table 40 and Fig. 1 indicated that no mortality was seen up to ESP 36. The mortality per cent was statistically similar due to ESP 36 and 41. Significant decrease in mortality per cent was observed at ESP 48 and 60. The ESP 60 started showing mortality symptoms right from 240 days after planting and plants were completely dried when they attained 360 days age. The initial symptoms of mortality were burning of old leaves margin and it gradually reached the iner parts of leaves.

4.1.5.7 Effect on root length

The effect of ESP on length of root (Table 41) indicated that the ESP from 24, to 48 resulted significant decrease in length of root. Whereas the other ESP levels were statistically similar in effect.

4.1.5.8 Effect on root volume

An every increased level of ESP affected significant decrease in root value (Table 41). As

showed significant differences throughout the course of investigation. However, among ESP levels viz. 41 (problematic soil) and ESP 48 no significant differences were recorded during entire growth periods except at 360 days after planting.

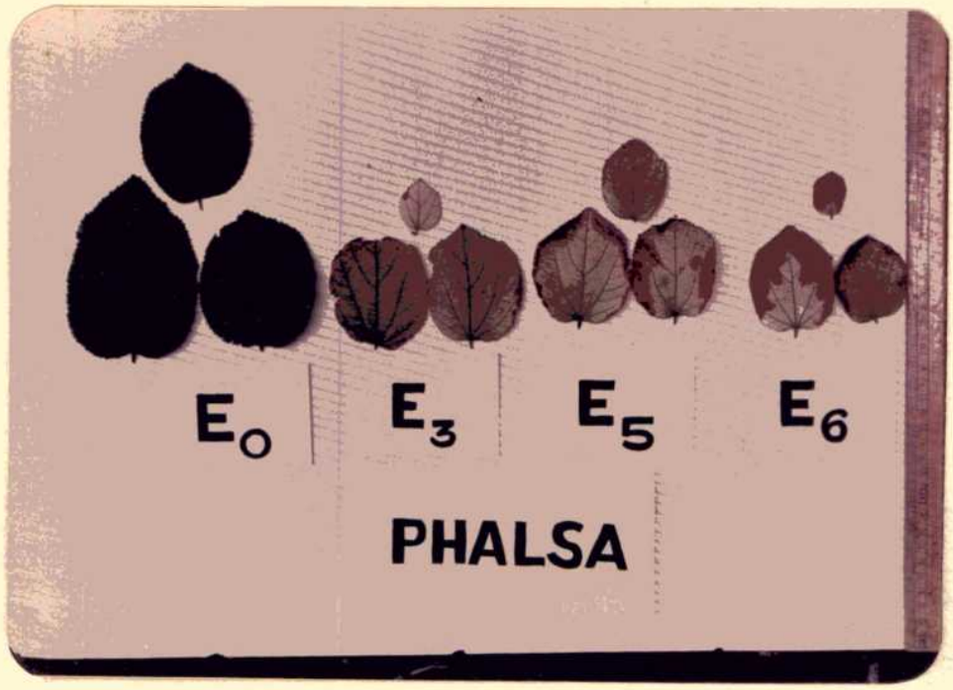
4.1.5.4 Effect on plant spread

The effect of ESP on plant spread, is shown in Table 40. From the table it was seen that ESP 36 and 41 and 48 and 60 had statistically similar decreases in plant spread. In rest of the ESP levels the decrease in plant spread was significant.

Table 40: Effect of ESP on plant spread, total leaf area per plant and plant mortality of Phalsa

Treatments	Plant spread (cm)	Total leaf area (sq.cm.)	Mortality per cent
Control	45.50	3392.75	00.00 (00.57)
ESP 12	39.10	30.53,49	00.00 (00.57)
ESP 24	34.10	2811.05	00.00 (00.57)
ESP 36	27.17	2067.59	35.00 (36.27)
ESP 41	25.17	1811.00	40.33 (39.41)
ESP 48	16.20	1061.25	76.66 (61.34)
ESP 60	15.30	870.20	100.00 (90.00)
SE ±	0.850	42.027	- 2.248
CD at 5%	2.578	127.486	- 6.820

The figures in parentheses indicate transformed value into arcsine value.



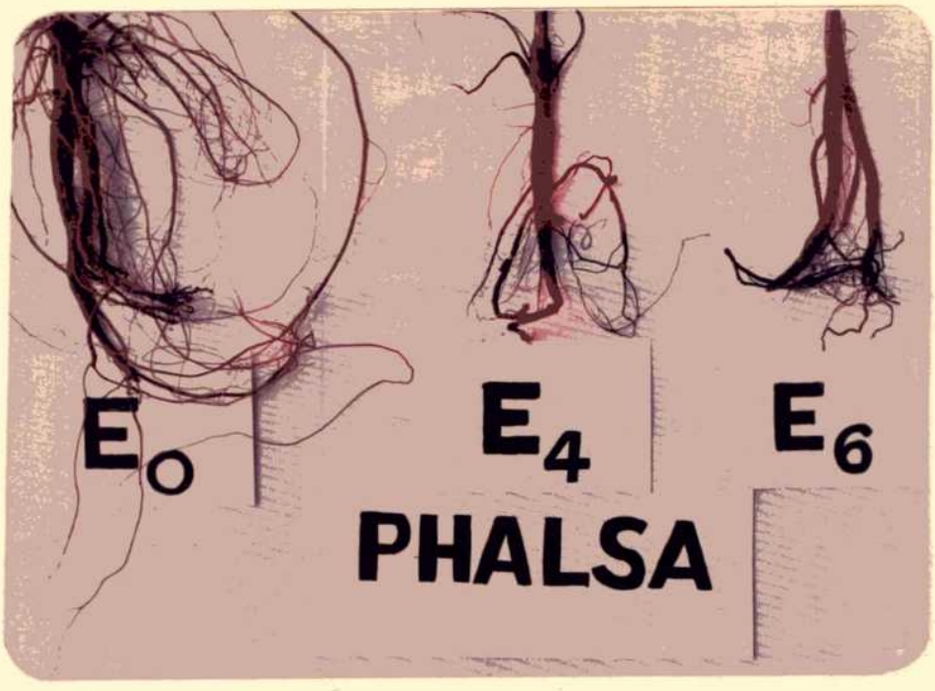


Photo plate No. 13 : Effect of ESP causing leaf injury observed at and above ESP 36 levels. The effect of ESP 41 (problematic soil) and ESP 60 on root as visualised by blackening of roots

compared to control, the root volume was three times decreased at ESP 60.

Table 41: Effect of ESP on root length, root volume, number of primary roots, number of secondary roots and total number of roots of Phalsa

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots	Number of branches
Control	50.00	25.00	13.97	104.99	118.96	4.33
ESP 12	47.60	27.90	12.00	77.20	89.20	4.00
ESP 24	45.50	20.20	11.30	61.30	72.60	4.10
ESP 36	37.80	18.10	9.99	55.00	64.99	3.30
ESP 41	25.10	14.30	8.30	28.10	36.10	2.67
ESP 48	22.10	12.50	8.00	26.40	34.40	2.33
ESP 60	20.83	9.03	6.33	20.70	27.03	2.00
S.E.±	2.542	0.514	0.433	2.507	3.009	0.218
C.D.at 5%	2.542	1.885	1.374	7.596	9.117	0.662

4.1.5.9 Effect on number of primary roots

The primary roots were also decreased due to subsequent higher levels of ESP (Table 41). Except ESP levels of 24 and 36 and ESP 36 and 41 all other levels showed statistically significant decrease in number of primary roots.

4.1.5.10 Effect on number of secondary roots

The effect of ESP on number of secondary roots (Table 41) showed that there was non-significant

decrease in number of secondary roots due to ESP 24 and 36 and from ESP 41 to 60.

4.1.5.11 Effect on total number of roots

The ESP at 12 and 48 respectively resulted into significant decrease in total number of roots compared to control and ESP 36 (Table 41).

4.1.5.11a Effect on number of branches

The effect of ESP on number of branches was not so pronounced. Though there was decrease in number of branches due to higher ESP level, the decrease was not so marked.

4.1.5.12 Effect on fresh weight of whole plant

The effect of ESP on fresh weight of whole plant (Table 42) indicated that the ESP 36 and 41 and ESP 48 and 60 had decreased the fresh weight of whole plant non-significantly. In rest of the treatments the effects were significant.

4.1.5.13 Effect on fresh weight of root

The effect of ESP on fresh weight of root due to various ESP levels was also similar to that of fresh weight of whole plant.

4.1.5.14 Effect on fresh weight of top

The fresh weight of top was found to be non significantly affected due to the ESP from 41 to 60. But the effects in earlier low level of ESP were statistically significant.

Table 42: Effect of ESP on fresh and dry weight of whole plant, root and top of Phalsa

Treatment	Fresh weight of whole plant (g)	Fresh weight of root (g)	Fresh weight of top (g)	Dry weight of whole plant (g)	Dry weight of root (g)	Dry weight of top (g)
Control	76.43	29.67	46.76	27.77	19.43	18.34
ESP 12	65.33	26.67	38.66	26.37	8.97	17.40
ESP 24	44.60	23.27	21.33	23.03	7.79	15.24
ESP 36	31.06	17.33	13.73	19.19	5.16	14.03
ESP 41	27.43	16.00	11.63	14.00	5.00	9.00
ESP 48	22.00	12.17	9.83	12.33	4.83	7.50
ESP 60	19.76	10.83	8.93	10.83	4.00	6.83
S.E.±	1.502	0.776	0.826	0.631	0.369	0.365
C.D.at 5%	4.557	2.353	2.506	1.914	1.120	1.119

4.1.5.15 Effect on dry weight of whole plant

The ESP from 12 to 41 showed significant decrease in dry weight of whole plant from each other (Table 42 and Fig. 5).

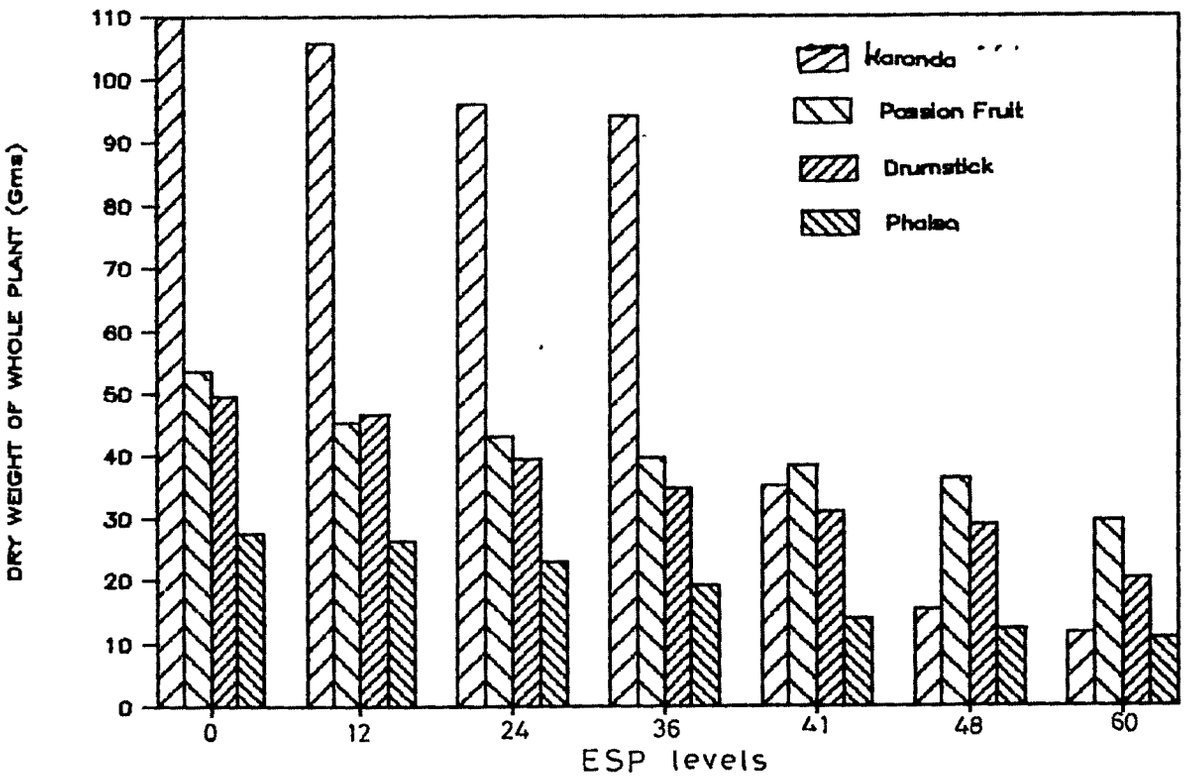


Fig 5. Effect of different levels of ESP on dry matter accumulation in Karonda, Passion fruit Drumstick and Phalsa at the time of harvest



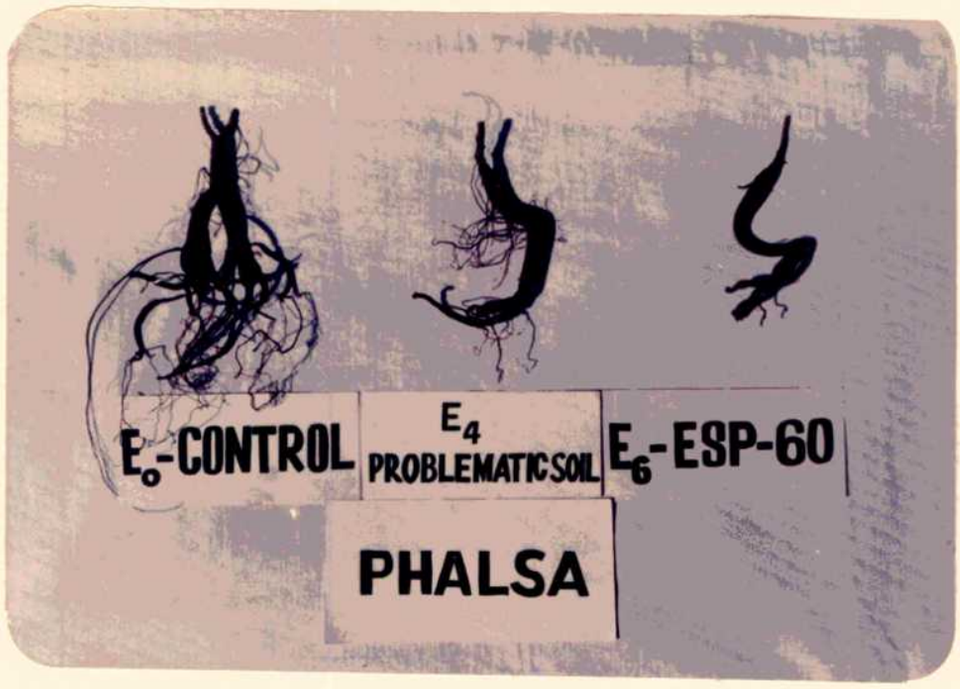


Photo plate No. 14 : Effect of ESP showing mortality symptoms on leaves and roots under problematic soil and ESP 60 at 360 days after planting

4.1.5.16 Effect on dry weight of root

The ESP 12 and 24 resulted into significant decrease in dry weight of root as compared to control. However, the higher concentrations of ESP were more or less equal in effects on dry weight of root.

4.1.5.17 Effect on dry weight of top

Except ESP 24 and 36 and ESP 36 and 41 the effects of ESP on dry weight of roots were non significant (Table 42).

4.1.5.2 Physiological parameters

4.1.5.2.1 Effect of exchangeable sodium percentage on chlorophyll content of leaves

The chlorophyll 'a' and 'b' was decreased at every increase of higher level of ESP (Table 43). However, the effect of ESP from 12 to 36 was statistically significant. Similarly, the total chlorophyll content in leaves was significantly reduced when ESP was increased from 12 to 36 and from ESP 41 to 48.

4.1.5.2.2 Effect on number of stomata

The number of stomata were statistically and significantly reduced due to the ESP from 12 to 24 and from ESP 36 to 41 (Table 43 and Fig. 3).

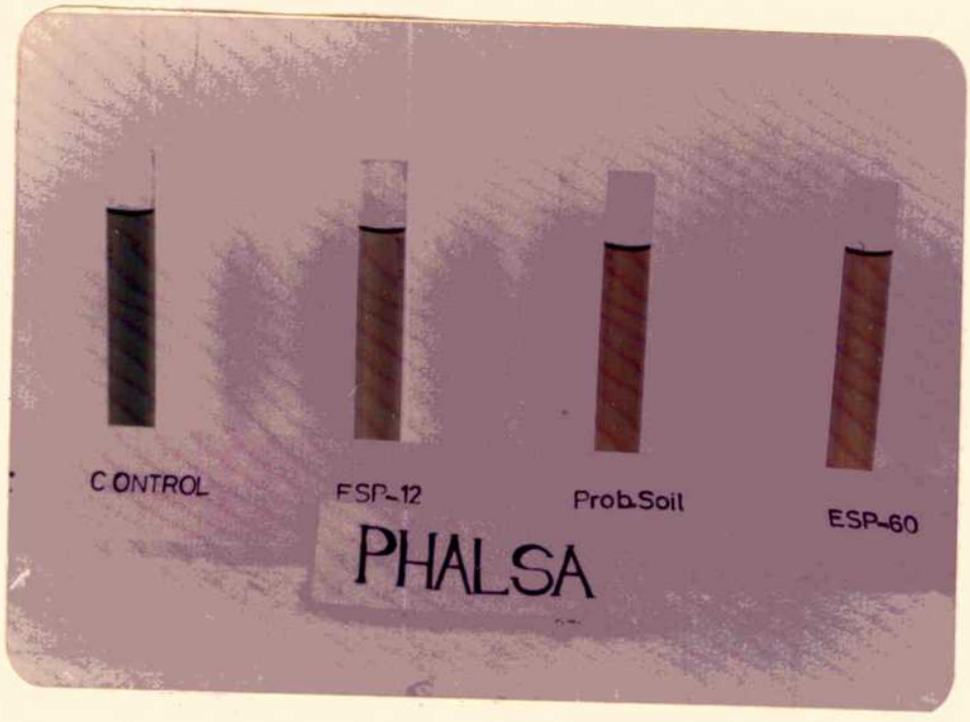


Photo plate No. 15 : Effect of ESP levels showing gradual change in chlorophyll content in Phalsa

Table 43: Effect of ESP on chlorophyll content of leaves number of stomata per unit area and rate of transpiration of Phalsa

Treatments	Chlorophyll 'a'	Chlorophyll 'b'	Chlorophyll Total	Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
	mg/g				
			Leaves		
Control	1.3700	1.2200	2.5900	21.00	0.8483
ESP 12	1.2680	1.2100	2.4780	25.00	0.0485
ESP 24	0.6830	0.6290	1.3117	31.33	0.8414
ESP 36	0.4860	0.4220	0.9080	33.00	0.83551
ESP 41	0.4200	0.4200	0.8400	36.66	0.0292
ESP 48	0.3670	0.3200	0.6870	41.00	0.0280
ESP 60	0.2700	0.2630	0.5330	43.33	0.0232
S.E.±	0.0480	0.047	0.0934	1.681	0.0022
C.D.at 5%	0.144	0.144	0.2833	5.099	0.0060

4.1.5.2.3 Effect on rate of transpiration

There was significant decrease in rate of transpiration when the ESP was increased from 12 to 36 (Table 43 and Fig. 3). In rest of the ESP levels the decrease in rate of transpiration was on par.

4.1.5.3 Effect of excahngeable sodium percentage on chemical composition

The data regarding chemical composition of leaves, roots and stem of phalsa as influenced by various ESP levels are presented in Table 44 and 45.

4.1.5.3.1 Macronutrient content of leaves, roots and stem

4.1.5.3.1.1 Nitrogen

Leaves : The N content of leaves was increased significantly upto ESP 36 thereafter significant decrease was observed (Table 44).

Roots : Though there was decrease in N content of roots at increased levels of ESP except ESP from 36 to 41, the decrease was at par to each other.

Stem : The N content of the stem statistically decreased due to ESP from 24 to 36 and ESP 41 to 48.

4.1.5.3.1.2 Phosphorus

Leaves : The P content of leaves except ESP 24 and 36 was significantly decreased in all other eESP levels (Table 44).

Roots : The ESP 24 and 36 and ESP 36 and 41 were on par in decreasing the P content of roots.

Stem : The P content of the stem was significantly decreased due every increase of higher level of ESP.

4.1.5.3.1.3 Potassium

Leaves : The control and ESP 12 and ESP 24 and 36 behaved similarly in decreasing the K content of leaves (Table 44).

Table 44: Effect of ESP on macronutrient content (Percentage) of leaves, roots and stem of phalsa

Treatments	N	P	K	Ca	Mg	S	Na
				Leaves			
Control	3.04	1.15	1.88	1.92	2.16	0.54	0.21
ESP 12	3.23	1.01	1.80	1.72	1.94	0.49	0.25
ESP 24	3.50	0.85	1.65	1.56	1.77	0.37	0.30
ESP 36	3.84	0.80	1.58	1.44	1.59	0.35	0.34
ESP 41	2.90	0.67	1.36	1.41	1.36	0.29	0.38
ESP 48	2.74	0.55	1.17	1.20	1.17	0.19	0.41
ESP 60	2.30	0.42	0.90	0.95	0.98	0.10	0.54
S.E.±	0.034	0.017	0.034	0.033	0.028	0.012	0.013
C.D.at 5%	0.103	0.052	0.103	0.101	0.085	0.036	0.041
				Roots			
Control	2.24	1.35	1.63	1.40	0.92	0.51	0.35
ESP 12	2.10	1.00	1.58	1.32	0.65	0.32	0.38
ESP 24	1.96	0.82	1.49	1.24	0.51	0.28	0.64
ESP 36	1.94	0.72	1.34	1.04	0.48	0.25	0.66
ESP 41	1.54	0.67	0.88	1.00	0.41	0.22	0.76
ESP 48	1.39	0.32	0.73	0.92	0.34	0.14	0.90
ESP 60	1.27	0.10	0.62	0.88	0.29	0.12	0.96
S.E.±	0.109	0.044	0.045	0.019	0.023	0.013	0.023
C.D.at 5%	0.332	0.134	0.138	0.057	0.069	0.040	0.069
				Stem			
Control	1.54	0.67	1.98	1.37	2.25	0.39	0.10
ESP 12	1.50	0.62	1.83	1.29	1.99	0.37	0.11
ESP 24	1.26	0.49	1.80	1.11	1.84	0.31	0.13
ESP 36	1.07	0.40	1.69	1.09	1.81	1.21	0.14
ESP 41	1.35	0.31	1.61	0.87	1.65	0.22	0.27
ESP 48	0.96	0.23	1.39	0.80	1.26	0.17	0.39
ESP 60	0.84	0.10	1.22	0.69	0.76	0.11	0.50
S.E.±	0.122	0.014	0.034	0.055	0.235	0.013	0.036
C.D.at 5%	0.369	0.043	0.103	0.166	0.714	0.039	0.109

Roots : The K content of roots was decreased significantly when the ESP was raised from 24 to 48.

Stem : The K content of stem also decreased significantly due to higher levels of ESP i.e. from 41 to 60.

4.1.5.3.1.4 Calcium

Leaves : The ESP 36 and 41 did not affect Ca content of leaves from each other. But due to other levels of ESP Ca was significantly decreased (Table 44).

Roots : The Ca content of roots was also significantly decreased upto the ESP level of 36. There was also significant decrease in Ca content of roots due to ESP 41 to 48.

Stem : Though there was decrease in Ca content of the stem due to every higher level of ESP, it was only significant due to ESP from 12 to 24 and ESP 41 to 48.

4.1.5.3.1.5 Magnessium

Leaves : The Mg content of leaves was significantly reduced due to higher subsequent levels of ESP (Table 44).

Roots : The Mg content of roots was significantly decreased when the ESP was raised from 36 to 48.

Stem : Though there was decrease in Mg content of stem due to various levels of ESP, the decrease was within the statistical limit.

4.1.5.3.1.6 Sulphur

Leaves : Except ESP from 24 to 36 all other ESP level resulted in significant decrease of sulphur content of leaves (Tabl 44).

Roots : The S content of roots was only decreased significantly due to increase level of ESP from 41 to 48.

Stem : The S content of stem decreased significantly by the ESP level from 12 to 26 and from ESP 41 to 60.

4.1.5.3.1.7 Sodium

Leaves : The Na content of leaves was increased at every increase of ESP level (Table 44). However, the increase was statistically high due to ESP from 48 to 60.

Roots : The Na content of roots was significantly increased due to the ESP from 12 to 24 and ESP from 36 to 48.

Stem : The Na content of stem though increased upto ESP 36, the increase was within the statistical limit. But beyond ESP 36 the increase was significant.

4.1.5.3.1.8 Ca : Na

Leaves : The ESP 12 and 24 showed similar effects in Ca : Na content of leaves (Table 45). But it decreased significantly due to ESP from 48 to 60.

Roots : Only the ESP from 12 to 24 resulted significantly decrease in Ca : Na content of roots.

Table 45: Effect of ESP on macronutrient ratio of Ca : Na and Ca + Mg + K : Na and micronutrient content of leaves, roots and stem of Phalsa

Treatments	Ca/Na	Ca+Mg+K/Na	Micronutrient in ppm			
			Zn	Fe	Mn	Cu
			Leaves			
Control	9.22	28.55	38.88	1730.01	249.29	78.75
ESP 12	6.92	21.93	37.98	1628.38	232.06	74.33
ESP 24	4.99	16.64	28.48	1602.44	225.74	65.33
ESP 36	2.24	13.58	28.03	1574.78	201.81	56.31
ESP 41	3.73	10.90	26.67	1481.65	189.70	48.67
ESP 48	2.95	8.64	25.32	1480.62	168.89	32.74
ESP 60	1.77	5.25	12.87	1098.37	149.36	23.68
S.E.±	0.375	0.737	1.463	39.996	3.647	2.410
C.D.at 5%	1.139	2.235	4.438	121.325	11.062	7.312
			Roots			
Control	4.31	7.97	56.06	1595.98	97.68	78.75
ESP 12	3.76	7.65	44.48	1468.75	95.30	74.33
ESP 24	2.23	4.87	25.31	1347.96	88.46	65.48
ESP 36	1.97	4.27	24.41	1165.41	86.73	48.67
ESP 41	1.12	3.01	21.70	1107.32	74.62	32.74
ESP 48	0.90	2.18	20.34	982.72	65.38	20.35
ESP 60	0.82	1.86	15.99	438.88	29.87	11.69
S.E.±	0.350	0.747	1.707	59.743	3.853	2.232
C.D.at 5%	1.062	2.667	5.177	181.227	11.687	6.770
			Stem			
Control	13.72	59.06	33.45	1632.86	147.62	68.14
ESP 12	11.12	45.12	30.82	1489.99	140.19	64.63
ESP 24	7.51	34.27	24.41	1288.11	118.83	52.78
ESP 36	5.01	21.22	23.26	1096.25	99.37	46.90
ESP 41	3.13	13.33	18.51	1076.26	93.71	30.13
ESP 48	1.78	6.79	16.73	812.32	71.80	29.20
ESP 60	1.20	4.38	8.33	648.39	58.66	17.13
S.E.±	0.560	2.970	2.15	37.880	5.619	1.972
C.D.at 5%	1.698	9.008	6.54	114.906	17.045	5.983

Stem : The ESP upto 41 showed significant decrease in Ca : Na content of stem.

4.1.5.3.1.9 Ca + Mg + K : Na

Leaves : The Ca + Mg + K : Na of leaves was decreased significantly due to different levels of ESP (Table 45).

Roots : The Ca + Mg + K : Na content of roots was decreased significantly only due to ESP when raised from 12 to 24.

Stem : The ESP upto 36 only resulted significant decrease of Ca + Mg + K : Na content of stem.

4.1.5.3.2.1 Zinc

Leaves : The ESP from 12 to 24 and from 48 to 60 only resulted significant decrease of Zn content of leaves (Table 45).

Roots : The ESP upto 24 showed significant decrease in Zn content of roots.

Stem : Though there was decrease in Zn content of stem, the decrease due to each subsequent increase of ESP level was within the statistical limit.

4.1.5.3.2.2 Iron

Leaves : The Fe content of leaves was decreased due to increase of ESP. But the ESP upto 36 and ESP from 36 to 48 showed on par decrease in iron content. The

ESP 60 showed significant decrease in Fe content to that of ESP 48 (Table 45).

Roots : The Fe content of roots was significantly decreased due to ESP 36 and 60 to that of ESP 24 and 48 respectively.

Stem : Except ESP from 36 to 41 the Fe content of stem was decreased significantly in other levels of ESP.

4.1.5.3.2.3 Manganese

Leaves : The Mn content of leaves was significantly decreased due to various concentrations of ESP except from ESP 12 to 24(Table 45).

Roots : The ESP level upto 36 and from 41 to 48 showed similar decrease in Mn content of roots. At ESP 60 the decrease was maximum.

Stem : The Mn content of stem was decreased significantly when the ESP was raised from 12 to 36 and from 41 to 48.

4.1.5.3.2.4 Copper

Leaves : All higher levels of ESP resulted into significant decrease in Cu content of leaves as compared to control (Table 45).

Roots : The decrease in Cu content of roots due to different ESP level was similar to that of leaves.

Stem : The Cu content of stem was decreased significantly when the ESP level was raised from 12 to 41 and ESP from 48 to 60.

4.1.6 Karonda

4.1.6.1 Effect on plant height

The data presented in Table 46 indicate that control plants were tallest throughout the period of investigation. Adverse effect of ESP was noted only at ESP 24. Right from 60 days after planting, marked depressive effect due to ESP was seen. The differences in plant height due to ESP 24 and ESP 36 was more or less similar except at 360 days after planting. ESP 60 showed severest depressive effect in which plants were survived only upto 240 days after planting.

4.1.6.2 Effect on number of leaves

It is evident from the data (Table 46) that the adverse effect of ESP on number of leaves was first recorded at 180 days after planting. The ESP 12 and ESP 24 showed similar effect on number of leaves from 120 to 360 days after planting. The highest level of ESP showed lowest number of leaves, which was followed by ESP 48 and ESP 41, respectively.

4.1.6.3 Effect on stem diameter

The data presented in Table 46 indicate that plants under control and ESP 12 had statistically

Table 46: Effect of ESP on percentage increase in plant height, number of leaves and stem diameter of Karonda

Treatments	Days after planting					
	60	120	180	240	300	360
			Plant height			
Control	38.36	126.66	238.20	350.48	417.12	458.36
ESP 12	33.25	118.03	225.00	308.55	367.23	404.05
ESP 24	29.29	103.27	196.18	271.07	319.21	359.79
ESP 36	25.44	100.81	191.11	266.83	311.54	337.10
ESP 41	19.03	87.26	160.51	214.19	246.77	263.17
ESP 48	16.56	74.17	132.33	176.33	197.00	209.34
ESP 60	12.36	58.15	110.61	142.14	-	-
S.E.±	1.160	2.100	3.840	7.800	8.060	9.190
C.D.at 5%	3.530	6.380	11.670	23.670	24.830	28.330
			Number of leaves			
Control	120.69	348.25	650.19	1071.45	1283.60	1389.57
ESP 12	115.38	325.79	596.78	985.20	1165.38	1248.00
ESP 24	111.30	302.63	568.34	951.63	1116.02	1186.41
ESP 36	108.20	291.10	478.27	837.11	967.27	1032.33
ESP 41	96.67	226.90	303.58	650.51	740.91	784.17
ESP 48	79.54	168.51	230.44	468.80	543.40	571.70
ESP 60	65.66	132.30	177.60	292.58	-	-
S.E.±	2.330	7.800	15.190	30.420	32.510	30.550
C.D.at 5%	7.080	23.680	48.260	92.290	100.14	94.120
			Stem diameter			
Control	75.81	151.66	266.10	379.75	465.43	502.12
ESP 12	71.90	143.67	251.67	337.32	411.08	439.98
ESP 24	66.75	137.48	220.11	275.82	344.90	367.20
ESP 36	61.35	125.11	193.27	250.12	317.34	337.18
ESP 41	47.30	80.16	131.12	167.48	199.18	211.47
ESP 48	34.77	61.20	106.39	131.55	153.26	162.31
ESP 60	28.71	58.32	100.15	117.73	-	-
S.E.±	1.840	3.380	8.110	6.730	10.920	12.060
C.D. at 5%	5.590	10.250	24.600	20.420	33.080	37.590

similar effect upto 180 days after planting and thereafter depressive effect of ESP was noted. ESP 41 produced lower stem diameter as compared to that of ESP 36 at subsequent period of investigation. ESP 48 and 60 behaved by and large similarly and showed severe depressive effect in growth as determined by stem girth.

4.1.6.4 Effect on plant spread

From the Table 47 it is evident that the plant spread declined significantly with the increase in ESP levels. The plant spread at ESP 48 and 60 was least than control and rest of treatments.

Table 47 : Effect of ESP on plant spread, total leaf area per plant and mortality of Karonda

Treatments	Plant spread (sq.cm.)	Total leaf area (sq.cm.)	Mortality (per cent)
Control	75.50	4411.98	00.00 (00.57)
ESP 12	68.90	4265.19	00.00 (00.57)
ESP 24	63.10	3827.46	00.00 (00.57)
ESP 36	50.50	3112.53	39.66 (39.41)
ESP 41	43.10	2545.67	54.00 (47.29)
ESP 48	30.70	2317.00	79.66 (63.44)
ESP 60	22.02	1671.51	100.00 (90.00)
S.E. ±	1.000	56.039	- 2.044
C.D. at 5%	3.033	169.992	- 6.200

* The figures in parenthese indicate transformed value in to arcsine value.

4.1.6.5 Effect on leaf area

The data presented in Table 47 indicates that the total leaf area per plant decreased with the increase in ESP level. However, ESP 12 produced similar leaf area as compared to control of treatment. The effect of ESP 24 and above ESP levels, the leaf area differed significantly from each other.

4.1.6.6 Effect on plant mortality

The data regarding plant mortality are presented in Table 47 and graphically shown in Fig. 1. The plants under ESP 12 and 24 did not show any kind of mortality. The mortality symptoms were started from ESP 60 and after 180 days after planting. The plants were completely died when they attained 300 days after planting at this level. The burning symptoms were first noticed on top younger leaves.

4.1.6.7 Effect on root length

It is evident from the data (Table 48) that there was corresponding decrease in root length with increase in ESP level. However, extent of root length reduction was more pronounced at 48 and 60 though they behaved similarly.





Photo plate No. 16 : Effect of ESP 41(problematic soil) showing reduced leaf area and ESP 60 with mortality symptoms of complete dechlorotic leaves 240 days after planting

4.1.2.8 Effect on root volume

Table 48 revealed that the root volume decreased with increased ESP level. The root volume at ESP 24 and 36 was statistically similar and showed more root volume as compare to higher levels of ESP.

Table 48: Effect of ESP on root length, root volume, number of primary roots, number of secondary roots and total number of roots of Karonda

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots	Number of branches
Control	68.20	50.10	21.00	124.30	145.30	18.00
ESP 12	62.50	45.30	17.90	107.00	124.90	14.68
ESP 24	57.20	39.00	14.40	83.17	97.57	12.10
ESP 36	44.00	35.20	10.70	78.17	88.87	10.00
ESP 41	42.08	27.40	8.10	63.30	71.40	9.20
ESP 48	40.10	21.40	5.96	25.12	31.08	9.00
ESP 60	40.00	14.30	4.20	20.24	24.44	9.00
S.E.±	0.969	1.303	0.626	4.306	11.052	0.617
C.D.at 5%	2.940	3.963	1.895	13.061	33.487	1.872

4.1.6.9 Number of primary roots

From the perusal of the data in Table 48 it is evident that the depressive effect of ESP was started from 24 and was continued with increase in the ESP upto 41. The most striking depressive effect was at 60 ESP which was however, not different from that of ESP 48.



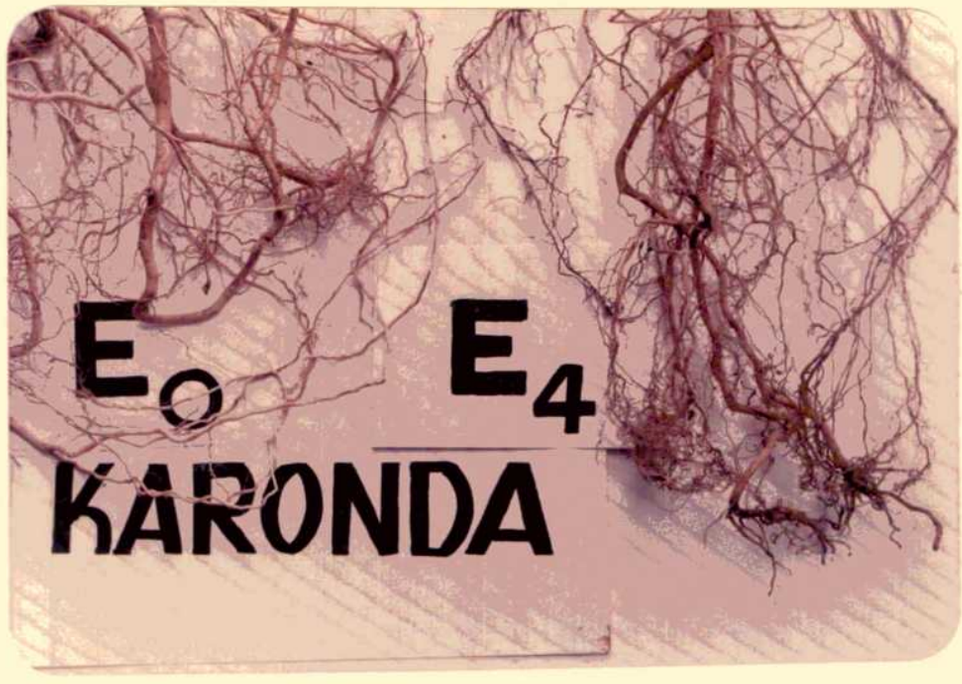


Photo plate No. 17 : Effect of ESP 60 showing sodic soil structure with blackening of roots in E 4 (problematic soil) compared to control (E_0)

4.1.6.10 Effect on number of secondary roots

The number of secondary roots decreased right from ESP level of 24 and was not different from that of ESP 36. Similarly the ESP level of 48 and 60 were statistically equal in effect.

4.1.6.11 Effect on total number of roots

It was seen from the data (Table 48) that the total number of roots reduced with the increased ESP levels. The total number of roots at ESP 48 and 60 were lower than control and other ESP levels, which were statistically similar to each other.

4.1.6.11a Effect on number of branches

The data in Table 48 indicated that the effects of at 36 and above ESP were statistically similar, but they gave minimum number of branches than ESP 12, 24 and control.

4.1.6.12 Effect on fresh weight of whole plant

In general, there was decrease in fresh weight of whole plant with the increase in ESP (Table 49). The fresh weight of whole plant was high at ESP 12, 24 and control than other ESP levels, but they were statistically similar to each other. Lowest fresh weight was recorded under ESP 60.

4.1.6.13 Effect on fresh weight of root

The depressive effect of ESP was started from 41. The most striking depressive effect was noticed at ESP of 60 which was however, not different from that of ESP 48.

Table 49: Effect of ESP on fresh and dry weight of whole plant, root and top of Karonda

Treatments	Fresh weight of whole plant (g)	Fresh weight of root (g)	Fresh weight of top (g)	Dry weight of whole plant (g)	Dry weight of root (g)	Dry weight of top (g)
Control	297.16	98.67	198.50	109.73	26.64	83.09
ESP 12	284.00	93.50	190.50	105.61	26.10	79.51
ESP 24	261.17	75.33	185.84	96.10	21.85	74.25
ESP 36	169.67	59.33	110.34	94.04	20.49	73.35
ESP 41	74.17	27.17	47.00	35.16	9.79	25.37
ESP 48	28.83	13.50	15.33	15.54	6.65	8.89
ESP 60	21.17	11.17	10.00	11.70	5.69	6.01
S.E.±	19.052	2.492	7.449	3.350	0.710	2.958
C.D.at 5%	57.794	7.560	22.449	10.162	2.154	8.879

4.1.6.14 Effect on fresh weight of top

The data regarding fresh weight of top are presented in Table 49. There was no difference in the fresh weight of top recorded under ESP 48 and 60. The ESP 12, 24 and control plant statistically similar with each other in decreasing the fresh weight of top.

4.1.6.15 Effect on dry weight of whole plant

The data on dry weight of whole plant as influenced by various ESP levels are presented in Table 49 and shown graphically in Fig. 5. The dry weight of whole plant was only decreased significantly at ESP 24, 41 and 48 compare to their respective immidiate lower level of ESP.

4.1.6.16 Effect on dry weight of root

A significant drop in dry weight was observed at 48 and 60 ESP level as compare to other ESP levels. The effect at 48 and 60 ESP was not different from each other.

4.1.6.17 Effect on dry weight of top

From Table 49 it is evident that the ESP 12, 24 and control and ESP 12, 24 and 36 were statistically similar with more dry weight than at highest level of ESP i.e. 60.

4.1.6.2 Physiological parameters

4.1.6.2.1 Effect of exchangeable sodium percentage on chlorophyll content of leaves

The data in Table 50 indicated that the lowest chlorophyll 'b' content was estimated under ESP 60 which was similar to that recorded under ESP 48.



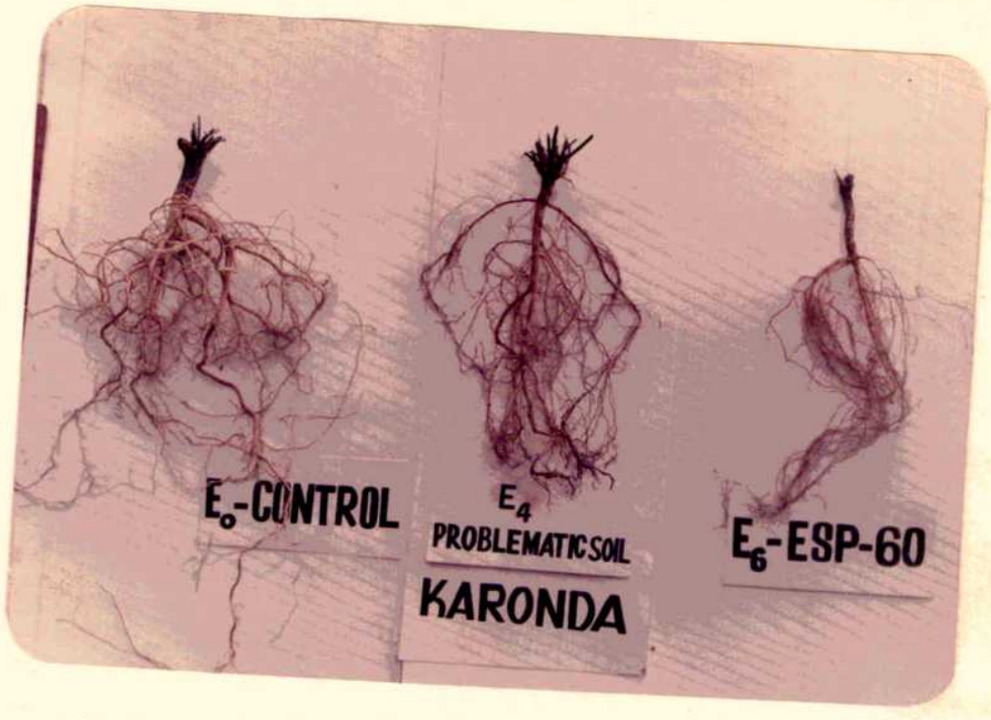


Photo plate No. 18 : Effect of ESP on shoot and root growth at the time of termination of experiment (360 days after planting)

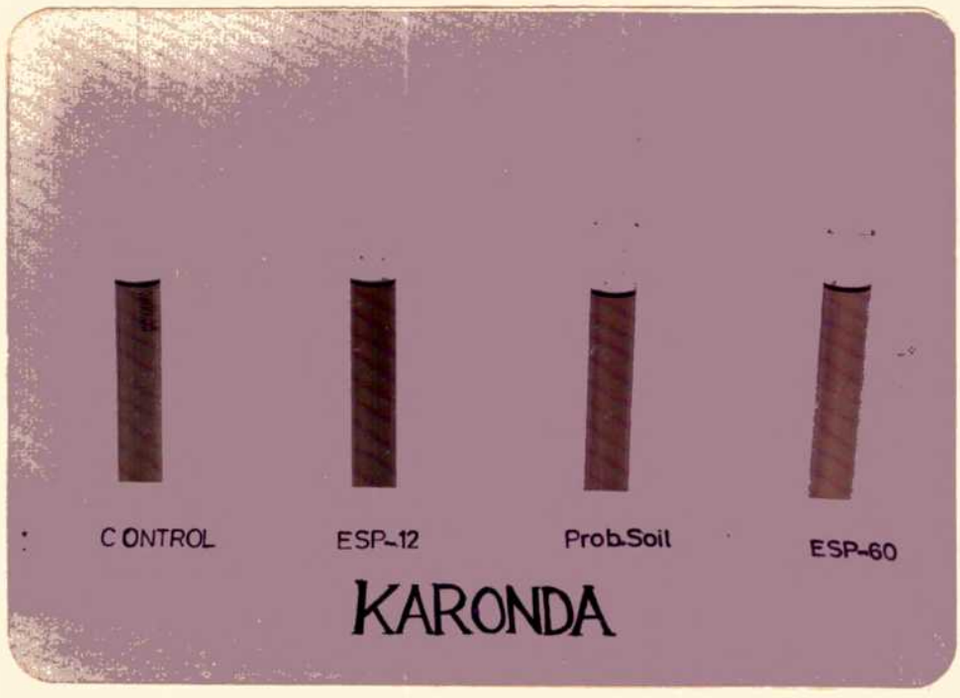


Photo plate No. 19 : Effect of ESP levels showing gradual change in chlorophyll content in Karonda

Although chlorophyll 'b' was not decreased with increase in the ESP 12, the chlorophyll 'a' and total chlorophyll decreased significantly.

Table 50: Effect of ESP on the chlorophyll content of leaves number of stomata per unit area and rate of transpiration of Karonda

Treatments	Chlorophyll 'a'	Chlorophyll 'b'	Chlorophyll Total	No.of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
	mg/g				
Control	0.826	1.1750	2.0013	13.60	0.0250
ESP 12	0.740	1.0670	1.8070	15.33	0.0260
ESP 24	0.655	0.9413	1.5960	18.33	0.0260
ESP 36	0.563	0.8330	1.3963	29.30	0.0270
ESP 41	0.525	0.7703	1.2950	30.66	0.0280
ESP 48	0.373	0.5337	0.9060	30.66	0.0310
ESP 60	0.293	0.3037	0.5977	33.00	0.0320
S.E. ±	0.024	0.135	0.023	1.628	0.0006
C.D.at 5%	0.074	0.409	0.072	4.939	0.0020

4.1.6.2.2 Effect on number of stomata

The data in Table 50 and Fig. 3 indicated that number of stomata were increases significantly at ESP 36.

4.1.6.2.3 Effect on rate of transpiration

Data in Table 50 and Fig. 3 indicated that

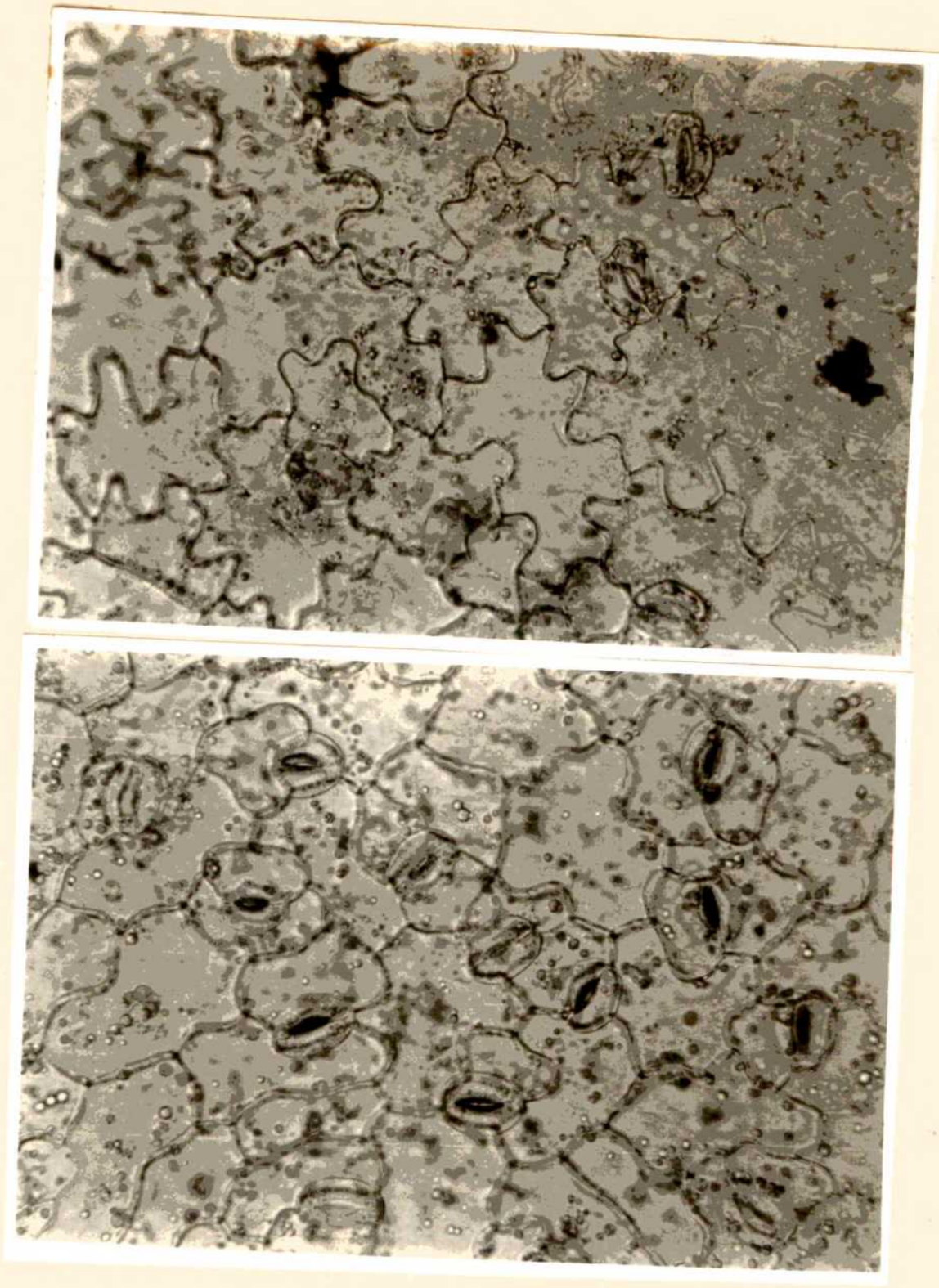


Photo plate No. 20 : Effect of ESP 60 on density of stomata number compared to control in Karonda

the highest rate of transpiration was recorded under ESP 60 which was similar to that of ESP 48.

4.1.6.3 Effect of exchangeable sodium percentage on chemical composition

The data regarding chemical composition of leaves and roots of Karonda as influenced by various ESP levels are presented in Table 51 and 52.

4.1.6.3.1 Macronutrient content of leaves, roots and stem

4.1.6.3.1.1 Nitrogen

Leaves : There was increase in N content of the leaves with increased ESP upto 41. However, ESP 12 compared to control and ESP from 36 to 41 behaved similarly. Beyond problematic soil the N content was decreased bu non-significantly.

Roots : In case of the roots the nitrogen declined when the ESP was raised to 24. Lowest root nitrogen content was recorded under ESP 60, which was significantly low to that under ESP 48.

Stem : The stem nitrogen increased when the ESP was raised to 12. It was further decreased with the increase of ESP level. The significant lowest stem nitrogen was recorded under higher ESP level.

Table 51: Effect of ESP on macronutrient content (Percentage) of leaves, roots and stem of Karonda

Treatments	N	P	K	Ca	Mg.	S	Na
			Leaves				
Control	3.35	1.22	2.43	1.24	0.96	0.84	0.41
ESP 12	3.40	1.05	2.35	1.12	0.86	0.79	0.53
ESP 24	3.52	0.92	2.18	0.96	0.77	0.72	0.59
ESP 36	3.74	0.83	2.00	0.92	0.67	0.71	0.66
ESP 41	3.77	0.68	1.89	0.86	0.65	0.60	0.76
ESP 48	2.68	0.60	1.68	0.68	0.60	0.55	0.71
ESP 60	2.33	0.45	1.43	0.60	0.44	0.45	0.99
S.E.±	0.052	0.024	0.033	0.016	0.016	0.016	0.024
C.D.at 5%	0.179	0.072	0.099	0.048	0.048	0.048	0.073
			Roots				
Control	3.10	0.82	1.40	1.16	0.60	0.37	0.34
ESP 12	3.00	0.77	1.09	0.92	0.55	0.30	0.41
ESP 24	2.68	0.67	1.00	0.88	0.45	0.29	0.45
ESP 36	2.33	0.60	0.85	0.84	0.38	0.58	0.59
ESP 41	1.82	0.55	0.68	0.76	0.36	0.25	0.68
ESP 48	1.71	0.45	0.41	0.69	0.29	0.21	0.71
ESP 60	1.23	0.42	0.30	0.34	0.22	0.15	0.88
S.E.±	0.089	0.022	0.047	0.053	0.018	0.017	0.049
C.D.at 5%	0.270	0.066	0.143	0.161	0.050	0.051	0.149
			Stem				
Control	1.26	0.87	1.50	1.32	1.81	0.34	0.19
ESP 12	1.38	0.81	1.41	1.24	1.63	0.30	0.25
ESP 24	0.92	0.67	1.28	1.08	1.51	0.27	0.53
ESP 36	0.84	0.53	1.29	0.91	1.23	0.21	0.72
ESP 41	0.72	0.38	1.04	0.85	1.00	0.18	0.86
ESP 48	0.70	0.30	0.93	0.73	0.46	0.15	1.01
ESP 60	0.48	0.17	0.67	0.52	0.34	0.10	1.24
S.E.±	0.048	0.015	0.031	0.026	0.058	0.012	0.034
C.D.at 5%	0.146	0.046	0.095	0.079	0.176	0.035	0.103

4.1.6.3.1.2 Phosphorus

Leaves : The P content of the leaves (Table 51) was significantly low at every higher level of ESP from its preceeding.

Roots : The P content of roots was not different in ESP level of 36 and 41 and 48 and 60.

Stem : There was a significant reduction in stem P content with each incremental level of ESP.

4.1.6.3.1.3 Potassium

Leaves : There was (Table 51) decrease in K content of leaves with the increase in ESP. The K content was significantly reduced at every increased ESP level.

Roots : There was fall in K content of roots with the increase in ESP. The lowest K content in ESP 60 was observed which was similar to ESP 48.

Stem : The K content of the stem was highest at ESP 12 as compared to other higher ESP levels. However, it was equal to control.

4.1.6.3.1.4 Calcium

Leaves : The Ca content (Table 51) of leaves decreased at the highest level of ESP (i.e. at ESP 60) similarly the decrease was significant at ESP from 41 to onwards.

Roots : There was no statistical difference between ESP 12 to 41 and from 36 to 48.

Stem : The progressive significant decrease in Ca content of stem was observed with the increase in ESP.

4.1.6.3.1.5 Magnessium

Leaves : The Mg content of leaves decreased significantly with the increase of ESP upto 24 (Table 51). The differences in decrease was also significant between ESP 48 and 60.

Roots : In case of roots the Mg declined significantly when the ESP was raised from 12 to 36. The difference was non significant at ESP 12 and 41 as compared to their next lower treatment.

Stem : There is a corrosponding decrease in stem Mg with increase in ESP. Except ESP at 48 and 60, all other ESP levels resulted into significant decreases in Mg content of stem.

4.1.6.3.1.6 Sulphur

Leaves : Sulphur content of leaves was decreased significantly when the ESP was raised to 24. There was no difference between ESP 24 and 36 in S content of leaves (Table 51).

Roots : The effect of ESP 12, 24, 36 and 41 as well as 41 and 48 were statistically similar in this behalf.

Stem : A progressive declined in the stem S was observed with the increase in ESP. The ESP 12, 36 and 60 showed significant decrease of stem S from their immediate preceeding ESP level.

4.1.6.3.1.7 Sodium

Leaves : A maximum Na content was observed at ESP 60 (Table 51), which was significantly high as compared to 48 ESP level.

Roots : The data showed that the root Na content increased with increase in ESP. The effect of ESP upto 48 in Na content of roots were more or less similar.

Stem : The stem Na content was increased significantly with the increase in ESP except at ESP at 12. The highest Na content was estimated under ESP 60.

4.1.6.3.1.8 Ca : Na

Leaves : There was a significant decrease in Ca : Na of leaves with each incremental level of ESP over their previous lower levels except ESP 41 (problematic soils), which was similar with ESP 48.

Roots : The lower ratio was recorded under ESP 60, which was similar to that under ESP 48.

Stem : A significantly increase in Ca : Na content of stem was observed with the increase in ESP upto 24. Similarly the effects of ESP from 24 to 60 were statistically similar.

Table 52: Effect of ESP on macronutrients ratios of Ca : Na and Ca + Mg + K : Na and micronutrient content of leaves, roots and stem of Karonda

Treatments	Ca/Na	Ca+Mg+K/Na	Micronutrient in ppm			
			Zn	Fe	Mn	Cu
			Leaves			
Control	3.04	11.37	37.97	1768.40	572.10	48.67
ESP 12	2.11	8.18	36.36	1612.58	561.76	38.07
ESP 24	1.63	6.64	35.26	1469.45	536.99	28.23
ESP 36	1.40	5.45	30.74	1384.84	518.88	25.18
ESP 41	1.00	4.34	30.29	1331.37	492.11	21.67
ESP 48	0.84	3.67	26.22	1252.08	449.88	19.63
ESP 60	0.61	2.50	24.41	1095.37	439.42	13.27
S.E.±	0.071	0.291	0.501	24.151	8.385	1.292
C.D.at 5%	0.214	0.882	1.519	73.260	25.465	3.920
			Roots			
Control	3.44	9.53	42.04	1549.88	203.91	55.75
ESP 12	2.24	6.29	38.99	1529.60	202.79	53.98
ESP 24	1.97	5.21	36.62	1449.51	164.28	41.59
ESP 36	1.42	3.51	31.19	1371.94	146.47	40.71
ESP 41	1.11	2.65	23.51	1335.98	143.03	35.40
ESP 48	0.82	2.03	22.61	1255.39	118.90	34.51
ESP 60	0.38	0.97	20.34	1248.76	112.58	30.09
S.E.±	0.164	0.224	0.801	10.500	3.624	1.140
C.D.at 5%	0.497	0.679	2.429	31.852	10.992	3.458
			Stem			
Control	6.99	24.36	75.95	1421.72	142.18	30.70
ESP 12	5.30	18.33	70.78	1358.37	130.33	27.22
ESP 24	1.72	7.36	58.96	1132.88	102.89	26.15
ESP 36	1.27	4.69	44.17	1027.36	102.82	20.31
ESP 41	0.99	3.36	36.35	941.36	80.66	19.43
ESP 48	0.72	2.10	30.83	849.16	68.45	15.04
ESP 60	0.42	1.23	11.29	593.05	52.85	6.83
S.E.±	0.389	1.351	1.855	33.639	2.900	1.257
C.D.at 5%	1.180	4.098	5.628	102.042	8.798	3.813

4.1.6.3.1.9 Ca + Mg + K : Na

Leaves : All ESP levels differed significantly with each other except 41 and 48.

Roots : The Ca + Mg + K : Na content of the roots decreased significantly when ESP was raised to 41.

Stem : A significantly high ratio was observed at ESP 12 as compared to other levels.

4.1.6.3.2. Micronutrient content of leaves, roots and stem

4.1.6.3.2.1 Zinc

Leaves : It is evident from data (Table 52) that the ESP 12 and 24 and ESP 36 and 41 were statistically similar.

Roots : The Zn content of roots decreased significantly with increase in ESP upto 41. The ESP 48 and 60 showed the significant decrease of ratio.

Stem : Zn content of stem in control was highest and lowest Zn was recorded under ESP levels of 60, which was more than 6 times less.

4.1.6.3.2.2 Iron

Leaves : The Fe content of leaves was high at ESP 12 and control plant than other ESP levels. The ESP 48 and 60 were statistically different from each other (Table 52).

Roots : Control plants showed maximum Fe content in roots. The lowest Fe content was estimated under ESP 60 which was statistically similar to that recorded under ESP 48.

Stem : The Fe content of stem also decreased with increased ESP of the soil. The lowest and significant Fe content was estimated under ESP 60 as compared to ESP 48.

4.1.6.3.2.3 Manganese

Leaves : The Mn content of the leaves of ESP 12, 36 and 60 was non significantly decreased from their preceeding treatments (Table 52).

Roots : There was no difference in Mn content in roots in treatments of ESP 36 and 24, ESP 48 and 60.

Stem : There was significant decrease in Mn content of stem at every incremental level of ESP except the ESP at 24 and 36.

4.1.6.3.2.4 Copper

Leaves : The leaf Cu content decreased with an increase ESP 24. The lowest Cu content in the leaves recorded on highest ESP level which was statistically different to its lower ESP.

Roots : Roots of control plants showed highest Cu content and lowest was recorded under ESP 60. There were no difference in the effect of ESP 24 and 36 as well as ESP 41 and 48.

Stem : The stem Cu decreased markedly when the ESP was at 60. Cu of stem were similar under ESP 12 and control plants ESP 12 and 24 and ESP 36 and 41.

4.1.7 Passion Fruit

4.1.7.1 Effect on plant height

Plant height was decreased with the first ESP level itself when the plants were 120, 180, 300 and 360 days old from planting. Severe decrease in growth as determined by plant height was recorded under ESP 60 followed by ESP 48.

4.1.7.2 Effect on number of leaves

The first level of ESP itself showed significant decrease in number of leaves compared to control during the entire course of investigation. The effect on number of leaves was also pronounced due to ESP levels from 12 and 24 during crop growth stages except 120 days after planting. The effect due problematic soil and ESP 48 was seen significant at 60 days after planting, whereas at 120, 180 and 240 days after planting, the non significant decrease was observed. After 10 months of planting, the plants under ESP 41 were completely died. Plants under ESP 60 were died at 180 days after planting. Severest depressive effect was noted under ESP 60.

Table 53: Effect of ESP on percentage increase in plant height, number of leaves, and stem diameter of passion Fruit

Treatments	Days after planting					
	60	120	180	240	300	360
Plant height						
Control	97.82	199.47	341.10	472.55	565.52	612.44
ESP 12	91.34	185.20	315.41	446.11	502.10	532.61
ESP 24	88.70	176.00	287.45	405.05	439.93	448.14
ESP 36	86.55	164.40	273.23	367.42	414.89	419.65
ESP 41	82.32	158.30	230.85	307.74	-	-
ESP 48	71.54	140.10	188.39	271.39	-	-
ESP 60	63.41	106.50	152.63	-	-	-
S.E.±	1.174	2.081	8.420	9.890	14.78	13.080
C.D.at 5%	6.594	6.300	25.54	30.480	48.200	46.680
Number of leaves						
Control	147.81	476.47	729.41	1017.63	1135.29	1176.47
ESP 12	125.10	368.75	600.56	831.25	921.50	954.25
ESP 24	68.33	334.29	534.76	688.58	774.81	792.86
ESP 36	64.71	176.47	329.41	417.65	472.65	486.20
ESP 41	50.18	116.67	211.76	276.47	-	-
ESP 48	30.58	76.95	173.21	206.67	-	-
ESP 60	15.90	40.10	106.25	-	-	-
S.E.±	5.090	15.650	18.720	31.420	38.180	32.080
C.D.at 5%	15.450	47.210	56.780	96.830	117.610	98.800
Stem diameter						
Control	33.33	66.67	87.71	153.33	197.10	225.83
ESP 12	27.90	65.54	84.68	133.33	150.67	165.70
ESP 24	26.83	59.28	81.32	116.67	128.42	136.43
ESP 36	23.10	56.10	80.71	102.18	110.85	117.29
ESP 41	21.33	42.89	70.43	81.43	-	-
ESP 48	19.37	40.79	67.55	73.16	-	-
ESP 60	18.10	37.84	53.20	-	-	-
S.E.±	0.522	1.290	1.340	4.720	6.040	6.980
C.D.at 5%	1.580	3.920	4.090	14.540	19.710	22.760

4.1.7.2 Effect on stem diameter

The first level of ESP (12 ESP) itself showed significant effect on stem diameter as compared to control in all growth periods except 120 and 180 days after planting. The ESP level of 24 and 36 behaved similarly during entire growth period except at the beginning of the investigation (60 days after planting). The highest eESP levels (60 ESP) recorded severest injury effect on stem diameter after 6 months of planting (Table 53).

4.1.7.4 Effect on plant spread

The plant spread showed a decreasing trend with increase in ESP (Table 54). ESP 12 and control plant were gave more plant spread than rest of the treatments. However, the effect of ESP 36 and 41 were similar, but they gave more spread than next higher levels of ESP.

4.1.7.5 Effect on leaf area

The total leaf area per plant (Table 54) decreased with the increase in ESP. Pronounced effect was seen at ESP 24 and onward. The data further revealed that the effect of ESP 24 and 36 were similar. Similarly, the leaf area was similar under ESP 48 and 60.

Table 54: Effect of ESP on plant spread, total leaf area per plant and mortality of Passion Fruit

Treatments	Plant spread (sq.cm.)	Total leaf area (sq.cm.)	Mortality (per cent)
Control	32.21	10642.93	00.00 (00.57)
ESP 12	30.00	10308.73	10.00 (18.44)
ESP 24	27.11	7129.02	32.00 (34.45)
ESP 36	22.33	6539.85	70.33 (56.98)
ESP 41	21.45	5020.66	100.00 (90.00)
ESP 48	17.17	3675.10	100.00 (90.00)
ESP 60	15.00	2850.00	100.00 (90.00)
S.E.±	0.773	273.490	- 2.740
C.D. at 5%	2.162	829.621	- 8.320

* The figures in parenthese indicate transformed value into arcsin value

4.1.7.6 Effect on plant mortality

The data regarding plant mortality is given in Table 54 and shown graphically in Fig. 1. Hundred per cent plant mortality was observed in ESP 41 and above (i.e. problematic soil). ESP 60 started showing mortality symptoms right from 150 days after planting. While the mortality symptoms were recorded under ESP 41 and 48, at 210 days after planting. Complete mortality of the plant under ESP 41 and 48 was observed at 300 days. But at ESP of 60, the plants were completely dried when they had attained 240 days. The initial symptoms of mortality were burning of lower leaves followed by sheding of leaves.



Photo plate No. 21 : Leaf injury caused by soil ESP in passion fruit

4.1.7.7 Effect on root length

It is evident from Table 55 that the significant reduction in root length was recorded in case of ESP at 12 and above as compared to control. The effect of ESP 12 and 24 as well as 48 and 60 were similar with each other.

Table 55: Effect of ESP on root length, root volume, number of primary roots, number of secondary roots and total number of roots of passion Fruit

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots
Control	25.33	20.50	7.77	47.10	54.87
ESP 12	19.96	17.60	4.10	30.10	34.20
ESP 24	19.33	15.00	3.20	25.00	28.20
ESP 36	14.40	12.10	3.00	13.16	16.16
ESP 41	16.88	9.40	3.05	10.33	13.38
ESP 48	15.00	9.00	2.25	5.27	7.52
ESP 60	15.00	7.10	2.00	5.11	7.11
S.E.±	0.618	0.585	0.499	1.732	2.073
C.D.at 5%	1.875	1.808	1.513	5.254	6.288

4.1.7.8 Effect on root volume

The data in Table 55 showed that the root volume at ESP 41 and 48 were statistically similar and showed more root volume as compared the ESP at 60. The effects of ESP 12, 24, 36 and control were statistically different from each other.

4.1.7.9 Effect on number of primary roots

The number of primary roots decreased with the increase in ESP levels. The ESP 12 and control plants showed more number of primary root than ESP 24 and above (Table 55).

4.1.7.10 Effect on number of secondary roots

The depressive effect of ESP was started from ESP 12. The most striking depressive effect was noticed at 48 and 60 ESP, though, they were not different from each other (Table 55).

4.1.7.11 Effect on total number of roots

The data pertaining to the total number of roots (Table 55) revealed that the plants under control, ESP 12 and 24 were with more total number of roots than all further ESP levels.

4.1.7.12 Effect on fresh weight of whole plant

The data on fresh weight of whole plant as affected by various ESP levels (Table 56) indicated a sharp drop in fresh weight of whole plant at ESP 12. The fresh weight of whole plant at ESP 60 was lowest and was similar at ESP 48. The effect of ESP 12, 24 and 36 were on par from each other.

4.1.7.13 Effect on fresh weight of root

The data in Table 56 indicated that ESP 48 and 60 were similar in fresh weight of root with lower weight.

Table 56: Effect of ESP on fresh and dry weight of whole plant, root and top of passion Fruit

Treatments	Fresh weight of whole plant (g)	Fresh weight of root (g)	Fresh weight of top (g)	Dry weight of whole plant (g)	Dry weight of root (g)	Dry weight of top (g)
Control	134.43	22.83	111.60	53.73	4.49	49.24
ESP 12	92.33	15.50	76.83	45.33	4.03	41.30
ESP 24	91.33	14.67	76.66	43.04	3.96	39.08
ESP 36	82.33	12.33	70.00	39.60	3.95	35.65
ESP 41	74.33	11.83	62.50	38.46	3.90	34.56
ESP 48	60.00	8.33	51.67	36.26	3.25	33.01
ESP 60	44.87	6.50	38.37	29.45	2.59	26.86
S.E.±	5.02	1.30	3.92	2.56	0.37	2.22
C.D.at 5%	15.22	3.94	11.88	7.77	1.12	6.75

4.1.7.14 Effect on fresh weight of top

On perusal of the data (Table 56) it was seen that no significant difference from 12 to 36 ESP was noticed but a sudden decrease of fresh weight of top was observed at ESP 12 compared to control.

4.1.7.15 Effect on dry weight of whole plant

The data regarding dry weight of whole plant are presented in Table 56 and shown graphically in Fig. 5. The dry weight of whole plant was lower in higher ESP levels than control. The ESP 24, 36 and 41 (problematic soil) were similar with each other. There was no difference in the dry weight of whole plant recorded under ESP 48 and 60.

4.1.7.16 Effect on dry weight of root

It was seen from the data (Table 46) that the dry root weight was reduced to a greater extent at ESP 48 and 60 as compared to control and other ESP levels and were not different from each other.

4.1.7.17 Effect on dry weight of top

The dry weight of top decreased with the increase in ESP (Table 56). The dry weight of top at ESP 48 and 60 where lower than control and other levels and were statistically similar to each other.

4.1.7.2 Physiological parameters

4.1.7.2.1 Effect of excahngeable sodium percentage on chlorophyll content of leaves

It is evident from the data (Table 57) that the increase in ESP decreased the chlorophyll 'a',



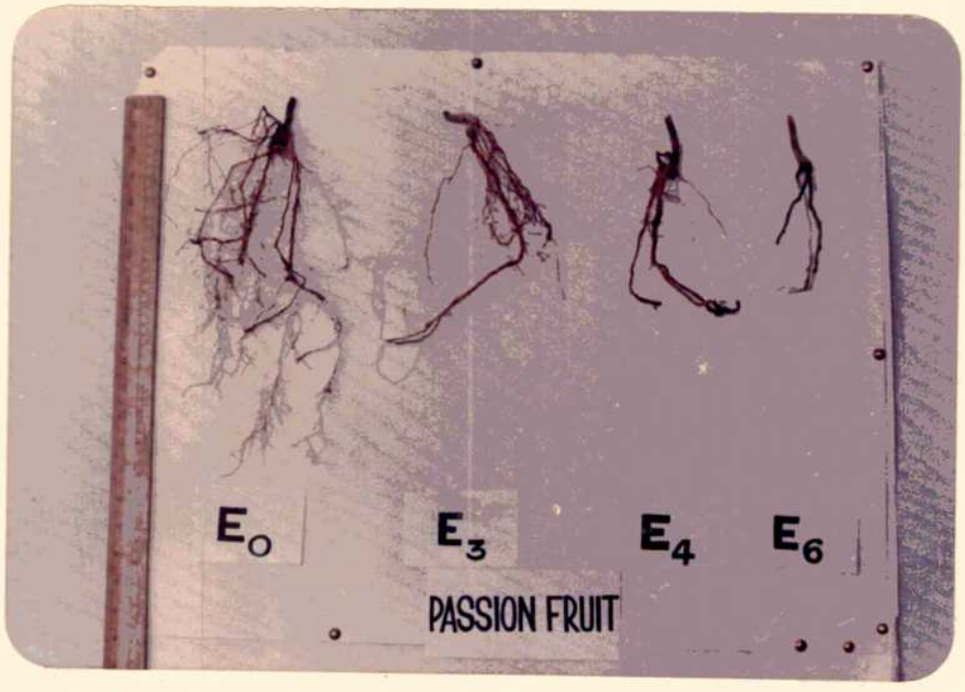


Photo plate No. 22 : Effect of ESP under problematic soil (E_4) and ESP 60 (E_6) on shoot and roots in control (E_0), ESP 36 (E_3), ESP 41 (problematic soil) (E_4) and ESP 60 (E_6) respectively



Photo plate No. 23 : Effect of ESP levels showing gradual change in chlorophyll content in passion fruit

'b' and total of leaves. A significantly higher chlorophyll content was observed in control plants as compared to the plants in artificially treated soils.

Table 57: Effect of ESP on chlorophyll content of leaves number of stomata per unit area and rate of transpiration of Passion Fruit

Treatments	Chlorophyll 'a'	Chlorophyll 'b'	Chlorophyll Total	Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
	mg/g				
			Leaves		
Control	0.8250	1.1557	1.9810	16.33	0.0267
ESP 12	0.6380	0.8620	1.4997	17.33	0.0264
ESP 24	0.5043	0.6167	1.0913	18.00	0.0261
ESP 36	0.3097	0.3507	0.6600	28.00	0.0241
ESP 41	0.2683	0.3023	0.5687	28.33	0.0238
ESP 48	0.2423	0.2493	0.5857	30.33	0.0224
ESP 60	0.2000	0.2113	0.4107	39.33	0.0213
S.E. ±	0.025	0.035	0.059	1.960	0.0004
C.D.at 5%	0.075	0.106	0.177	5.945	0.0013

4.1.7.22 Effect on number of stomata

The number of stomata Table 57 and Fig. 3 showed increasing trend with increase in ESP levels. A significantly more number of stomata was recorded at ESP 60 as compared to all ESP levels.

4.1.7.2.3 Effect on rate of transpiration

It is observed from Table 57 and from Fig. 3 that the rate of trnaspiration decreased with the increase ESP levels. The minimum rate of transpiration was noticed in ESP 60, which was not different from 48 ESP.

4.1.7.3 Effect of exchangeable sodium percentage on chemical composition

The data on the chemical composition of leaves, roots and stem as affected by various ESP levels are presented in Table 58 and 59.

4.1.7.3.1 Macronutrient content of leaves, roots and stem

4.1.7.3.1.1 Nitrogen

Leaves : From the data in Table 58 seen that N content of leaves increased with the increase in ESP levels upto ESP 36, beyond that limit it was decreased. At highest level of ESP there was more decline of N in leaves which was significantly different from its earlier lower level of ESP.

Roots : From the data it was seen that with successive increase in ESP levels there was significantly decrease in root N.

Stem : The stem N content was significantly low in higher ESP levels than control and other ESP levels.

Table 58: Effect of ESP on macronutrient content (Percentage) of leaves, roots and stem of passion Fruit

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	2.82	1.09	1.83	1.44	1.20	0.93	0.45
ESP 12	2.97	0.92	1.60	1.36	1.08	0.88	0.61
ESP 24	3.25	0.81	1.39	1.18	0.98	0.71	0.75
ESP 36	3.40	0.69	1.15	1.02	0.79	0.65	0.90
ESP 41	2.52	0.42	0.99	0.92	0.65	0.59	1.11
ESP 48	2.24	0.34	0.93	0.71	0.58	0.53	1.39
ESP 60	1.78	0.16	0.71	0.52	0.38	0.39	1.46
S.E.±	0.104	0.031	0.037	0.024	0.019	0.015	0.029
C.D.at 5%	0.315	0.093	0.113	0.073	0.057	0.047	0.087
			Roots				
Control	2.52	0.51	1.88	0.96	0.57	0.46	0.31
ESP 12	2.24	0.42	1.37	0.92	0.50	0.44	0.43
ESP 24	2.00	0.40	0.70	0.88	0.46	0.39	0.64
ESP 36	1.78	0.32	0.42	0.76	0.40	0.35	0.69
ESP 41	1.50	0.27	0.32	0.67	0.36	0.34	0.75
ESP 48	1.36	0.22	0.28	0.63	0.34	0.31	0.81
ESP 60	1.01	0.18	0.23	0.57	0.29	0.28	0.90
S.E. ±	0.054	0.008	0.034	0.022	0.029	0.017	0.019
C.D.at 5%	0.163	0.024	0.104	0.067	0.070	0.053	0.057
			Stem				
Control	3.12	0.92	1.85	1.48	0.77	0.52	0.13
ESP 12	3.00	0.85	1.83	1.42	0.70	0.47	0.25
ESP 24	2.79	0.77	1.81	1.35	0.62	0.40	0.55
ESP 36	2.60	0.67	1.51	1.17	0.53	0.32	0.96
ESP 41	2.38	0.55	1.26	1.00	0.41	0.20	1.03
ESP 48	2.15	0.48	1.00	0.79	0.34	0.18	1.28
ESP 60	1.68	0.31	0.85	0.51	0.19	0.09	1.57
S.E.±	0.054	0.014	0.036	0.036	0.015	0.013	0.047
C.D.at 5%	0.165	0.042	0.108	0.107	0.047	0.038	0.143

4.1.7.3.1.2 Phosphorus

Leaves : The P content of leaves declined with increasing level of ESP. The ESP levels 41 and 48 were statistically similar and exhibited high P in leaves than other higher levels of ESP.

Roots : In general, there was decrease in P content of roots with the increase in ESP levels. The ESP 12 and 24 were similar effect on P content of roots.

Stem : The P content of stem significantly decreased at 12 ESP and above. In general, a decreasing trend in P content was recorded with increasing of each ESP level.

4.1.7.3.1.3 Potassium

Leaves : The K content in leaves decreased significantly when ESP was raised upto 36. There was no difference in the K content of leaves under ESP 41 and 48 (Table 58).

Roots : The root K content decreased significantly with increase in ESP level upto 24. The K content was similar under ESP 36 and 41 and from 41 to 60 ESP.

Stem : The data in Table 58 showed that the stem K content was decreased significantly with increase in the ESP from 36 and above.

4.1.7.3.1.4 Calcium

Leaves : The Ca content (Table 58) of leaves significantly decreased atand all above 12 ESP.

Roots : The Ca content of roots in ESP 12 and control was similar and was maximum than the rest of treatments.

Stem : The stem Ca decreased with the increase ESP upto 24, but thereafter the decreased wit was significant.

4.1.7.3.1.5 Magnesium

Leaves : The data presented in Table 58 indicate that Mg content on leaves decreased significantly with increased ESP levels(Table 58).

Roots : The plants under control and ESP 12 recorded higher root Mg than those plant under rest of the treatments, though the decreases were more or less similar from each other at various ESP levels.

Stem : The Mg content of stem was decreased significantly with increase ESP levels. The decline was more pronounced at 60 ESP.

4.1.7.3.1.6 Sulphur

Leaves : The S content in leaves was significantly high in control plants than all other ESP levels. The minimum S was recorded under ESP 60 (Table 58).

Roots : The roots S was decreased but non significantly when ESP was raised from 12 to onwards.

Stem : The S content of stem was also decreased significantly when the soil was artificially increased with exchangeable sodium from 12 to 41. The lowest S content was noted under ESP 60.

4.1.7.3.1.7 Sodium

Leaves : The data presented in Table 58 indicated that there was a significant increase in Na content of leaves over control with each incremental level of ESP over their previous lower level except ESP at 60 and was similar with ESP 48.

Roots : The Na content of roots also increased with the increase in ESP levels. It was highest at ESP 60.

Stem : The Na content of stem increased with the increase in ESP levels. A significant more Na content was recorded at higher levels of the ESP like 48 and 60.

4.1.7.3.1.8 Ca : Na

Leaves : There was decrease in Ca : Na of leaves with the increase in ESP levels (Table 59). The control showed significantly higher Ca : Na than all ESP levels.

Roots : With the increase in ESP the Ca : Na decreased in roots. Low ratio was observed under all ESP levels as compared to control.

Stem : There was decrease in Ca : Na of stem with the increase in ESP levels. It was highly significantly reduced at ESP 12 as compared to control.

4.1.7.3.1.9 Ca + Mg + K : Na

Leaves : It is evident from the data in (Table 59) that there was a progressive decrease in Ca + Mg + K : Na with the increase in ESP. However, the ESP 48 and 60 behaved similarly.

Table 59 : Effect of ESP on macronutrient ratios of Ca:Na and Ca + Mg + K : Na and micronutrient content of leaves, roots and stem of passion Fruit

Treatments	$\frac{Ca}{Na}$	$\frac{Ca+Mg+K}{Na}$	Micronutrient in ppm			
			Zn	Fe	Mn	Cu
			Leaves			
Control	3.22	9.97	34.81	1309.24	175.19	19.62
ESP 12	2.23	6.63	30.37	1200.88	163.86	17.30
ESP 24	1.57	4.73	28.93	1098.37	139.58	14.62
ESP 36	1.15	3.34	28.03	938.60	118.32	13.17
ESP 41	0.84	2.32	26.67	755.12	100.13	13.01
ESP 48	0.51	1.59	23.51	703.65	93.63	12.28
ESP 60	0.36	1.11	16.38	596.63	78.12	9.36
S.E.±	0.285	0.172	0.848	23.792	3.273	0.435
C.D.at 5%	0.863	0.522	2.572	72.172	9.928	1.320
			Roots			
Control	3.11	11.06	115.29	1635.63	96.07	45.13
ESP 12	2.19	5.72	107.60	1601.71	74.78	38.05
ESP 24	1.38	3.07	98.50	1566.34	70.65	32.74
ESP 36	1.14	2.85	94.38	1422.65	55.14	30.97
ESP 41	1.00	1.89	83.10	1365.48	51.70	31.35
ESP 48	0.77	1.54	70.80	1210.65	33.89	19.58
ESP 60	0.63	1.43	56.38	871.29	25.57	11.65
S.E.±	0.119	0.249	2.115	38.521	3.467	2.869
C.D. at 5%	0.361	0.755	6.416	116.852	10.517	8.803
			Stem			
Control	11.79	32.66	29.44	1092.00	68.23	28.13
ESP 12	6.22	17.31	28.54	980.87	65.10	26.10
ESP 24	2.49	6.93	25.37	811.17	50.83	20.83
ESP 36	1.22	3.34	22.73	798.10	39.20	14.10
ESP 41	0.97	2.59	19.40	701.33	30.13	10.31
ESP 48	0.65	1.66	16.37	633.15	21.83	7.96
ESP 60	0.31	0.98	10.85	364.15	10.14	2.65
S.E.±	0.768	2.142	0.739	32.265	2.031	0.903
C.D.at 5%	2.330	6.498	2.241	97.876	6.162	2.740

Roots : With the increase in ESP the Ca + Mg + K : Na was decreased but most severe decreased of the ratio was noticed at ESP 12.

Stem : The Ca + Mg + K : Na was significantly decline 12 ESP thereafter all the decline was non significant but to a great extent as compared ESP 12 and control.

4.1.7.3.2 Micronutrient content of leaves, roots and stem

4.1.7.3.2.1 Zinc

Leaves : The Zn content of leaves (Table 59) under control plant was high than all ESP levels. The ESP 12, 24 and 36 and ESP 24 and 36 and 41 were statistically similar with each other.

Roots : The Zn content of roots was higher at ESP 12 and control than other ESP levels. Similar effects were noted in this regard with ESP 24 and 36.

Stem : The ESP 12 and control plant showed maximum Zn content in roots, but were statistically similar. Further increased in ESP, the Zn content of the stem was decreased significantly.

4.1.7.3.2.2 Iron

Leaves : The Fe content of leaves was decreased significantly only when the ESP was raised up to 41.

Roots: The decrease in Fe content of roots was observed with the increase in ESP levels up to 24 and was statistically similar. The Fe content was low at ESP 60 as compared to control and other levels of ESP.

Stem : The stem Fe was high at ESP 12 and control than other ESP levels. The ESP 24 and 36, ESP 36 and 41 (problematic soils) were similar with each other.

4.1.7.3.2.3 Manganese

Leaves : The Mn content of leaves (Table 58) decreased with the increase in ESP. However, the ESP 41 and 48, ESP 48 and 60 were similar with each other.

Roots : The Mn content of roots decreased with the increase in ESP, but it was not consistent.

Stem : The stem Mn in ESP 12 and control was similar. But all other higher ESP levels resulted significant decrease of stem Mn content.

4.1.7.3.2.4 Copper

Leaves : The Cu content of leaves decreased significantly upto ESP 36 (Table 58). There was no difference in Cu content of leaves in ESP from 36 to 48.

Roots : There was decrease in Cu content of roots with the increase in ESP with more or less similar decrease.

Stem : Except ESP 12 all higher ESP levels indicated significantly less Cu content of stem. The decrease was very much severe at highest ESP level of 60.

4.1.8 Drumstick

4.1.8.1 Effect on plant height

The periodical plant height as affected by various levels of ESP is reported in Table 60. The results showed that first level of ESP i.e. 12 except at 120 days after planting differed significantly from control in reducing the plant height. There was no difference between ESP 12 and 24 in decreasing plant height except at 60 and 180 days after planting. The plant height was significantly decreased in ESP levels from 36 to 48 from each other during entire course of investigation. But ESP at 48 resulted into death of plants after 300 days of planting. The ESP 48 and 60 behaved similar up to 6 months of planting.

4.1.8.2 Effect on number of leaves

The ESP 12 affected significantly decrease of number of leaves at 60 and upto 240 days of planting. Upto 4 months, the ESP 12 and 24 exhibited similar decreases in number of leaves and after 6 months of planting in number of leaves were decreased at increasing rate.

Table 60: Effect of ESP on percentage increase in plant height, number of leaves and stem diameter of Drumstick

Treatments	Day after planting					
	60	120	180	240	300	360
			plant height			
Control	29.03	83.87	200.26	443.39	608.25	610.11
ESP 12	25.58	78.11	162.81	387.11	517.79	597.28
ESP 24	22.17	71.77	139.10	361.29	484.17	554.83
ESP 36	19.35	64.94	129.04	309.58	389.33	433.50
ESP 41	15.24	45.16	81.62	191.62	247.50	281.05
ESP 48	10.81	31.35	54.27	144.33	-	-
ESP 60	9.09	29.27	51.20	-	-	-
S.E.±	0.830	2.860	5.000	11.960	16.640	19.60
C.D.at 5%	2.540	8.680	15.170	36.860	52.440	61.760
			Number of leaves			
Control	89.79	166.68	250.29	323.34	358.82	402.77
ESP 12	76.43	150.18	227.33	297.71	344.47	371.20
ESP 24	71.44	137.44	201.04	248.23	282.34	300.44
ESP 36	63.51	112.51	189.11	229.18	261.18	273.11
ESP 41	50.11	75.25	123.77	144.83	167.11	176.36
ESP 48	38.33	70.49	106.40	123.11	-	-
ESP 60	25.73	62.36	91.20	-	-	-
S.E.±	3.600	5.170	5.760	7.120	9.870	10.740
C.D. at 5%	10.940	15.660	17.450	21.920	31.100	33.850
			Stem diameter			
Control	50.15	123.37	234.61	284.27	316.48	330.11
ESP 12	42.70	116.48	217.00	257.63	287.31	292.40
ESP 24	40.11	113.24	200.49	238.40	245.27	253.07
ESP 36	36.44	100.20	183.73	219.72	233.18	238.22
ESP 41	33.57	87.11	151.08	176.30	184.75	188.63
ESP 48	31.36	71.96	134.75	151.69	-	-
ESP 60	28.63	66.39	118.50	-	-	-
S.E.±	1.000	6.020	4.120	5.430	5.970	7.360
C.D.at 5%	3.040	18.260	12.510	16.730	18.810	23.200

Further the next higher levels of ESP i.e. 36 and 41 was found in decreasing the number of leaves at increasing rate right from the first growth stage to till the termination of experiment. The plants were not survived due to 48 and 60 ESP at 300 days and 240 days of planting respectively.

4.1.8.3 Effect on stem diameter

From the results in Table 60 it was observed that the effect of different ESP levels showed more or less similar decreases in stem diameter upto 4 months.after planting. However, the differents due to various ESP levels in decrease of stem diameter in all growth stages except ESP 24 and 36 at 300 and 360 days after planting were statistically significant. Lowest stem diameter was recorded under higher level of ESP (i.e. 60 ESP).

4.1.8.4 Effect on plant spread

The effect of ESP resulted into significant decrease in spread of plant due to every increase of ESP level (Table 61).

4.1.8.5 Effect on leaf area

Except control and ESP 12 all other ESP levels were found similar in effect, though there was successive decrease in total leaf area (Table 61).

Table 61: Effect of ESP on plant spread, total leaf area per plant and mortality of Drumstick

Treatments	Plant spread (sq.cm.)	Total leaf area (sq.cm.)	Mortality (Per cent)
Control	49.33	4151.47	00.00 (00.57)
ESP 12	43.00	4037.70	00.00 (00.57)
ESP 24	39.50	3680.81	18.33 (25.33)
ESP 36	32.40	3010.81	45.33 (42.30)
ESP 41	26.10	2283.88	64.66 (53.31)
ESP 48	23.30	1557.72	100.00 (90.00)
ESP 60	18.00	1100.46	100.00 (90.00)
S.E.±	0.766	118.42	- 4.745
C.D. at 5%	2.325	359.23	- 14.397

* The figures in parenthese indicate transformed value into arcsine value.

4.1.8.6 Effect on plant mortality

The mortality symptoms were started from ESP 24 (Table 61). The ESP levels from 24 to 60 resulted into significant increase of mortality.

4.1.8.7 Effect on root length

The effect of ESP on length of root (Table 62) indicated that due to increased levels of ESP, the length of root was decreased, significantly except ESP from 36 to 41.





Photo plate No. 24 : Effect of ESP 60 showing yellowing of leaves and reduced leaf area in problematic soil

4.1.8.8. Effect on root volume

The ESP levels from 12 to 24 and from 48 to 60 behaved similarly in decrease of root volume (Table 62).

Table 62: Effect of ESP on root length, root volume, number of primary roots, number of secondary roots and total number of rootss of Drumstick

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots	Root diameter (mm)
Control	54.50	70.50	12.50	15.20	27.50	17.70
ESP 12	48.50	62.70	11.00	12.10	23.10	15.10
ESP 24	41.70	60.50	8.80	8.10	16.90	15.10
ESP 36	31.00	53.10	6.50	6.60	13.10	11.50
ESP 41	28.10	41.30	5.00	2.67	7.67	8.20
ESP 48	28.20	25.50	2.67	2.00	4.67	6.67
ESP 60	25.75	23.10	2.17	3.10	5.27	6.05
S.E.±	1.857	1.791	0.740	0.549	1.185	0.549
C.D. at 5%	3.814	5.432	2.241	1.666	3.595	1.866

4.1.8.9 Effect on number of primary roots

The primary roots were significantly decreased due to ESP from 12 to 24 and ESP from 41 to 48 (Table 62). In rest of the ESP levels the decrease was similar

4.1.8.10 Effect on number of secondary roots

The number of secondary roots decreased but non-significantly due to the ESP level from 41 to 60. Due to these higher concentrations of ESP, the decrease in number of secondary roots was severe as compared to the low ESP levels (Table 62).

4.1.8.11 Effect on total number of roots

The total number of roots also behaved similarly as secondary roots due to various ESP levels (Table 62).

4.1.8.11a Effect on root diameter

The root diameter was also decreased due to each higher concentration of ESP. However, the ESP 12 and 24 and ESP 36 to 60 were on par in decreasing of root diameter.

4.1.8.12. Effect on fresh weight of whole plant

The effect of ESP on fresh weight of whole plant was observed severely from ESP 36. The ESP level 36 and 41 behaved similarly. The fresh weight of whole plant was 7 times reduced at ESP 60 as compared to control (Table 63 and Fig. 5).

4.1.8.13 Effect on fresh weight of root

The fresh weight of root was also decreased due to higher concentrations of ESP. The ESP 36 and 41 and ESP 48 and 60 behaved similarly.

Table 63: Effect of ESP on fresh and dry weight of whole plant, root and top of Drumstick

Treatments	Fresh weight of whole plant (g)	Fresh weight of root (g)	Fresh weight of top (g)	Dry weight of whole plant (g)	Dry weight of root (g)	Dry weight of top (g)
Control	200.00	70.67	130.00	49.56	16.26	33.30
ESP 12	185.83	63.20	122.63	46.74	14.80	32.14
ESP 24	151.53	52.70	98.83	39.34	12.65	26.69
ESP 36	87.22	28.35	58.67	34.82	11.93	22.89
ESP 41	80. 17	27.67	52.50	30.95	9.98	20.97
ESP 48	54. 33	19.33	35.00	28.89	9.09	19.80
ESP 60	37.47	16.33	21.14	20.29	7.92	12.37
S.E.±	3.10	1.694	2.265	1.366	0.638	0.878
C.D. at 5%	9.42	5.139	6.872	4.145	1.939	2.638

4.1.8.14 Effect on fresh weight of top

There was significant decrease in fresh weight due to every higher concentration of ESP except 36 and 41 (Table 63).

4.1.8.15 Effect on dry weight of whole plant

The dry weight of whole plant was decreased significantly when the ESP was raised from 12 to 36 (Table 63 and Fig. 5).

4.1.8.16 Effect on dry weight of root

The ESP 12 and 24 and ESP 36 and 41 resulted significant decrease in dry weight of root (Table 63).

4.1.8.17 Effect on dry weight of top

The ESP 36 and ESP 48 behaved similarly as the decrease in dry weight of top was on par to their succeeding ESP levels.

4.1.8.2 Physiological parameters

4.1.8.2.1 Effect of exchangeable sodium percentage on chlorophyll content of leaves

The chlorophyll 'a' and 'b' decreased due to every higher level of ESP. However, the higher levels of ESP resulted in significant decrease of chlorophyll 'a' but, the control, ESP 12 and 24, were similar in effect as they were at par. The total chlorophyll of leaves decreased significantly beyond the ESP 24.





Photo plate No.25 : Effect of ESP on shoot and root growth and stem diameter under E_4 (problematic soil) and E_6 (ESP 60) observed 8 months of planting



Photo plate No. 26 : Effect of ESP levels showing gradual change in chlorophyll content in Drumstick

4.1.8.2.2 Effect on number of stomata

The number of stomata were decreased due to every increase of ESP concentration (Table 64 and Fig. 2). However, the ESP 48 and 60 were on par.

Table 64: Effect of ESP on chlorophyll content of leaves number of stomata per unit area and rate of transpiration of Drumstick

Treatments	Chlorophyll 'a' mg/g	Chlorophyll 'b' mg/g	Chlorophyll Total mg/g	Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
			Leaves		
Control	1.0070	0.9197	1.9267	20.67	0.0286
ESP 1 2	1.0030	0.9393	1.9110	19.00	0.0264
ESP 24	0.8263	0.9317	1.6913	17.33	0.0254
ESP 36	0.7393	0.8050	1.5453	15.00	0.0251
ESP 41	0.6220	0.7380	1.3600	13.67	0.0247
ESP 48	0.3867	0.4950	0.8817	12.07	0.0233
ESP 60	0.2900	0.3670	0.6570	11.00	0.0220
S.E.±	0.026	0.024	0.0342	0.519	0.0004
C.D.at 5%	0.079	0.073	0.1040	1.576	0.0013

4.1.8.2.3 Effect on rate of transpiration

Except ESP from 41 to 48 all other decreases in rate of transpiration due to various ESP levels were statistically non-significant (Table 64 and Fig. 3).

4.1.8.3 Effect of exchangeable sodium percentage on chemical composition

The data on chemical composition of leaves, roots and stem of drumstick as influenced by various ESP levels is reported in Table 65 and 66.

4.1.8.3.1 Macronutrient content of leaves, roots and stem

4.1.8.3.1.1 Nitrogen

Leaves : The effect of ESP on N content of leaves was seen in increasing order upto problematic soil after which N was decreased but significantly compare to ESP 48. In ESP 48 to 60, the N content was also decreased but with a non-significant effect.

Roots : Every higher concentration of ESP resulted into statistically significant decrease of N content of roots.

Stem : The decrease in N content of stem due to various levels of ESP resulted similarly as in stem.

4.1.8.3.1.2 Phosphorus

Leaves : The P content of leaves was significantly reduced due to ESP at 12, 36 and 60 (Table 65).

Roots : The decrease in P content of roots was significant in the ESP level from 36 to 60. The earlier ESP levels behaved similarly.

Table 65: Effect of ESP on macronutrient content (Percentage) of leaves, roots and stem of Drumstick

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	2.40	0.72	3.15	3.24	1.12	1.17	0.20
ESP 12	2.88	0.51	3.03	3.00	1.00	1.10	0.25
ESP 24	2.99	0.46	2.98	2.70	0.91	0.88	0.37
ESP 36	3.30	0.34	2.49	2.10	0.78	0.75	0.57
ESP 41	3.60	0.30	2.21	1.75	0.59	0.48	0.62
ESP 48	2.80	0.25	1.93	1.46	0.44	0.33	0.93
ESP 60	2.68	0.10	1.78	0.98	0.22	0.13	1.08
S.E. ±	0.084	0.020	0.046	0.079	0.027	0.031	0.030
C.D.at 5%	0.257	0.062	0.139	0.241	0.082	0.093	0.090
			Roots				
Control	1.96	0.85	1.78	1.12	1.01	1.12	0.38
ESP 12	1.88	0.80	1.73	0.92	0.97	0.90	0.48
ESP 24	1.69	0.75	1.65	0.84	0.85	0.78	0.66
ESP 36	1.58	0.72	1.55	0.75	0.72	0.61	0.81
ESP 41	1.39	0.67	1.48	0.60	0.50	0.53	0.98
ESP 48	1.28	0.55	1.39	0.53	0.43	0.42	1.16
ESP 60	0.97	0.21	1.23	0.28	0.31	0.28	1.45
S.E.±	0.035	0.039	0.016	0.027	0.023	0.025	0.035
C.D.at 5%	0.105	0.117	0.048	0.081	0.069	0.075	0.107
			Stem				
Control	1.76	0.80	2.45	1.00	0.82	1.50	0.20
ESP 12	1.80	0.77	2.35	0.95	0.78	1.39	0.30
ESP 24	1.95	0.67	2.04	0.84	0.68	1.12	0.41
ESP 36	1.52	0.58	1.90	0.68	0.59	0.89	0.50
ESP 41	1.35	0.51	1.78	0.52	0.50	0.74	0.57
ESP 48	1.19	0.31	1.49	0.45	0.41	0.66	0.68
ESP 60	0.84	0.24	1.36	0.37	0.29	0.43	0.80
S.E.±	0.049	0.018	0.111	0.016	0.014	0.036	0.039
C.D.at 5%	0.131	0.056	0.337	0.050	0.049	0.109	0.117

Stem : The every higher concentration of ESP i.e. from 12 to 60 resulted significant decrease in P content of stem.

4.1.8.3.1.3 Potassium

Leaves : The results of K content in leaves (Table 65) indicated that the ESP levels 12 and 24 were on par to each other. The ESP levels from 36 to 60 resulted in to significant decrease in K content of the leaves.

Roots : The K content of the roots due to various ESP levels was decreased significantly.

Stem : The difference in K content of the stem due to ESP 41, 48 and 60 were at par. Similarly the ESP levels 24, 36 and 41 resulted similar decreases in K content of the stem.

4.1.8.3.1.4 Calcium

Leaves : The Ca content of theleaves showed that the ESP level of 12 decreased the Ca content of the leaves but non significantly as compared to control (Table 65). The higher concentrations of ESP from 24 to 60 showed significant decrease in Ca content of the leaves.

Roots : The Ca content of the roots due to ESP 12 and 24 and ESP 41 and 48 was non-significant. However the ESP concentration of 36 and 60 resulted significant decrease in Ca content of the roots from their respective preceding concentrations of ESP.

Stem : Every higher subsequent concentration of ESP showed significant decrease in Ca content of the stem.

4.1.8.3.1.5 Magnesium

Leaves : The Mg content of the leaves was found significantly decreased due to every subsequent increase of ESP (Table 65).

Roots : Except ESP 12 all other ESP levels showed significant decreases in ESP content of the roots.

Stem : Similar to that of roots the Mg content of the stem was decreased significantly due to every increase of ESP beyond 24.

4.1.8.3.1.6 Sulphur

Leaves : Except ESP 12 all other higher concentrationsof ESP resulted into significant decrease in S content of leaves (Table 65)

Roots : All the ESP concentrations indicated significant decrease in S content of the roots.

Stem : The ESP at 48 from its preceeding ESP level only resulted into non-significant decrease in S content of the stem. There was significant decrease in S content due to other ESP levels.

4.1.8.3.1.7 Sodium

Leaves : The increase in ESP concentrations resulted into

increase of Na content of the leaves. However, the increase was non-significant at ESP 12 and 41 (Table 65).

Roots : The ESP concentrations from 12 to 60 were accompanied with significant increases in Na content of the roots.

Stem : There was also increase in Na content of stem due to various ESP concentrations, but only significant increase in Na content of the stem was noticedat ESP 60.

4.1.8.3.1.8 Ca : Na

Leaves : The Ca : Na of the leaves decreased similarly due to the ESP levels from 36 to 48 (Table 66). In rest of the cases the decrease in Ca : Na due to ESP levels was significant.

Roots : As compared to control the increased concentrations of ESP resulted into significant decrease in Ca : Na ratio of roots.

Stem : The ESP concentrations from 12 to 48 showed significant decrease in Ca : Na content of the stem.

4.1.8.3.1.9 Ca + Mg + K : Na

Leaves : The ESP levels from 36 to 41 and ESP from 48 to 60 showed non-significant decrease in Ca + Mg + K : Na of leaves (Table 66).

Table 66: Effect of ESP on micronutrient ratios of Ca:Na and Ca + Mg + K : Na and micronutrient contents of leaves, roots and stem of Drumstick

Treatments	Ca/Na	Ca+Mg+K/Na	Micronutrient in ppm Zn	Fe	Mn	Cu
			Leaves			
Control	17.00	38.49	46.11	1742.58	367.04	75.50
ESP 12	12.15	28.41	41.59	1737.05	333.82	73.45
ESP 24	7.55	18.25	35.72	1481.58	326.15	60.92
ESP 36	3.69	9.43	30.74	1081.51	290.65	45.37
ESP 41	2.87	7.46	29.39	984.70	218.32	38.05
ESP 48	1.57	4.18	23.05	795.52	182.13	28.32
ESP 60	0.91	2.76	10.08	528.99	143.60	15.42
S.E.±	0.679	1.524	1.555	50.950	7.855	2.149
C.D.at 5%	2.061	4.623	4.717	154.553	23.827	6.518
			Roots			
Control	2.96	10.31	74.60	1606.42	159.47	83.18
ESP 12	1.92	7.57	62.36	1520.38	137.28	75.79
ESP 24	1.27	5.06	53.40	1450.90	121.20	65.32
ESP 36	0.93	3.73	43.40	1268.45	107.17	53.10
ESP 41	0.61	2.63	40.07	1189.38	95.68	47.82
ESP 48	0.46	2.04	38.43	1100.23	82.33	39.17
ESP 60	0.19	1.26	33.00	1035.41	70.83	23.01
S.E.±	0.094	0.195	1.470	18.986	2.885	2.238
C.D.at 5%	0.286	0.593	4.460	57.593	8.753	6.787
			Stem			
Control	5.00	21.35	125.23	1484.42	82.14	23.89
ESP 12	3.18	13.66	115.83	1359.03	75.25	21.15
ESP 24	2.05	8.69	97.24	1181.13	68.15	18.87
ESP 36	1.36	4.90	80.13	1008.84	60.12	13.37
ESP 41	0.91	4.37	63.10	989.43	49.87	9.75
ESP 48	0.68	3.50	43.85	781.72	45.36	7.10
ESP 60	0.47	2.11	24.41	593.43	44.92	4.18
S.E.±	0.029	0.382	3.420	31.629	5.388	0.652
C.D.at 5%	0.229	2.372	10.375	95.946	16.315	1.777

Roots : The every higher concentrations of ESP compared to control resulted into significant decrease in Ca + Mg + K : Na ratio of roots.

Stem : The ESP concentrations from 36 to 60 behaved similarly in decrease of Ca + Mg + K : Na ratio in stem.

4.1.8.3.2 Micronutrient content of leaves, roots and stem

4.1.8.3.2.1 Zinc

Leaves : The ESP 12 over control and ESP 41 over 36 only showed non-significant decrease in Zn content of the leaves. There was five times decrease in Zn content of the leaveas as was noticed due to ESP 60 as compared to control.

Roots : Highly significant decrease in Zn content of the roots was noticed due to each subsequent higher concentrations of ESP.

Stem : Only ESP 12 resulted into non-significant decrease in Zn content of the stem but the ESP concentrations beyond 24, resulted into significant decreases in Zn content of stem.

4.1.8.3.2.2 Iron

Leaves : The ESP concentration of 24 and the ESP from 48 to 60 showed significant decrease in Fe content of leaves (Table 66).

Roots : There was high reduction in Fe content of the roots due to various concentrations of ESP.

Stem : Except ESP from 24 to 41 all other ESP concentrations showed significant decrease in Fe content of stem.

4.1.8.3.2.3 Manganese

Leaves : The ESP level from 36 to 60 showed severe significant reduction in Mn content of the leaves (Table 66). The ESP 12 and 24 though showed increase in Mn content, but it was non-significant.

Roots : All ESP concentrations from 12 to 60 resulted into highly significant decrease in Mn content of the roots.

Stem : Though there was decrease in Mn content of the stem due to various ESP concentration, in most of the cases it was non-significant.

4.1.8.3.2.4 Copper

Leaves : The higher concentration of ESP from 12 to 60 recorded significant decreases in Cu content of the leaves. The ESP 12 and control were similar in effect (Table 66).

Roots : All higher concentrations of ESP as compare to control were found to be effective in significant decrease of Cu content of roots.

Stem : Similar to roots the higher concentrations of ESP resulted into significant decrease in Cu content of the stem (Table 66).

4.1.4 Estimates of ratios of sodium

The estimation of ratios of sodium in leaves and roots and stem and roots (Table 66 a) indicated that the ratio of leaves to root was increasing order with the increase in ESP levels in cashew, markingnut, karonda, passion fruit and drumstick. Whereas in rest of the crops the ratio was not in order. The results further indicated that except phalsa and drumstick the ratio was more than one indicating high amount of deposiation of sodium in leaves.

The ratio of sodium of stem to root was increased in all the fruit crops with the increase in ESP levels. Similarly the ratio was higher than one in cashew, coconut and markingnut indicating thereby high amount of sodium in stem also. It was interesting to note that fruit crops like soapnut, phalsa and drumstick, deposiations of sodium in leaves was more as compare to stem. But in rest of the crops the accumulation of sodium in stem was greater in all ESP levels. Generally the ratio more than one is the indication of resistant of the crop to ESP and the ratio below one is the indication of susceptibility of the crop to ESP. But the results in the present investigation showed that the plants of cashew, markingnut and passion fruit were not servived might be becuase of higher amount of

Table 66a: Sodium concentration ratio in leaves:roots and stem:roots as influenced by varied levels of ESP in fruit crops

Fruit crops		ESP levels		
		12	41	60
Cashew	L:R	1.65	1.88	1.89
	S:R	1.30	1.36	2.00
	D	-	360	300
Coconut	L:R	1.00	0.95	0.80
	S:R	-	-	-
	D	-	-	300
Markingnut	L:R	1.10	1.04	1.31
	S:R	1.05	1.23	1.66
	D	-	300	240
Soapnut	L:R	1.68	1.43	1.69
	S:R	0.40	0.64	0.65
	D	-	-	300
Phalsa	L:R	0.65	0.50	0.56
	S:R	0.29	0.35	0.52
	D			
Karonda	L:R	1.29	1.11	1.12
	S:R	0.60	1.26	1.40
	D	-	-	300
Passion fruit	L:R	1.41	1.48	1.61
	S:R	0.58	1.27	1.74
	D	-	-	240
Drumstick	L:R	0.52	0.63	0.74
	S:R	0.62	0.58	0.55
	D	-	300	240

L:R - Leaves:Root, S:R - Stem:Root
D - Days after planting

deposiation of sodium in stem compare to leaves. Therefore these crops are said to be sensitive one to ESP. However, in case of karonda even if the deposiation of sodium in stem was higher compare to leaves, the plants did not show severe mortality, which indicated its tolerance to ESP.

4.1.5 Response analysis of dry matter under varying exchangeable sodium percentage (ESP) level

Quadratic response function of ESP on dry matter production of cashew, coconut, markingnut, soapnut, phalsa, karonda, passion fruit and drumstick is presented in Table 66b.

4.1.5.1 Cashew

The quadratic response function was highly significant giving high value of R^2 0.9684 explaining thereby 96.84 per cent variation in dry matter of cashew by different ESP levels. The partial regression coefficient attached to the quadratic term X^2 was negatively significant, which implied existence of maxima of the dry matter with respect to ESP levels and diminishing return in dry matter after the maxima. The maximum tolerabble level of ESP was estimated to be as ESP 3.75 and estimated dry matter at this levels was 39.03. Beyond this levels of ESP the dry matter declined with additional increment in ESP level.

Table 66b: Quadratic response function of ESP on dry matter production

Fruit crops	Intercept	Partial regression coefficient	Partial regression	Estimated tolerable level of ESP	Estimated dry matter (g)	Coefficient of multipee determination (R^2)	F
1.	2.	3.	4.	5.	6.	7.	8.
Cashew	39.39	0.0549	-0.0074*	3.74	39.73	0.9684**	61.39
	S.E. ±	0.1508	0.0023				
	t	0.3607	-3.1952				
Coconut	788.20	2.6223	-0.1143*	11.47	723.39	0.9639**	53.41
	S.E.±	1.8427	0.0285				
	t	1.4232	-4.0066				
Markingnut	16.50	-0.0664	-0.0015			0.9749**	77.76
	S.E. ±	0.0582	0.0007				
	t	-1.3232	-1.9087				
Soapnut	75.10	-1.6943 X	0.0103			0.9550**	42.48
	S.E.±	0.4489	0.0069				
	t	-3.7766	-1.4885				

Contd....

Table 66b. Contd...

1.	2.	3.	4.	5.	6.	7.	8.
Phalsa	29.98	-0.3381	-0.0002			0.9573**	44.91*
	S.E. ±	0.1382	0.0021				
	t	-2.4469	0.0112				
Karonda	115.72	-0.4979	0.0239			0.8464**	115.71
	S.E.±	1.6780	0.0260				
	t	-0.2967	-0.9179				
Passion fruit	53.00	-0.3952 X	0.0006			0.9462**	35.17
	S.E.±	0.1722	0.0067				
	t	-2.2952	0.1445				
Drumstick	51.73	-0.4822	-0.0095*			0.9916**	236.64
	S.E.±	0.4000	0.0062				
	t	-0.7351	-3.3930				

No. of observations = 7, * and ** significant at 5 and 1 per cent level, respectively.

Y = Estimated dry matter, X = ESP levels, b_0, b_1, b_2 regression coefficients.

4.1.5.2 Coconut

The coefficient determination R^2 for this crop was 0.9639 explaining thereby 96.39 per cent variation in dry matter of coconut by the levels of ESP. The partial regression coefficient attached to quadratic term X^2 was negatively significant explaining thereby diminishing rate in dry matter with increase in ESP after certain level of ESP. The dry matter significantly increased upto 11.47 and after this level of ESP the dry matter declined the estimated dry matter at this level was 0.72.

4.1.5.3 Markingnut

The quadratic relationship between the levels of ESP and dry matter of markingnut was highly significant giving high value of R^2 as 0.9749. The coefficient of multiple determination R^2 explained 97.49 per cent variation in dry matter of markingnut by the various levels of ESP. The partial regression coefficient attached to the X and X^2 were both negative and non significant.

4.1.5.4 Soapnut

The quadratic function in R^2 of soapnut was highly significant giving high value of R^2 as 0.9550. The R^2 explained 95.50 per cent variation in soapnut dry matter by the levels of ESP. The partial regression coefficient

attached to the linear term X was negative and significant, whereas the partial regression coefficient attached to quadratic term X^2 was positive and non significant implying thereby consistant decrease in soapnut dry matter with respective levels of ESP.

4.1.5.5 Phalsa

The quadratic relationship between the levels of ESP and dry matter of phalsa was highly significant giving high value of R^2 as 0.9573 and explaining thereby 95.73 per cent variation in dry matter of phalsa. The partial regression coefficient attached to the linear term was negative and significant implying thereby consistant decrease in dry matter of phalsa with respect to increase in the levels of ESP.

4.1.5.6 Karonda

The functional relationship in karonda was highly significant giving high value of R^2 0.8464. The coefficient of multiple determination R^2 thus explained 84.64 variation in dry matter yield with respect to increase level of ESP. But noneof the coefficients were significant.

4.1.5.7 Passion fruit

The quadratic trend between dry matter of passion fruit and various level of ESP was significant.

The coefficient of multiple determination R^2 was 0.9462 implying thereby 94.62 per cent variation in passion fruit dry matter by the different levels of ESP. The partial regression coefficient attached to the linear term X was negative and significant indicating negative correlation and thus decline in dry matter yield with increase in levels of ESP.

4.1.5.8 Drumstick

The quadratic functional relationship of drumstick dry matter with various levels of ESP was highly significant. The coefficient of determination R^2 was 0.9916 implying 99.16 per cent variation in drumstick dry matter with various levels of ESP. The coefficient of quadratic linear term X^2 was negative and highly significant. Similarly the coefficient of linear term X was negative and non significant indicating drumstick fall in dry matter yield due to ESP levels.

Conclusions

The quadratic functional relationship in all the crops was highly significant. In case of cashew and coconut, the maximum tolerable level of ESP could be established whereas the yield consistently declined in case of other fruit crops. In case of drumstick, the consistent declining trend was observed.

4.2 Effect of salinity on growth

4.2.1 Cashew

4.2.1.1 Effect on plant height

The results indicated that the salinity effects were started at its initial level itself as evidenced by different significantly from control after 60, 300 and 360 days of planting. The results further showed that the next higher levels of salinity i.e. from 8 to 12 mmhos/cm.reduced the plant height significantly at all growth stages (Table 67). At 60 days after planting due to salinity level 12 and 14 mmhos/cm differed significant in reducing the plant height but there after the height was reduced to a greated extent. It was interesting to note that the salinity levels like 16 and 20 mmhos/cm were statistically similar at 60, 120 and 180 days after planting but after 180 days of planting the salinity levels resulted into complete death of plants.

4.2.1.2 Effect on number of leaves

The number of leaves were reduced but non significantly at 60 days after planting due to salinity levels of 4 and 8 mmhos/cm. However, the same salinity levels at 120 and above growth periods, the number of leaves were tremendously decreased. At the same time the salinity levels of 8 and 12 mmhos/cm.attected significant

Table 67: Effect of salinity on percentage increase in the plant height, number of leaves and stem diameter of Cashew

Treatments	Days after planting					
	60	120	180	240	300	360
			plant height			
Control	50.00	95.88	141.67	233.21	279.10	317.83
4 mmhos/cm	46.36	90.91	136.36	221.58	254.50	268.50
8 mmhos/cm	40.27	77.27	116.00	195.45	225.07	242.33
12 mmhos/cm	27.00	62.03	102.00	168.18	184.35	203.64
14 mmhos/cm	25.00	54.17	86.83	135.44	-	-
16 mmhos/cm	20.83	48.01	62.23	-	-	-
20 mmhos/cm	19.23	45.83	54.50	-	-	-
S.E.±	1.082	1.691	3.397	7.112	4.220	5.110
C.D.at 5%	3.281	5.131	10.304	22.402	13.293	16.065
			Number of leaves			
Control	50.03	160.67	397.48	516.17	563.33	583.27
4 mmhos/cm	40.37	120.65	323.33	421.43	446.65	457.12
8 mmhos/cm	38.20	101.01	280.44	345.10	328.57	363.16
12 mmhos/cm	33.33	71.41	195.13	238.90	245.83	249.83
14 mmhos/cm	16.67	38.33	183.33	200.67	-	-
16 mmhos/cm	12.50	37.50	150.18	-	-	-
20 mmhos/cm	9.30	28.50	133.33	-	-	-
S.E.±	1.534	4.372	10.699	19.079	19.943	15.204
C.D.at 5%	4.653	13.262	32.454	60.100	65.037	49.582
			Stem diameter			
Control	55.23	152.89	197.04	221.75	233.37	240.37
4 mmhos/cm	50.83	145.83	185.28	206.29	215.10	221.22
8 mmhos/cm	44.40	131.10	162.14	177.74	185.33	189.10
12 mmhos/cm	44.83	126.44	157.48	164.23	171.24	175.49
14 mmhos/cm	38.10	115.31	134.54	141.33	-	-
16 mmhos/cm	37.93	110.18	126.84	-	-	-
20 mmhos/cm	25.13	91.18	104.43	-	-	-
S.E. ±	3.834	2.513	2.311	4.649	3.400	3.123
C.D.at 5%	11.631	7.624	7.010	14.649	11.084	16.700

reduction in number of leaves during the entire period of experimentation. Actually the salinity levels from 14 to 20 mmhos/cm were found statistically similar upto 180 days after planting but at 300 and 360 days after planting the plants could not survived indicating thereby their severe effects of salinity (Table 67).

4.2.1.3 Effect on stem diameter

From the results in Table 67 it was noticed that the very first two salinity levels though not reduced stem diameter significantly at 60 days after planting but at 120 days and above the diameter was reduced significantly with increasing order. The results further revealed that except at 300 days of planting the salinity levels i.e. 8 and 12 mmhos/cm behaved similarly. The higher levels of salinity also showed their significant decrease in stem diameter upto 180 days after planting but beyond 6 months plants were not survived.

4.2.1.4 Effect on plant spread

The salinity levels of 4 and 8 mmhos/cm were on par and significant over higher salinity levels. The differences in the levels of 14, 16 and 20 mmhos/cm were non significant between themselves, but they significantly reduced plant spread even than 12 mmhos/cm salinity.

4.2.1.5 Effect on leaf area

Salinity levels significantly reduced the leaf area than control. There was no significant difference in total leaf area per plant in salinity levels 14 and 16 mmhos/cm. A sudden decrease in total leaf area was noticed at salinity level of 12 mmhos/cm.

Table 68. Effect of salinity on plant spread, total leaf area per plant and mortality of Cashew

Treatments	Plant spread (cm)	Total leaf area (sq.cm.)	Mortality (per cent)
Control	23.50	1581.33	00.00 (00.57)
4 mmhos/cm	20.10	1351.34	00.00 (00.57)
8 mmhos/cm	20.00	1200.22	17.33 (24.58)
12 mmhos/cm	17.17	995.11	24.66 (30.00)
14 mmhos/cm	13.17	735.17	100.00 (90.00)
16 mmhos/cm	11.00	650.20	100.00 (90.00)
20 mmhos/cm	11.00	433.67	100.00 (90.00)
S.E.±	0.777	38.326	- 4.493
C.D.at 5%	2.356	115.251	- 13.000

The figures in parenthese indicate transformed percentage value in to arcsine value.

4.2.1.6 Effect on plant mortality

The data regarding mortality are presented in Table 68 and shown graphically in Fig. 6. There was no mortality recorded upto 4 mmhos/cm. As the salinity increased from 8 to 20 mmhos/cm the mortality was increased.

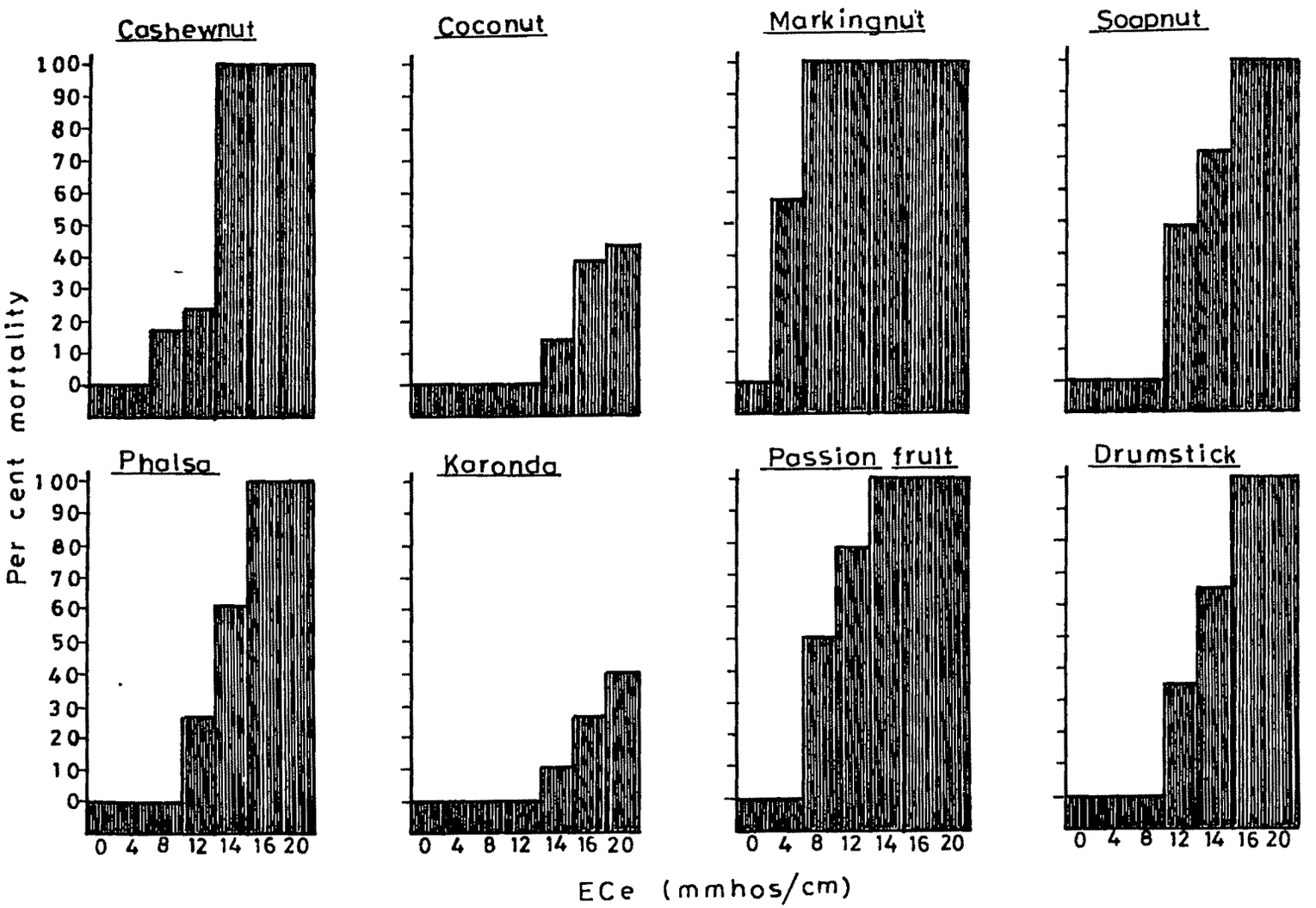


Fig 6. Effect of different levels of salinity on mortality at the time of termination of experiment



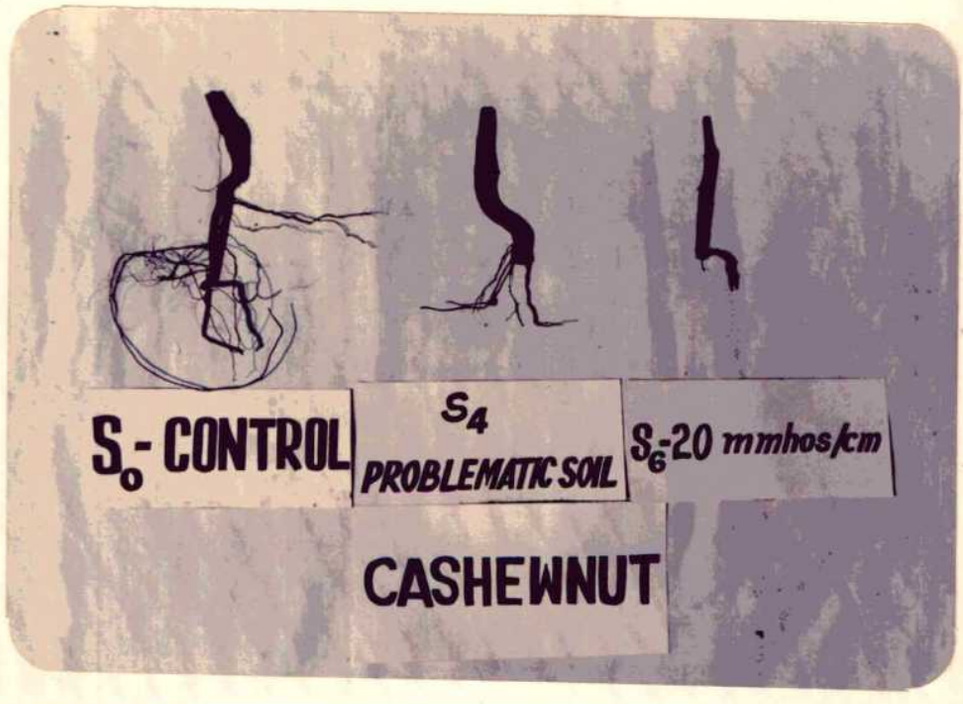


Photo plate No. 27 : Plant mortality symptoms as observed on shoot and root under 20 mmhos/cm 240 days after planting

There was complete mortality at salinity 14 mmhos/cm and above. The signs of mortality were started from 150 days after planting and plant death occured at 240 days after planting in both higher salinity levels (i.e. 16 and 20 mmhos/cm). Plant under salinity 8 and 12 mmhos/cm were recorded statistical similar effectson platn mortality.

4.2.1.7 Effect on root length

The salinity levels upto 8 mmhos/cm did not significantly reduce the root length. The salinity levels of 12 and 14 mmhos/cm were on par with 4 and 8 mmhos/cm, they significantly reduced the root length over control. The lowest root length was recorded under 20 mmhos/cm (Table 69).

4.2.1.8 Effect on root volume

From the data in Table 69, it is seen that the root volume significantly decreased when salinity was raised upto 8 mmhos/cm. There was no difference in the root volume from 8 to 16 mmhos/cm. Minimum root volume was recorded in 20 mmhos/cm, which was similar to next higher salinity levels.

4.2.1.9 Effect on number of primary roots

Table 69 showed that the primary roots decreasedwith increasedsalinity level. Salinity levels

4 and 8 mmhos/cm was recorded similar effect on primary roots. But they produced more number of primary roots. But they produced more number of primary roots than other higher level of salinity (i.e. 12 to 20 mmhos/cm). The salinity level of 16 and 20 mmhos/cm were also similar in effect.

Table 69: Effect of salinity on root length, root volume, number of primary root, number of secondary root and total number of root of Cashew

Treatments	Root lenght (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots
Control	19.23	10.10	11.20	29.40	40.60
4 mmhos/cm	17.10	8.03	9.00	23.27	32.27
8 mmhos/cm	16.50	7.50	7.50	12.12	19.62
12 mmhos/cm	13.01	6.00	7.50	7.00	14.50
14 mmhos/cm	13.05	6.00	6.00	5.21	11.21
16 mmhos/cm	9.11	5.50	4.33	2.20	6.53
20 mmhos/cm	8.50	5.33	2.00	2.31	4.31
S.E.±	1.550	0.090	1.060	1.230	1.552
C.D.at 5%	4.721	2.093	3.240	3.721	4.723

4.2.1.10 Effect on number of secondary roots

The increasing salinity levels upto 12 mmhos/cm significantly reduced the secondary roots (Table 69) from their respective lower salinity levels. The difference between 12 and 14 mmhos/cm was similar.

4.2.1.11 Effect on total number of roots

Increased salinity level upto 12 mmhos/cm significantly reduced the total roots number than its lower level. Though the salinity level of 14 mmhos/cm (problematic soil) was at par with 12 and 16 mmhos/cm. The salinity level of 20 mmhos/cm significantly reduced total root number than all salinity levels except that of 16 mmhos/cm (Table 69).

4.2.1.12 Effect on fresh weight of whole plant

Among different salinity levels, 4 and 8 mmhos/cm were on par and significantly superior over remaining salinity levels. Further increase in salinity levels upto 20 mmhos/cm significantly reduced the fresh weight of whole plant than its respective lower level (Table 70).

4.2.1.13 Effect on fresh weight of root

The salinity level upto 4 mmhos/cm did not reduce the fresh weight of roots significantly than control, but the salinity level of 8 mmhos/cm though was at par with 4 mmhos/cm. Similarly the salinity levels of 12 and 14 mmhos/cm were on par and they significantly reduced fresh weight of roots than their lower salinity levels.

4.2.1.14 Effect on fresh weight of top

The effect of 4 mmhos/cm salinity was not evident, but further increase in salinity significantly reduced the fresh weight of tops than their respective lower levels. However, lowest fresh weight of top was recorded under 20 mmhos/cm. Which was significantly different than the rest of the treatments.

Table 70: Effect of salinity on fresh and dry weight of whole plant, root and top of cashew

Treatments	Fresh weight of whole plant	Fresh weight of root	Fresh weight of top	Dry weight of whole plant	Dry weight of root	Dry weight of top
Control	103.66	23.33	80.33	41.570	8.33	33.24
4 mmhos/cm	97.33	20.33	77.00	39.967	7.22	32.75
8 mmhos/cm	92.00	19.33	72.67	38.693	7.44	31.25
12 mmhos/cm	70.56	14.67	55.89	36.759	7.18	28.57
14 mmhos/cm	59.33	14.00	45.33	34.213	7.00	27.21
16 mmhos/cm	47.33	10.00	37.33	27.000	5.15	21.85
20 mmhos/cm	33.56	7.00	26.56	20.050	4.45	15.60
S.E.±	1.746	1.620	1.106	0.673	0.552	0.539
C.D.at 5%	5.236	3.524	3.350	2.039	1.584	1.633

4.2.1.15 Effect on dry weight of whole plant

The data regarding the dry weight of whole plant are given in Table 70 and shown graphicall in Fig. 7.

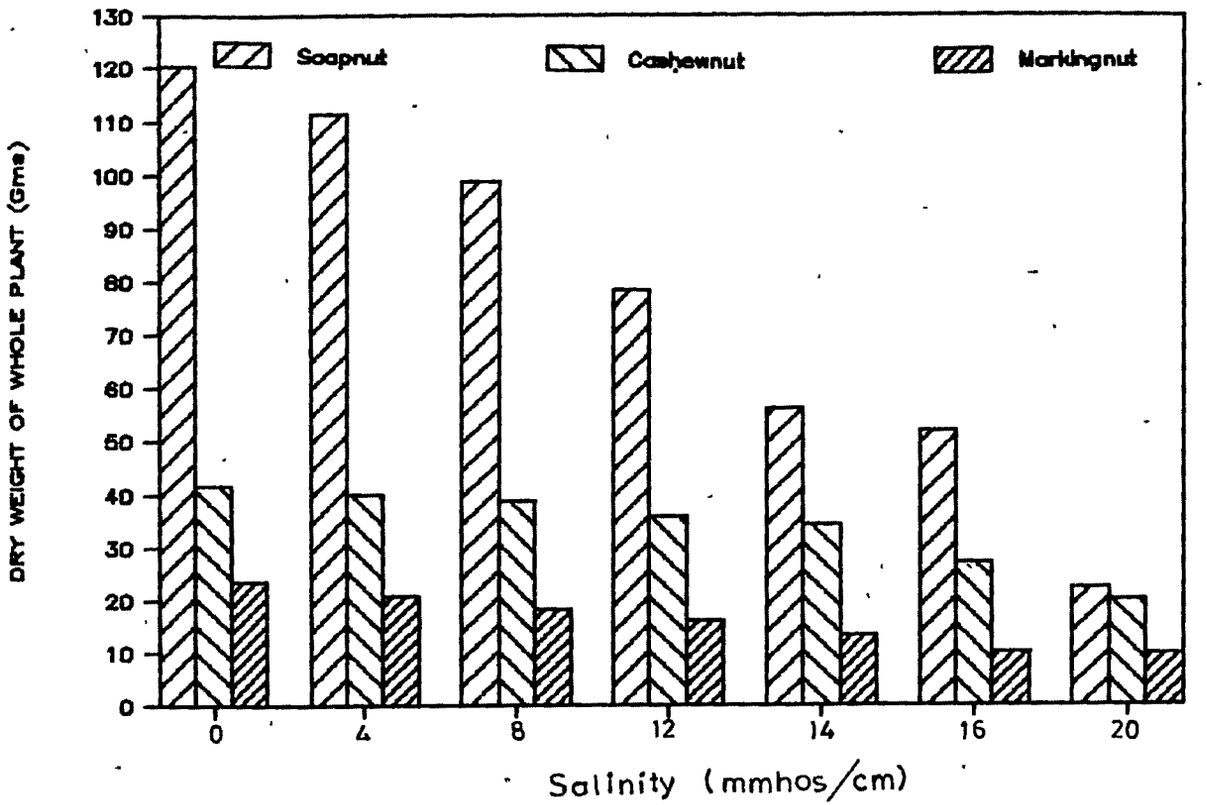


Fig 7. Effect of salinity on dry matter accumulation in Cashewnut, Soapnut and Markingnut at the time of harvest

The salinity levels of 12 and 14 mmhos/cm were on par among themselves and they significantly reduced the dry weight of whole plant than their lower salinity levels. The salinity levels of 16 and 20 mmhos/cm significantly reduced the dry weight of whole plant than their respective lower levels.

4.2.1.16 Effect on dry weight of root

The data in Table 70 indicated that the effects of salinity levels upto 14 mmhos/cm on dry weight of roots were not significant as compared to control, but the salinity levels of 16 and 20 mmhos/cm were on par among themselves, they significantly reduced root dry matter than other level of salinity.

4.2.1.17 Effect on dry weight of top

The salinity level of 4 mmhos/cm was at par with control as well as with 8 mmhos/cm, but the later significantly reduced top weight than control. The salinity levels of 12 and 14 mmhos/cm were at par among themselves and significantly reduced the top weight than their lower levels. Similarly the further increase in salinity levels upto 20 mmhos/cm significantly reduced the top weight than their respective lower levels (Table 70).

4.2.1.2 Physiological parameters

4.2.1.2.1 Effect of salinity on chlorophyll content of leaves

Chlorophyll 'a' and 'b' were tended to decrease with the increase in salinity (Table 71). The decrease of chlorophyll 'a', 'b' and total due to salinity levels of 16 and 20 mmhos/cm was statistically similar.

Table 71: Effect of salinity on chlorophyll content of leaves, number of stomata per unit area and rate of transpiration of Cashew

Treatments	Chlorophyll			Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
	'a'	'b'	Total		
	mg/g				
		Leaves			
Control	1.6607	1.6500	3.3107	11.00	0.0941
4 mmhos/cm	1.1563	1.2337	2.2613	13.00	0.0784
8 mmhos/cm	0.8240	1.1553	1.3793	13.33	0.0767
12 mmhos/cm	0.7983	0.8477	1.3860	19.60	0.0762
14 mmhos/cm	0.5430	0.5443	1.0873	21.33	0.0573
16 mmhos/cm	0.1968	0.4560	0.6420	23.33	0.0487
20 mmhos/cm	0.1750	0.3750	0.5490	24.00	0.0435
S.E.±	0.095	0.033	0.143	1.254	0.0024
C.D. at 5%	0.301	0.133	0.432	3.799	0.0067

4.2.1.2.2 Effect on number of stomata

The data in Table 72 and Fig. 8 indicated that an increasing trend of stomata with the increase level

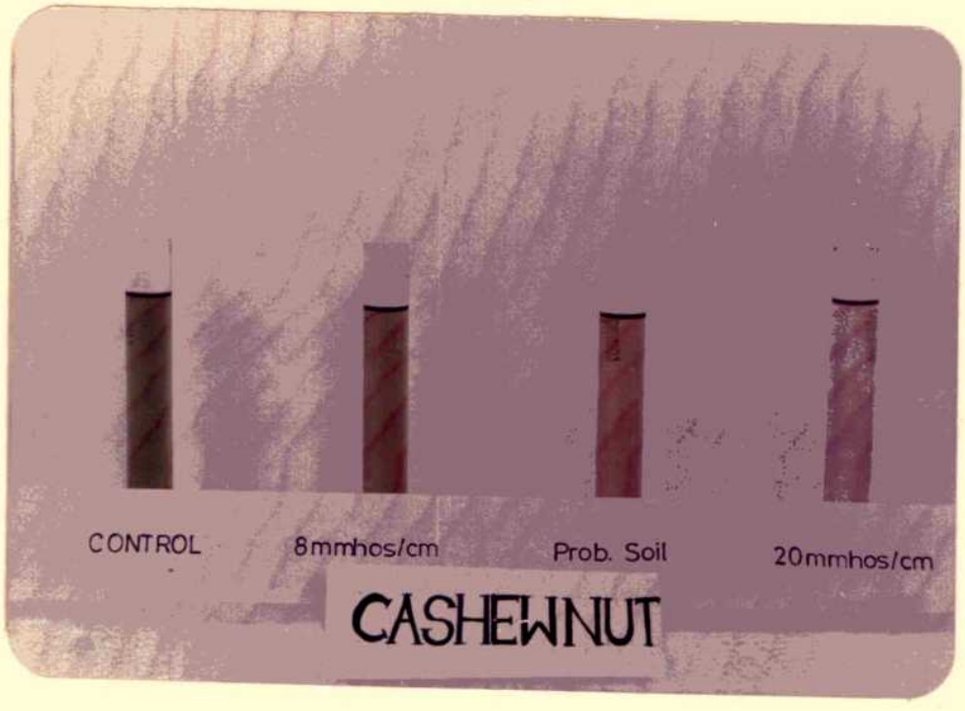


Photo plate No. 28 : Effect of salinity levels showing gradual change in chlorophyll content in Cashew

of salinity was seen. More number of stomata were recorded under 20 mmhos/cm, however not different from that under 14 and 16 mmhos/cm.

4.2.1.2.3 Effect on rate of transpiration

The data regarding rate of transpiration are presented in Table 71 and shown graphically in Fig. 8 which indicated that the rate of trnaspiration decreased with the increase in salinity levels. There was no difference in rate of transpiration under 16 and 20 mmhos/cm, but significantly decreased from salinity level of 14 mmhos/cm.

4.2.1.3 Effect of salinity on chemical composition

The data on chemical composition of leaves, roots and stem in cashew as affected by different salinity levels are presented in Table 72 and 73.

4.2.1.3.1 Macronutrient content of leaves, roots and stem

4.2.1.3.1.1 Nitrogen

Leaves : The N content (Table 72) of leaves decreased with the salinity increase, but it was not consistant. The N content in 4 mmhos/cm was non significantly reduced as compared to control but significant decrease was observed at 8 mmhos/cm. Highly significant reduction in N content of leaves was observed in 16 and 20 mmhos/cm.

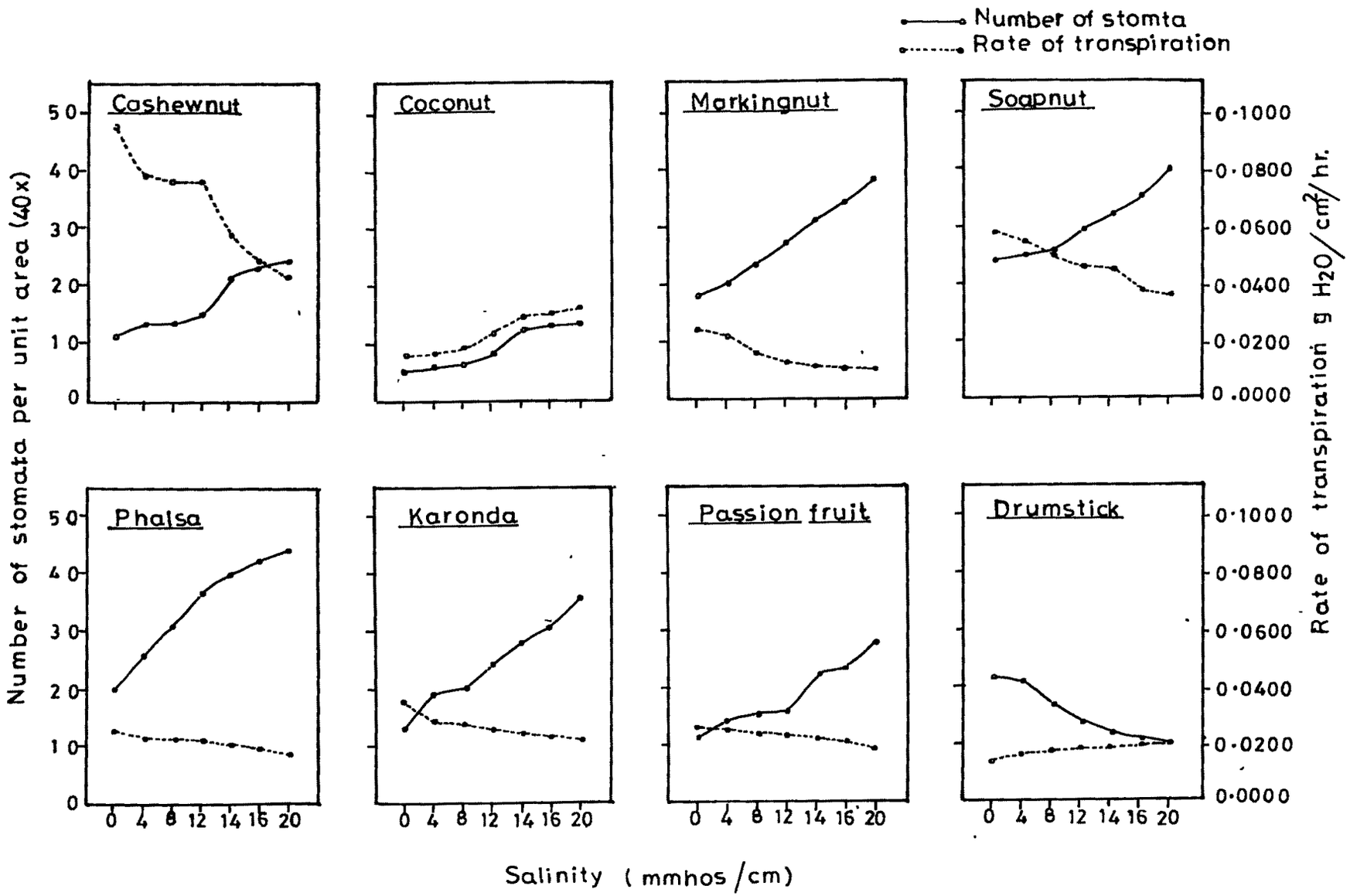


Fig 8. Effect of salinity on number of stomata and rate of transpiration

Table 72: Effect of salinity on macronutrient content (percentage) of leaves, roots and stem of Cashew

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	3.46	0.55	1.75	0.92	1.98	0.48	1.28
4 mmhos/cm	3.29	0.50	1.60	0.85	1.36	0.67	1.39
8 mmhos/cm	3.02	0.38	1.30	0.72	1.25	0.75	1.52
12 mmhos/cm	2.79	0.29	1.30	0.60	1.13	0.52	1.63
14 mmhos/cm	2.62	0.23	1.10	0.41	0.96	0.43	1.98
16 mmhos/cm	2.10	0.20	0.75	0.32	0.73	0.38	2.25
20 mmhos/cm	1.34	0.11	0.32	0.23	0.48	0.19	2.94
S.E. ±	0.086	0.015	0.054	0.023	0.033	0.030	0.078
C.D.at 5%	0.261	0.046	0.163	0.068	0.101	0.090	0.235
			Roots				
Control	3.05	0.55	0.51	1.40	0.94	0.27	0.26
4 mmhos/cm	3.08	0.48	0.50	1.38	0.86	0.27	0.36
8 mmhos/cm	2.82	0.48	0.35	1.07	0.70	0.42	0.52
12 mmhos/cm	2.51	0.37	0.30	1.04	0.67	0.39	0.54
14 mmhos/cm	2.28	0.35	0.23	0.96	0.43	0.32	0.60
16 mmhos/cm	1.94	0.30	0.19	0.88	0.36	0.20	0.61
20 mmhos/cm	1.57	0.23	0.10	0.49	0.19	0.12	0.74
S.E.±	0.155	0.011	0.012	0.047	0.024	0.013	0.021
C.D.at 5%	0.471	0.034	0.036	0.143	0.074	0.039	0.065
			Stem				
Control	3.08	0.42	1.63	1.76	0.56	0.23	0.65
4 mmhos/cm	2.89	0.40	1.60	1.54	0.50	0.51	0.84
8 mmhos/cm	2.53	0.35	1.48	1.40	0.39	0.65	0.97
12 mmhos/cm	2.32	0.28	1.36	1.21	0.31	0.59	1.31
14 mmhos/cm	1.93	0.21	1.19	1.01	0.28	0.45	1.63
16 mmhos/cm	1.98	0.20	0.94	0.72	0.25	0.38	1.82
20 mmhos/cm	1.62	0.11	80.62	0.34	0.13	0.19	2.23
S.E.±	0.071	0.012	0.045	0.047	0.014	0.025	0.043
C.D.at 5%	0.215	0.035	0.168	0.143	0.043	0.077	0.130

Roots : The lowest N content of roots was recorded under 20 mmhos/cm, which was similar to 16 mmhos/cm. The salinity level of 12 mmhos/cm behaved similarly with its lower and higher level of salinity.

Stem: The stem N content significantly decrease with the increase in salinity upto 8 mmhos/cm. There was similar effect between 8 and 12 mmhos/cm as well as between 14 and 16 mmhos/cm in stem content of the N.

4.2.1.3.1.2 Phosphorus

Leaves : There was a decrease in P content of the leaves with the successive increase in salinity except 14 to 16 mmhos/cm. Low P content was recorded under 20 mmhos/cm (Table 72).

Roots : There was no different in the P content of the roots in salinity levels of 4 to 8 mmhos/cm as well as in 12 to 14 mmhos/cm. However, lowest P content was recorded under 20 mmhos/cm, which was significantly less as compared to previous lower levels of 16 mmhos/cm.

Stem : The P content of the stem was significantly decreased when salinity was raised from 4 to 14 mmhos/cm. However, salinity at 14 and 16 mmhos/cm were similar in effect.

4.2.1.3.1.3 Potassium

Leaves : The leaves K content was significantly reduced from 14 mmhos/cm onward (Table 72). Maximum K content of

leaves was noticed under lower level of salinity (i.e. 4 to 12 mmhos/cm).

Roots : The K content of the roots was decreased significantly with the every increase of salinity level from 4 to 20 mmhos/cm.

Stem : The K content of the stem was significantly reduced at salinity of 14 mmhos/cm compare to its lower and higher salinity levels.

4.2.1.3.1.4 Calcium

Leaves : There was significantly decrease in Ca content (Table 72) of leaves with every increase in salinity level. Pronounced decrease in Ca content of the leaves was observed at salinity level of 14 mmhos/cm.

Roots : The salinity levels like 8, 14 and 20 mmhos/cm resulted into significant reduction in Ca content of roots as compared to their respective lower salinity levels.

Stem : The very first salinity level i.e. 4 mmhos/cm differ significantly from control but was similar to 8 mmhos/cm in Ca content of stem. Significant reduction was observed beyond salinity level of 12 mmhos/cm. However, severe effect was seen at 20 mmhos/cm compared to lower salinity levels.

4.2.1.3.1.5 Magnesium

Leaves : The Mg content of the leaves was significantly decreased with the incremental level of salinity. But reduction was maximum when salinity was shifted from 16 to 20 mmhos/cm(Table 72)

Roots : The Mg content of the root was significantly low under 20 mmhos/cm, which was also different from 16 mmhos/cm.

Stem : The Mg content of the stem decreased significantly with the increase of salinity upto 12 mmhos/cm. More stricking effect was noticed at highest level of salinity i.e. 20 mmhos/cm.

4.2.1.3.1.6 Sulphur

Leaves : The S content (Table 72) of the leaves was found to be increased with the increasing level of salinity upto 8 mmhos/cm. However, beyond this salinity, the S content was found to be declined.

Roots : It is observed from the data that the S content of the roots was also increased with increasing level of salinity upto 8 mmhos/cm. The lowest S content was estimated under 20 mmhos/cm, which was significantly different from its next lower level of salinity (i.e. 16 mmhos/cm).

Stem : It is seen from the data that salinity levels upto 12 mmhos/cm increased S content of stem. The S content of the stem at 16 mmhos/cm was similar to 14 mmhos/cm but it was highly and significantly different from 20 mmhos/cm.

4.2.1.3.1.7 Sodium

Leaves : The Na content of the leaves increased with the increased salinity level (Table 72), and was significantly increased from salinity from 12 to 20 mmhos/cm.

Roots : The Na content of root was significantly increased at 4 mmhos/cm as compared to control. Similarly it was significantly increased at salinity 20 mmhos/cm as compared to 16 mmhos/cm.

Stem : The Na content of the stem was significantly increased with the every increases in salinity levels except 4 mmhos/cm.

4.2.1.3.1.8 Ca : Na

Leaves : The Ca : Na content of the leaves significantly decreased with each incremental level of salinity over previous lower salinity levels (Table 73).

Roots : The Ca : Na content of the root was on par at salinity levels from 8 to 20 mmhos/cm.

Stem : The Ca : Na ratio content of the stem was decreased significantly at every increased level of salinity.

4.2.1.3.1.9 Ca + Mg + K : Na

Leaves : The Ca + Mg + K : Na ratio of the leaves was decreasedwith the increase of salinity levels (Table 73). However, lowest ratio was recorded under 20 mmhos/cm, which was statistically similar with its two next lower salinity levels.

Roots : A significant high Ca + Mg + K : Na ratio was observed at 4 mmhos/cm as compared to control plants. But next higher salinity levels resulted on par decreases in the ratio.

Stem : A corresponding significant decrease of Ca + Mg +K :Na ratio of stem was observed when salinity was raised upto 14 mmhos/cm.

4.2.1.3.2 Micronutrient content of leaves, roots and stem

4.2.1.3.2.1 Zinc

Leaves : From the data Table 73, it is seen that the Zn content of the leaves was high under control plant than all salinity levels. However, there was no difference between 14 and 16 mmhos/cm levelsof the salinity.

Roots : The Zn content of the roots at 20 mmhos/cm wa low but not significantly as compared to 16 mmhos/cm

Stem : The Zn content of the stem was decreasedwith increase of salinity levels. The lowest Zn content

4.2.1.3.2.4 Copper

Leaves : It is evident from the data (Table 73) that the Cu content of leaves was significantly reducedupto 14 mmhos/cm. There was no difference between 14 and 16 mmhos/cm of Cu content of the leaves.

Roots : The Cu content of the roots was significantly reduced at salinity level of 4 and 20 mmhos/cm as compared their next lower levels.

Stem : The results on Cu content of stem indicated that there was significant decrease in problematic soils as compared to next lower and higher salinity levels

4.2.2 Coconut

4.2.2.1 Effect on plant height

The adverse effect of the first level of salinity was noted from 240 days after planting. The second salinity level (8 mmhos/cm) showed still greater depressive effect from 180 days after planting. Severe depressive effect of salinity was noted at 16 and 20 mmhos/cm during the entire period of investigation except at 120 days after planting (Table 74).

4.2.2.2 Effect on number of leaves

It is observed from Table 74 that the first salinity level showed depressive effect only at 300 days after planting. At this stage the number of leaves

Table 74: Effect of salinity on percentage increase in plant height, number of leaves and stem diameter of Coconut

Treatments	Days after planting					
	60	120	180	240	300	360
			Plant height			
Control	55.15	237.84	451.87	787.90	934.64	1020.37
4 mmhos/cm	52.54	233.15	444.27	741.37	873.41	847.22
8 mmhos/cm	40.31	215.49	413.11	686.47	816.38	933.21
12 mmhos/cm	28.44	204.20	400.47	661.23	760.23	810.15
14 mmhos/cm	21.36	145.43	377.86	638.71	723.75	774.00
16 mmhos/cm	17.21	110.19	300.34	533.19	601.10	637.88
20 mmhos/cm	14.24	91.35	284.90	508.00	574.21	624.50
S.E.±	3.073	6.108	8.716	12.549	14.110	17.345
C.D.at 5%	9.343	18.528	26.409	38.023	42.795	52.555
			Number of leaves			
Control	33.33	80.67	150.33	238.89	350.57	431.00
4 mmhos/cm	33.33	77.48	146.87	232.19	329.05	355.24
8 mmhos/cm	30.89	66.67	140.18	218.33	300.03	320.51
12 mmhos/cm	25.15	66.67	133.32	186.67	257.33	269.00
14 mmhos/cm	23.89	60.18	117.30	178.07	230.55	241.11
16 mmhos/cm	22.09	58.89	100.89	175.81	202.00	209.72
20 mmhos/cm	20.62	50.19	80.10	153.52	181.90	193.33
S.E. ±	0.554	1.374	5.605	3.566	6.104	8.851
C.D. at 5%	1.680	4.167	16.983	10.817	18.495	26.818
			Stem diameter			
Control	43.65	122.22	212.00	261.11	285.10	303.00
4 mmhos/cm	40.49	117.11	209.17	255.00	269.33	290.17
8 mmhos/cm	33.65	112.11	191.10	231.33	253.00	262.78
12 mmhos/cm	25.19	100.01	173.43	210.55	235.50	243.00
14 mmhos/cm	22.49	80.44	155.50	182.00	198.11	205.33
16 mmhos/cm	20.23	63.03	137.50	160.33	175.22	179.00
20 mmhos/cm	18.34	55.15	130.00	149.20	162.00	166.00
S.E. ±	0.869	3.454	4.791	7.800	10.241	12.022
C.D.at 5%	2.635	14.476	14.535	23.634	31.030	36.426

decreased with increase in salinity. This trend was maintaioned by and large at the termination of 300 days. The salinity level of 20 mmhos/cm significantly reduced number of leaves than other salinity levels and control plants in all growth periods except 60 and 360 days after planting.

4.2.2.3 Effect on stem diameter

It is evident from Table 74 that the plants under control and 4 mmhos/cm recorded similar stem diameter from 120 days after planting. The effect at 16 and 20 mmhos/cm although were not significantly different from each other, the effect of 20 mmhos/cm salinity level was markedly depressive than rest of the levels.

4.2.2.4 Effect on plant spread

The effect of salinity on plant spread is shown in Table 76. It is seen from data that salinity at 4 mmhos/cm and control plant had statistically similar decreases in plant spread. In rest of the salinity levels the reduction in plant spread was significantly different from each other.

4.2.2.5 Effect on leaf area

The leaf area was significantly reduced at every increase of salinity level except 14 mmhos/cm. There was no difference in leaf area per plant in treatment

14 and 16 mmhos/cm. Lowest total leaf area was associated with salinity 20 mmhos/cm, which was 3 time less as compared to control.

4.2.2.6 Effect on plant mortality

The mortality per cent shown in Table 75 and Fig. 6 indicated that no mortality was seen upto 12 mmhos/cm. A significant decrease in mortality per cent was observed at salinity 14 mmhos/cm and above. Salinity 20 mmhos/cm started showing mortality symptoms right from 240 days after planting.

Table 75: Effect of salinity on plant spread, total leaf area per plant and mortality of Coconut

Treatments	plant spread (cm)	Total leaf area (sq.cm.)	Mortality (per cent)
Control	127.50	17295.56	00.00 (00.57)
4 mmhos/cm	121.00	15100.20	00.00 (00.57)
8 mmhos/cm	105.00	13159.63	00.00 (00.57)
12 mmhos/cm	96.25	10722.17	00.00 (00.57)
14 mmhos/cm	88.10	7763.64	14.33 (22.22)
16 mmhos/cm	72.50	7090.47	38.33 (38.23)
20 mmhos/cm	60.00	5231.40	43.00 (40.98)
S.E.±	2.638	227.955	- 0.798
C.D. at 5%	7.998	691.522	- 2.429

The figures in parenthese indicate transformed percentage value in to arcsine value.



Photo plate No. 29 : Leaf injury caused by salinity 20 mmhos/cm in Coconut

4.2.2.7 Effect on root length

The effect of salinity on root length (Table 76) indicated that the length of root decreased when the salinity was increased from 4 to 12 mmhos/cm. The root length was similar in 12 and 14 mmhos/cm. Further increase in salinity levels showed significantly reduction in root length.

Table 76: Effect of salinity on root length, root volume, number of primary root, number of secondary root and total number of root of Coconut

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots
Control	43.70	17.20	14.33	110.10	124.43
4 mmhos/cm	40.10	15.70	12.33	101.02	113.35
8 mmhos/cm	35.00	14.50	10.20	76.11	86.31
12 mmhos/cm	32.20	12.00	9.10	50.20	59.30
14 mmhos/cm	31.20	10.00	9.10	44.00	53.10
16 mmhos/cm	20.00	8.10	4.50	31.10	35.60
20 mmhos/cm	17.50	5.20	3.50	27.20	30.70
S.E.±	0.810	0.358	0.431	1.791	2.228
C.D.at 5%	2.472	1.047	1.321	5.453	6.750

4.2.2.8 Effect on root volume

The every increased level of salinity affected significantly reduction in root volume (Table 76). As compared to control, the root volume was three times reduced at 20 mmhos/cm.

4.2.2.9 Effect on number of primary roots

The primary roots decreased when the salinity was increased upto 8 mmhos/cm. The primary roots were similar in 8, 12 and 14 mmhos/cm (problematic soils). Similarly they were similar in 16 and 20 mmhos/cm (Table 76).

4.2.2.10 Effect on number of secondary roots

The effect of salinity on number of secondary roots (Table 76) showed that there was non significant decrease in number of secondary roots due to salinity 16 and 20 mmhos/cm.

4.2.2.11 Effect on total number of roots

It is evident (Table 76) that the significant reduction in total number of roots was observed when the salinity levels was increased upto 12 mmhos/cm. The total number of roots were similar under salinity 12 and 14 mmhos/cm and salinity 16 and 20 mmhos/cm.

4.2.2.12 Effect on fresh weight of whole plant

The data in Table 77 indicated that upto 4 mmhos/cm, there was no adverse effect. The lowest fresh weight of whole plant was recorded under 20 mmhos/cm which was significantly different from other levels of salinity and control plants.

4.2.2.13 Effect on fresh weight of roots

The effect of salinity on fresh weight of root due to various artificially salinity levels was also similar to that of fresh weight of roots (Table 77).

Table 77: Effect of salinity on fresh and dry weight of whole plant, root and top of Coconut

Treatments	Fresh weight of whole plant	Fresh weight of root	Fresh weight of top	Dry weight of whole plant	Dry weight of root	Dry weight of top
Control	2.240	0.640	1.600	0.688	0.160	0.528
4 mmhos/cm	2.100	0.600	1.500	0.614	0.156	0.458
8 mmhos/cm	1.523	0.423	1.100	0.491	0.114	0.377
12 mmhos/cm	1.221	0.321	0.900	0.479	0.106	0.373
14 mmhos/cm	1.130	0.300	0.830	0.468	0.102	0.367
16 mmhos/cm	0.960	0.190	0.770	0.305	0.093	0.212
20 mmhos/cm	0.720	0.140	0.580	0.257	0.062	0.212
S.E.±	0.057	0.049	0.044	0.013	0.004	0.021
C.D.at 5%	0.174	0.148	0.133	0.040	0.012	0.064

4.2.2.14 Effect on fresh weight of top

The fresh weight of top was found to be non significantly affected due to the salinity levels from 12 to 16 mmhos/cm (Table 77). But the effects in earlier low level of salinity were statistically significant.

4.2.2.15 Effect on dry weight of whole plant

The data regarding dry weight of whole plant are presented in Table 77 and shown graphically in Fig. 9. The dry weight of whole plant reduced when the salinity levels was increased to 8 mmhos/cm. Lowest dry weight of whole plant was recorded under salinity 20 mmhos/cm which was significantly different to that recorded under 16 mmhos/cm.

4.2.2.16 Effect on dry weight of roots

The salinity 16 and 20 mmhos/cm resulted into the significant decrease in dry weight of root as compared to control plant and rest of salinity levels (Table 77). However, the effect of salinity from 4 to 14 (problematic soils) mmhos/cm were more or less similar.

4.2.2.17 Effect on dry weight of top

The effect of salinity on dry weight of top (Table 77) showed that there was non significant decrease in dry weight of top due to salinity from 8 to 14 and 16 to 20 mmhos/cm.

4.2.2.2 Physiological parameters

4.2.2.2.1 Effect of salinity on chlorophyll content of leaves

It may be seen from the data (Table 78) that the increase in salinity resulted into decrease the

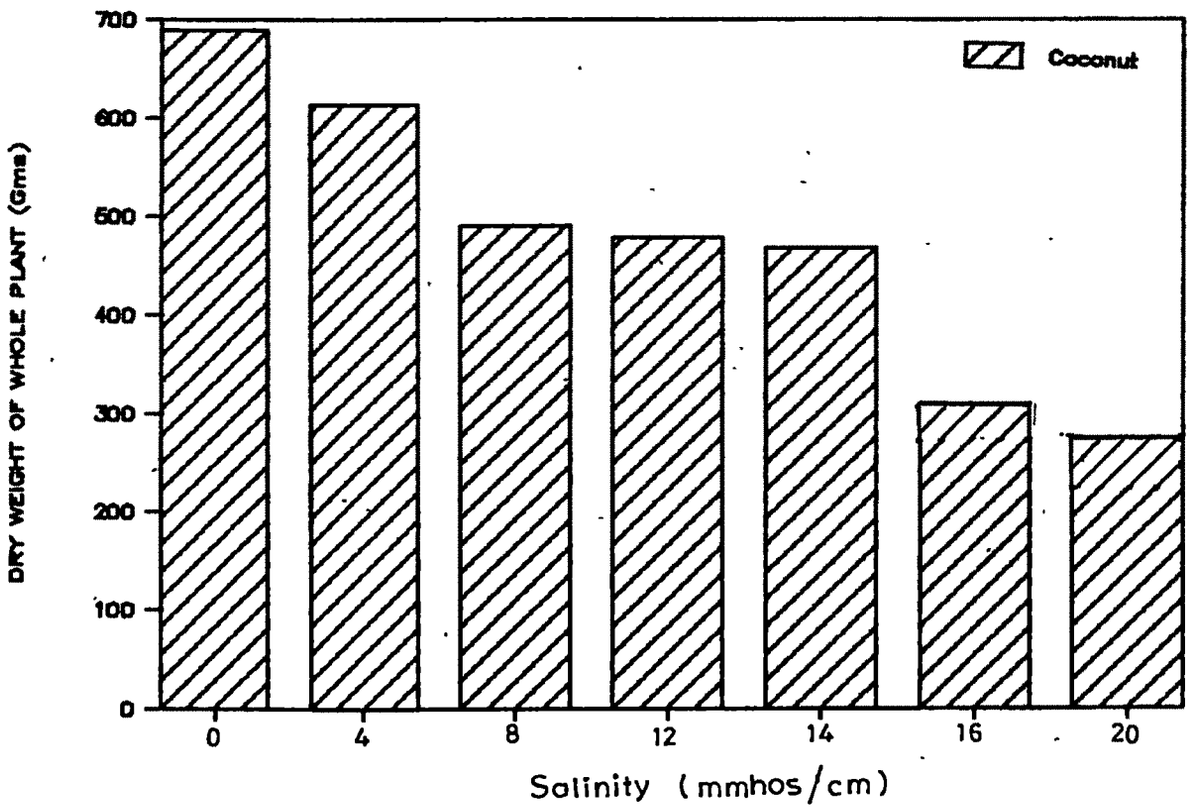


Fig 9. Effect of salinity on dry matter accumulation in Coconut at the time of harvest



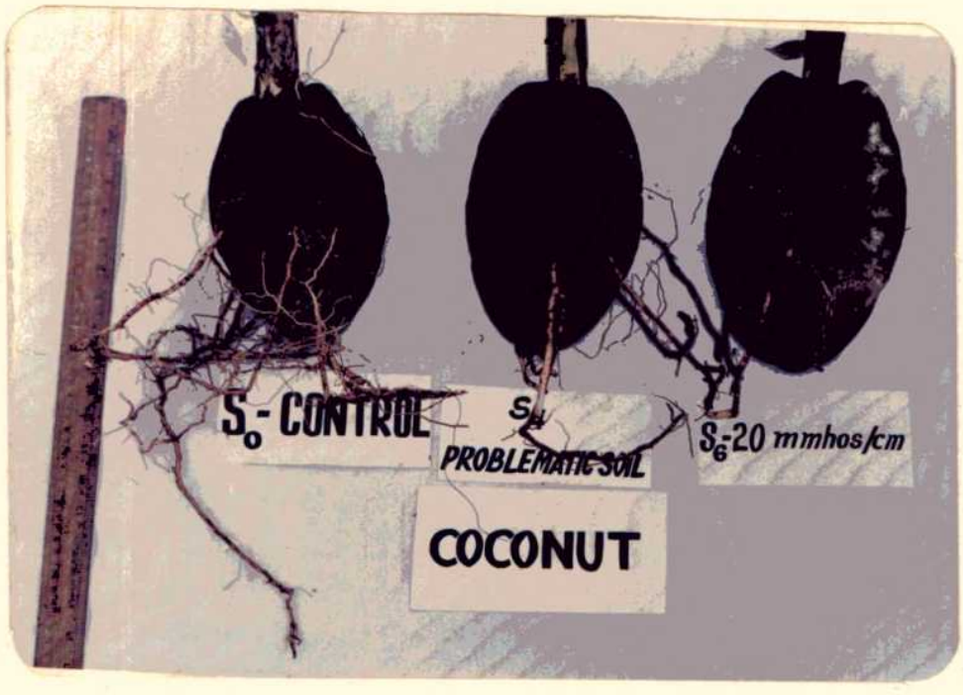


Photo plate No. 30 : Effect of 20 mmhos/cm causing depressed effects on leaves and roots, as evidenced 360 days after planting

chlorophyll 'a', 'b' and the total chlorophyll content of leaves. As compared to control, the total chlorophyll was near about five times decreased at salinity 20 mmhos/cm.

4.2.2.2.2 Effect on number of stomata

It is observed from Table 78 and Fig. 8 that the number of stomata increased with increase in salinity levels. A significantly more number of stomata was recorded under salinity 20 mmhos/cm as compared to 12 mmhos/cm but was statistically similar to salinity levels 14 and 16 mmhos/cm.

Table 78: Effect of salinity on chlorophyll content of leaves, number of stomata per unit area and rate of trnaspiration of Coconut

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Treatments	Chlorophyll			Number of stomata (40 x)	Rate of trnaspiration $gH_2O/cm^2/hr$
	'a'	'b'	Total		
	mg/g				
Control	1.1090	1.1230	2.2320	5.00	0.8161
4 mmhos/cm	1.0963	1.1160	2.2123	6.33	0.0165
8 mmhos/cm	0.4633	0.7750	1.0383	6.66	0.0180
12 mmhos/cm	0.3880	0.3977	0.7857	8.33	0.0246
14 mmhos/cm	0.3770	0.3738	0.7457	12.00	0.0294
16 mmhos/cm	0.2770	0.3300	0.6070	13.33	0.0306
20 mmhos/cm	0.2227	0.2573	0.4800	13.66	0.0318
S.E. ±	0.036	0.030	0.064	0.66	0.0001
C.D.at 5%	0.109	0.090	0.195	1.68	0.0004



Photo plate No. 31 : Effect of salinity levels showing gradual change in chlorophyll content in Coconut

4.2.2.2.3 Effect on rate of trnaspiration

The rate of trnaspiration was significantly reduced at every increase of salinity levels (Table 78 and Fig. 8). The highest rate of trnaspiration was associated with salinity 20 mmhos/cm which was near about two times more as compare to control plant.

4.2.2.3 Effect of salinity on chemical composition

The data on chemical composition of leaves and roots in coconut as influenced by various salinity levels are presented in Table 79 and 80.

4.2.2.3.1 Micronutrient content of leaves and roots

4.2.2.3.1.1 Nitrogen

Leaves : The N content of leaves declined with increasing level of salinity. The salinity levels 14 and 16 were statistically similar and exhibited high N than higher level of salinity 20 mmhos/cm (Table 79).

Roots : In general, there was decrease in N content of leaves with the increase in salinity levels. The salinity level 12 and 14 (problematic soil) were statistically similar.

4.2.2.3.1.2 Phosphorus

Leaves : The P content of leaves was non significantly decreased due to salinity at 4 mmhos/cm as compared to control(Table 79).

Table 79: Effect of salinity on macronutrient content (percentage) of leaves and roots of Coconut

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	3.08	1.77	2.73	1.84	0.94	1.02	0.38
4 mmhos/cm	3.03	1.75	2.65	1.60	0.79	1.14	1.41
8 mmhos/cm	2.52	1.10	2.50	1.38	0.63	1.46	0.52
12 mmhos/cm	2.18	0.80	2.45	1.09	0.42	1.26	0.54
14 mmhos/cm	2.00	0.55	2.28	0.92	8.41	0.92	0.58
16 mmhos/cm	1.95	0.39	2.19	0.52	0.36	0.73	0.62
20 mmhos/cm	1.72	0.17	1.86	0.32	0.15	0.43	0.78
S.E. ±	0.042	0.049	0.036	0.042	0.025	0.049	0.016
C.D. at 5%	0.140	0.149	0.109	0.127	0.077	0.149	0.050
			Roots				
Control	1.88	0.68	2.43	0.80	0.62	0.10	0.31
4 mmhos/cm	1.85	0.60	2.33	0.76	0.50	0.22	0.40
8 mmhos/cm	1.57	0.50	2.23	0.72	0.39	0.38	0.72
12 mmhos/cm	1.32	0.48	2.20	0.52	0.32	0.30	0.81
14 mmhos/cm	1.26	0.45	1.93	0.44	8.25	0.28	0.85
16 mmhos/cm	0.98	0.38	1.90	0.32	0.24	0.19	0.86
20 mmhos/cm	0.59	0.13	1.48	0.21	0.13	0.11	1.86
S.E. ±	0.052	0.026	0.048	0.020	0.017	0.014	0.036
C.D. at 5%	0.157	0.088	0.146	0.062	0.050	0.044	0.109

However, beyond this salinity level there was significant increase in P content of leaves.

Roots : From the data, it is seen that with successive increase in salinity levels there was decrease in the root P but with more or less similar effect.

4.2.2.3.1.3 Potassium

Leaves : The K content of leaves was significantly decreased at salinity level of 8, 14 and 20 mmhos/cm as compared to their respective lower levels of salinity.

Roots : The K content of roots significantly decreased at 14 mmhos/cm as compared to its lower level of salinity. But salinity levels 14 and 16 mmhos/cm were statistically similar.

4.2.2.3.1.4 Calcium

Leaves : The Ca content (Table 79) of leaves was significantly decreased when the salinity was raised from 8 mmhos/cm and above.

Roots : Except salinity levels 4 and 8 mmhos/cm, all other salinity levels resulted in the significant decrease of Ca content of roots.

4.2.2.3.1.5 Magnesium

Leaves : The Mg content of leaves was significantly decreased when the salinity was raised upto 12 mmhos/cm (Table 79). Salinity levels 12, 14 and 16 mmhos/cm were similar in Mg content.

Roots : Root Mg was decreased significantly when salinity was raised upto 14 mmhos/cm. There was no difference in root Mg content between salinity of 14 and 16 mmhos/cm.

4.2.2.3.1.6 Sulphur

Leaves : The S content of leaves was increased upto 8 mmhos/cm salinity (Table 79). Lowest S content was observed from 12 mmhos/cm and above.

Roots : Root S content was only decreased significantly due to increased level of salinity 8 mmhos/cm. The lowest S was noted under 20 mmhos/cm, which was significantly different from 16 mmhos/cm.

4.2.2.3.1.7 Sodium

Leaves : The Na content of leaves increased with increase in salinity levels. The salinity levels like 8, 14 and 20 mmhos/cm resulted into significant increase in Na content of leaves (Table 79).

Roots : The Na content of the roots was increased with increase in salinity levels. All most similar effect were found from 4 to 16 mmhos/cm. However, the highest Na content was recorded under 20 mmhos/cm which was significantly different from rest of treatments.

4.2.2.3.1.8 Ca : Na

Leaves : A correspondent decrease (Table 80) in Ca : Na ratio with the increase in salinity was noticed. A

significant low ratio was observed at salinity 16 and 20 mmhos/cm as compare to lower salinity levels.

Roots : A progressive but statistically non significant decrease in the Ca : Na of roots was observed from salinity level 8 to 20 mmhos/cm.

4.2.2.3.1.9 Ca + Mg + K : Na

Leaves : The data presented in Table 80 showed that a corresponding decrease in Ca + Mg + K : Na with each increment of salinity levels over previous lower level was observed. The effect was more pronounced at 8 mmhos/cm.

Roots : The Ca + Mg + K : Na content of roots was decreased significantly when salinity was raised to 4 mmhos/cm. The effects due salinity from 8 to 20 mmhos/cm were similar to each other.

4.2.2.3.2 Micronutrient content of leaves and roots

4.2.2.3.2.1 Zinc

Leaves : The Zn content of the leaves (Table 80) was significantly lowest at higher level of salinity.

Roots : The Zn content of roots was decreased when increase salinity levels. The lowest Zn content of roots was recorded under 20 mmhos/cm, which was significantly low as compared to in next lower salinity level.

Table 80: Effect of salinity on macronutreitn ratios of Ca:Na, Ca+Mg+K:Na and micronutrient contents of leaves and roots of Coconut

Treatments	Ca/Na	Ca+Mg+K/Na	Micronutrient in ppm			
			Zn	Fe	Mn	Cu
			Leaves			
Control	4.32	13.09	61.03	1494.56	137.86	90.18
4 mmhos/cm	3.90	12.27	55.38	1335.98	129.19	86.72
8 mmhos/cm	2.65	8.74	36.17	1200.17	93.05	70.33
12 mmhos/cm	2.02	7.35	33.44	1093.53	68.93	53.09
14 mmhos/cm	1.58	6.17	30.74	971.69	41.42	39.51
16 mmhos/cm	0.84	4.88	27.30	820.58	36.76	30.28,
20 mmhos/cm	0.41	2.99	10.45	702.56	29.87	25.83
S.E. ±	0.062	0.189	2.272	25.734	4.897	2.764
C.D. at 5%	0.189	0.574	6.803	78.063	14.854	8.235
			Roots			
Control	4.15	19.83	61.03	1551.74	124.64	45.14
4 mmhos/cm	2.01	9.45	55.83	1462.30	123.39	42.48
8 mmhos/cm	1.00	4.64	45.21	1444.61	99.37	38.94
12 mmhos/cm	0.62	3.75	42.05	1300.94	90.18	37.15
14 mmhos/cm	0.52	3.08	36.62	1139.35	67.38	33.64
16 mmhos/cm	0.37	2.59	35.26	993.85	59.73	21.16
20 mmhos/cm	0.20	1.70	12.66	693.31	29.19	10.87
S.E. ±	0.369	1.603	2.552	37.023	3.981	1.491
C.D.at 5%	1.120	4.863	7.742	112.307	12.077	4.523

4.2.2.3.2.2 Iron

Leaves : A significant decrease in Fe was noticed with each subsequent increment of salinity (Table 80).

Roots : The Fe content of roots was decreased due to increase of salinity. A plant under control and salinity levels 4 to 14 mmhos/cm recorded higher roots Fe content than those plant under rest of the treatments.

4.2.2.3.2.3 Manganese

Leaves : It is seen from data (Table 80) that the Mn content of leaves was significantly decreased when salinity was raised upto 14 mmhos/cm. However, the salinity levels of 14, 16 and 20 mmhos/cm exhibited similar differences.

Roots : It was observed that, the salinity levels like 4, 12 and 16 mmhos/cm were resulted into significant decrease of Mn content of roots as compared to their next higher levels.

4.2.2.3.2.4 Copper

Leaves : The Cu content of leaves was significantly reduced from each other when salinity was raised from 8 to 16 mmhos/cm (Table 80).

Roots : The data (Table 80) revealed that the Cu content in roots was significantly reduced from 14 mmhos/cm onward as compared to its previous salinity levels.

4.2.3 Markingnut

4.2.3.1 Effect on plant height

Periodic observations on the height of markingnut plants expressed in per cent increase over the initial observation under different salinity are presented in Table 81. The plant height decreased with the increasedsalinity upto 4 mmhos/cm during the intire investigation of experiment. Although there was not difference in 4 and 8 mmhos/cm in the initial two stages, the difference was noted after 180 days and onward. Plants under 8 mmhos/cm and above succumbed to salinity injury after 240 days after planting. Plants under 8 and 12 mmhos/cm showed similar effect. Although there was no difference in 16 and 20 mmhos/cm in the begining, the plants under 16 mmhos/cm showed greater height than those under 20 mmhos/cm.

4.2.3.2 Effect on number of leaves

During all growth stages of observation except 60 days after planting the control plant had more number of leaves than those under 4 mmhos/cm (Table 81). With further increase in salinity from 8 to 12 mmhos/cm the number of leaves decreasedconsistantly. Although in the begining there was no difference in 16 and 20 mmhos/cm and 16 mmhos/cm had significant more number of leaves as

Table 81: Effect of salinity on percentage increase in plant height, number of leaves and stem diameter of Markingnut

Treatments	Days after planting					
	60	120	180	240	300	360
			Plant height			
Control	10.79	25.83	39.79	48.62	54.44	58.15
4 mmhos/cm	8.33	15.17	24.00	30.14	35.83	39.27
8 mmhos/cm	7.74	15.17	19.23	-	-	-
12 mmhos/cm	7.20	15.00	17.43	-	-	-
14 mmhos/cm	7.14	11.17	-	-	-	-
16 mmhos/cm	4.00	10.33	-	-	-	-
20 mmhos/cm	3.70	6.17	-	-	-	-
S.E. ±	0.325	0.423	0.584	3.336	1.773	1.265
C.D. at 5%	0.986	1.282	1.904	13.196	6.952	6.371
			Number of leaves			
Control	124.50	266.89	308.21	347.47	364.37	370.01
4 mmhos/cm	101.47	233.78	273.39	305.30	318.20	322.12
8 mmhos/cm	80.87	153.67	188.60	-	-	-
12 mmhos/cm	51.83	98.51	128.84	-	-	-
14 mmhos/cm	39.57	75.19	-	-	-	-
16 mmhos/cm	25.47	66.48	-	-	-	-
20 mmhos/cm	23.22	35.98	-	-	-	-
S.E. ±	3.321	9.420	10.820	4.577	7.452	9.023
C.D. at 5%	10.075	28.576	42.414	17.943	29.211	35.370
			Stemdiameter			
Control	80.89	133.33	186.69	229.33	260.49	281.33
4 mmhos/cm	76.67	116.67	160.80	196.67	243.27	257.38
8 mmhos/cm	60.34	100.58	141.13	-	-	-
12 mmhos/cm	50.38	76.69	116.67	-	-	-
14 mmhos/cm	40.50	60.89	-	-	-	-
16 mmhos/cm	33.44	50.13	-	-	-	-
20 mmhos/cm	20.10	33.32	-	-	-	-
S.E. ±	4.642	3.576	4.659	5.302	4.376	3.875
C.D. at 5%	14.082	10.829	15.191	20.783	17.198	15.224

compare to those under 20 mmhos/cm levels at 120 days after planting. The plants under salinity 8 and 12 mmhos/cm died at 240 days and higher levels of salinity (from 14 to 20 mmhos/cm).

4.2.3.3 Effect on stem diameter

It is evident that (Table 81) there was decrease in stem diameter with the increase of salinity levels. From 120 days onward after planting, the stem diameter decreased consistently with the increased salinity upto 14 mmhos/cm. At 120 days after planting 20 mmhos/cm showed less stem diameter than 16 mmhos/cm levels. The plants under 8 and 12 mmhos/cm died at 240 days and higher levels (i.e. from 14 to 20 mmhos/cm) died at 180 days after planting.

4.2.3.4 Effect on plant spread

The data regarding plant spread under different salinity levels are given in Table 82. There was significant decrease in the plant spread with each increment of salinity levels over their respective previous lower level. The maximum plant spread was recorded under control plants followed by 4 mmhos/cm.

4.2.3.5 Effect on leaf area

The leaf area was significantly reducedat every increase of salinity except 12 and 14 mmhos/cm. Maximum leaf area was reduced when salinity was increased from 4 to 8 mmhos/cm.

Table 82: Effect of salinity on plant spread, total leaf area per plant and mortality of Markindnut

Treatments	plant spread (cm)	Total leaf area (sq.cm.)	Mortality (per cent)
Control	31.80	629.12	00.00 (00.57)
4 mmhos/cm	24.70	611.20	57.33 (49.20)
8 mmhos/cm	21.70	450.20	100.00 (90.00)
12 mmhos/cm	21.50	330.38	100.00 (90.00)
14 mmhos/cm	16.30	300.70	100.00 (90.00)
16 mmhos/cm	14.40	224.10	100.00 (90.00)
20 mmhos/cm	10.50	190.10	100.00 (90.00)
S.E.±	0.334	24.321	- 1.291
C.D.at 5%	1.012	73.992	- 3.911

The figures in parenthese indicate transformed percentage value in to arcsine value.

4.2.3.6 Effect on plant mortality

The mortality per cent shown in Table 82 and Fig. 6 indicated that no mortality was recorded upto 4 mmhos/cm. Hundred per cent plant mortality was observed at and above 8 mmhos/cm. Salinity 14, 16 and 20 mmhos/cm



Photo plate No. 32 : Yellowing of leaves caused by 20 mmhos/cm

started showing mortality symptoms right from 90 days after planting. While the mortality symptoms were recorded under 8 and 12 mmhos/cm at 120 days after planting. Complete mortality of the plants under 14, 16 and 20 mmhos/cm were observed at 180 days after planting. The plants under 8 and 12 mmhos/cm were completely dried when they reached 240 days after planting. The initial symptoms of mortality were drying of tips and leaf margin, which then continued towards midrib of leaves.

4.2.3.7 Effect on root length

Root length significantly decreased in the salinity 8 to 14 mmhos/cm. There was no difference in the effect of salinity from 14 to 20 mmhos/cm (Table 82).

4.2.3.8 Effect on root volume

The data in Table 83 showed that the root volume decreased with more or less consistantly throughout the salinity.

4.2.3.9 Effect on number of primary roots

The depressive effect of salinity was started from 12 mmhos/cm and was significant to salinity of 14 mmhos/cm. The lowest number of primary roots recorded under 20 mmhos/cm, which was similar to its next lower level of salinity.

4.2.3.10 Effect on number of secondary roots

It is evident from Table 83 that the significant reduction in secondary roots was recorded in salinity upto 12 mmhos/cm. But the next three higher salinity levels were statistically similar to each other.

Table 83: Effect of salinity on root length, root volume, number of primary root, number of secondary root and total number of root of Markingnut

Treatments	Root length (cm)	Root volume (ml)	Number of secondary roots	Number of primary roots	Total number of roots
Control	34.50	10.20	9.50	25.10	34.60
4 mmhos/cm	32.60	8.25	6.70	17.22	23.92
8 mmhos/cm	29.10	7.00	5.00	10.10	15.10
12 mmhos/cm	21.17	6.50	3.34	7.33	10.67
14 mmhos/cm	14.00	5.33	3.33	7.60	10.93
16 mmhos/cm	13.25	5.00	2.33	7.00	9.33
20 mmhos/cm	12.60	4.10	2.00	5.20	7.29
S.E.±	1.451	0.901	0.303	0.384	1.009
C.D. at 5%	4.410	2.730	0.918	1.163	3.057

4.2.3.11 Effect on total number of roots

Total number of roots decreased in a greater way with increase of salinity levels upto 12 mmhos/cm (Table 83). There was no difference in 12 and 14 mmhos/cm as well as 16 and 20 mmhos/cm.

4.2.3.12 Effect on fresh weight of whole plant

The data presented in Table 84 indicated that there was significantly decrease in fresh weight of whole plant with every increased salinity levels except 16 mmhos/cm. Lowest fresh weight of whole plant was recorded under higher salinity levels.

Table 84: Effect of salinity on fresh and dry weight of whole plant, root and top of Markingnut

Treatments	Fresh weight of whole plant	Fresh weight of root	Fresh weight of top	Dry weight of whole plant	Dry weight of root	Dry weight of top
Control	60.66	24.50	36.16	23.54	8.33	15.19
4 mmhos/cm	53.86	22.50	31.36	21.00	7.51	13.49
8 mmhos/cm	44.83	20.63	24.20	18.35	7.71	10.64
12 mmhos/cm	32.32	14.52	17.80	18.01	8.74	9.27
14 mmhos/cm	26.99	12.33	14.66	13.63	5.86	7.77
16 mmhos/cm	19.33	8.33	11.00	10.80	4.53	6.27
20 mmhos/cm	16.95	6.80	10.15	9.70	3.81	5.89
S.E.±	1.032	0.427	0.707	0.473	0.281	0.319
C.D.at 5%	3.384	1.298	2.142	1.435	0.841	0.969

4.2.3.13 Effect on fresh weight of root

The data regarding fresh weight of root presented in Table 84 showed highly significant reduction in fresh weight of root with every increase level of salinity.

4.2.3.14 Effect on fresh weight of top

From the data in Table 84, it was seen that fresh weight of top significantly decreased when the salinity level was raised upto 16 mmhos/cm. The fresh weight of top was similar in salinity 16 and 20 mmhos/cm.

4.2.3.15 Effect on dry weight of whole plant

The data on dry weight of whole plant as influenced by various salinity levels presented in Table 84 and shown graphically in Fig. 7. There was trend of decrease dry weight of whole plant with the increased in salinity levels. Low dry weight of whole plant was recorded under 20 mmhos/cm which was statistically similar to 16 mmhos/cm.

4.2.3.16 Effect on dry weight of root

There was no statistical difference between 4 and 8 and 16 and 20 mmhos/cm levels of salinity (Table 84).

4.2.3.17 Effect on dry weight of top

On perusal of the data in Table 84 it is seen that with the increase of salinity level upto 16 mmhos/cm level. There was consistent fall in dry weight of top due to corresponding increased salinity levels.



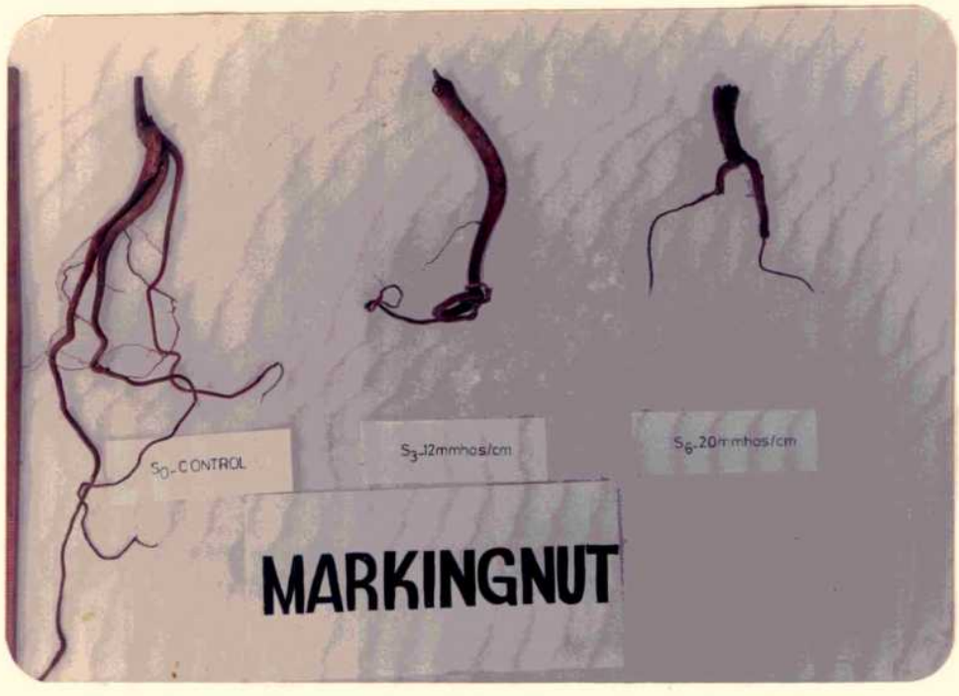


Photo plate No. 33 : Plant mortality symptoms observed on shoot and root under 20 mmhos/cm noticed 6 months after planting

4.2.3.2 Physiological parameters

4.2.3.2.1 Effect of salinity on chlorophyll content of leaves

From the Table 85 it is evident that chlorophyll 'a' decreased significantly with increased salinity upto 14 mmhos/cm. The chlorophyll 'a' noted under 14 and 16 mmhos/cm was statistically non significant. Whereas chlorophyll 'b' and total chlorophyll decreased significantly in all salinity levels.

Table 85: Effect of salinity on chlorophyll content of leaves, number of stomata per unit area and rate of transpiration of Markingnut

Treatments	Chlorophyll			Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
	'a'	'b'	Total		
	mg/g				
		Leaves			
Control	1.0767	1.3543	2.431	18.00	0.0247
4 mmhos/cm	0.9480	1.2247	2.172	20.33	0.0223
8 mmhos/cm	0.7790	1.0390	1.808	23.33	0.0161
12 mmhos/cm	0.6913	0.9317	1.623	27.66	0.0134
14 mmhos/cm	0.4660	0.5737	1.040	31.00	0.0125
16 mmhos/cm	0.4057	0.4620	0.868	34.66	0.0118
20 mmhos/cm	0.2760	0.3347	0.611	38.00	0.0113
S.E. ±	0.028	0.034	0.045	0.934	0.0003
C.D. at 5%	0.084	0.104	0.140	0.334	0.0009

4.2.3.2.2 Effect on number of stomata

The salinity level 4 mmhos/cm did not show any difference in stomata number as compare to control. But the subsequent higher salinity levels exhibited significantly more number of stomata (Table 85 and Fig. 8).

4.2.3.2.3 Effect on rate of transpiration

Rate of trnaspirations as influenced by various salinity levels (Table 85 and Fig. 8) was consequently decreased. However, significant decrease was observed upto salinity level of 12 mmhos/cm.

4.2.3.3 Effect of salinity on chemical composition

The data on chemical composition of leaves, roots and stem of markingnut as influenced by various salinity levels are presented in Table 86 and 87.

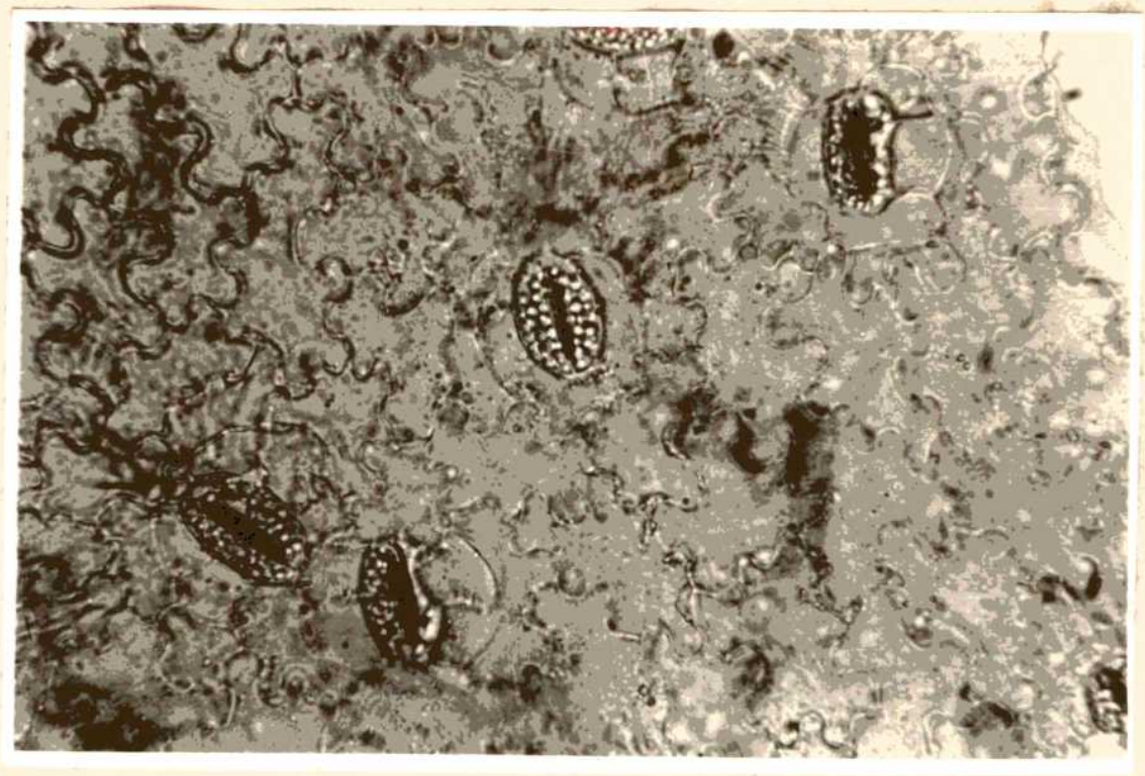
4.2.3.3.1 Macronutrient content of leaves, roots and stem

4.2.3.3.1.1 Nitrogen

Leaves : The N content of the leaves decreased significantly with increasing every level of salinity from 4 to 20 mmhos/cm.

Roots : There was no difference in root content of N between 8 and 12 mmhos/cm and 12 and 14 mmhos/cm.

Stem : Except salinity levels of 12 and 14 mmhos/cm, all other salinity levels resulted in the significant difference of N content of stem.



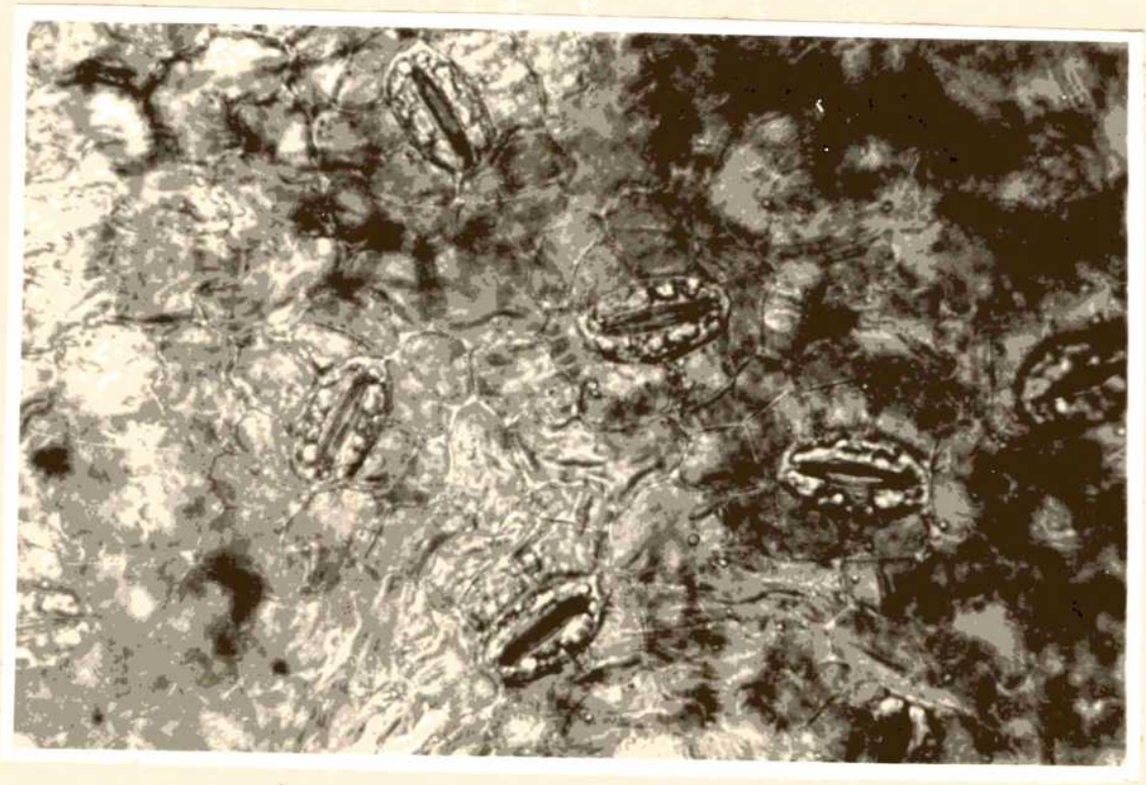


Photo plate No. 34 : Effect of 20 mmhos/cm on density of stomata number compared to control in Markingnut

Table 86: Effect of salinity on macronutrient content (percentage) of leaves, roots and stem of Markingnut

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	3.06	1.60	2.13	1.76	1.58	0.73	0.56
4 mmhos/cm	3.10	1.32	1.75	1.48	1.45	0.60	0.64
8 mmhos/cm	2.89	0.91	1.66	1.13	1.28	0.59	0.92
12 mmhos/cm	2.53	0.68	1.33	0.92	1.01	0.48	1.28
14 mmhos/cm	2.21	0.60	1.17	0.76	0.84	0.36	1.58
16 mmhos/cm	1.98	0.55	0.89	0.56	0.58	0.30	1.94
20 mmhos/cm	1.48	0.35	0.70	0.29	0.26	0.18	2.29
S.E. ±	0.063	0.036	0.040	0.047	0.044	0.022	0.054
C.D. at 5%	0.192	0.110	0.121	0.143	0.133	0.068	0.164
			Roots				
Control	3.38	0.68	1.28	2.48	1.70	0.35	0.29
4 mmhos/cm	3.09	0.60	1.25	2.26	1.49	0.43	0.67
8 mmhos/cm	2.81	0.53	1.01	1.66	1.20	0.45	0.80
12 mmhos/cm	2.67	0.40	0.98	1.81	0.98	0.43	0.81
14 mmhos/cm	2.55	0.35	0.88	1.56	0.67	0.36	0.87
16 mmhos/cm	2.28	0.28	0.73	1.31	0.43	0.28	0.98
20 mmhos/cm	1.83	0.12	0.39	1.28	0.31	0.10	1.03
S.E. ±	0.060	0.016	0.082	0.177	0.035	0.016	0.025
C.D.at 5%	0.182	0.050	0.248	0.536	0.048	0.048	0.077
			Stem				
Control	2.63	0.69	0.68	1.64	0.50	0.27	0.33
4 mmhos/cm	2.50	0.60	0.52	1.51	0.48	0.32	0.43
8 mmhos/cm	2.18	0.49	0.45	1.19	0.32	0.43	0.55
12 mmhos/cm	1.89	0.32	0.40	0.92	0.30	0.32	0.78
14 mmhos/cm	1.76	0.30	0.28	0.76	0.22	0.29	0.90
16 mmhos/cm	1.40	0.22	0.25	0.72	0.18	0.19	0.98
20 mmhos/cm	1.05	0.15	0.12	0.41	0.10	0.11	1.15
S.E. ±	0.060	0.015	0.015	0.044	0.014	0.015	0.023
C.D. at 5%	0.181	0.044	0.046	0.134	0.046	0.045	0.068

4.2.3.3.1.2 Phosphorus

Leaves : From the data in Table 86 it was found that maximum P was estimated under control plant, which was significantly different from rest of the treatments.

Roots : The P content of the roots statistically decreased except in salinity of 12 and 14 mmhos/cm. Most striking effect was observed at 12 mmhos/cm.

Stem : In general, there was significant decrease in P content of the stem with the increase in salinity levels except 12 and 14 mmhos/cm.

4.2.3.3.1.3 Potassium

Leaves : The K content of the leaves statistically decreased due to salinity from 12 mmhos/cm and above. The salinity level 4 and 8 mmhos/cm were similar in effect of K content of the leaves (Table 86).

Roots : There was more or less similar K content of the roots when the salinity was raised upto 16 mmhos/cm.

Stem : Except salinity levels 14 and 16 mmhos/cm, all rest of salinity levels resulted in significant decrease of K content of the stem.

4.2.3.3.1.4 Calcium

Leaves : The Ca content of the leaves (Table 86) was significantly decreased with each incremental level of salinity over previous lower salinity levels.

Roots : The salinity at 8 mmhos/cm showed significant difference from its immediate lower and higher salinity levels.

Stem : The Ca content of the stem was significantly decreased when the salinity was raised from 4 mmhos/cm to 14 mmhos/cm (problematic soil), which was similar in effect to that of 16 mmhos/cm.

4.2.3.3.1.5 Magnesium

Leaves : Except 4 mmhos/cm all salinity levels resulted into significant reduction in Mg content of leaves.

Roots : A progressive and significant decrease in Mg content of roots with the increase in salinity was observed.

Stem : The alternate salinity levels like 8, 14 and 20 mmhos/cm showed significant decrease of stem Mg content from their respective lower salinity level.

4.2.3.3.1.6 Sulphur

Leaves : The S content of the leaves was decreased at every increase of salinity levels (Table 86) except 14 and 16 mmhos/cm levels.

Roots : S content of the roots was increase when the salinity was raised upto 12 mmhos/cm. Further increase in salinity levels, there was significant decreased in S content of the roots.

Stem : The S content of the stem increased with increase in salinity levels upto 8 mmhos/cm. Lower S content of the stem was recorded under higher level of salinity.

4.2.3.3.1.7 Sodium

Leaves : The Na content of the leaves increased with every increase in salinity levels (Table 86). Higher Na content of the leaves was estimated under 20 mmhos/cm, which was significantly different from 16 mmhos/cm.

Roots : The salinity level 12 mmhos/cm behaved statistically similar to its immediate lower and higher level.

Stem : A progressive significantly increase in Na content of the stem with the every incremental level of salinity was observed.

4.2.3.3.1.8 Ca : Na

Leaves : The salinity levels 14 and 16 mmhos/cm and 16 and 20 mmhos/cm showed similar effect in Ca : Na content of the leaves (Table 87). But it decreased significantly due to salinity from 4 to 14 mmhos/cm.

Roots : Ca : Na content of the roots was highest in control plant. There was no statistical difference in Ca : Na content of the roots in salinity from 4 to 16 mmhos/cm and 8 to 20 mmhos/cm.

Stem : A significant decrease in Ca : Na content of stem was noticed with increased salinity upto 14 mmhos/cm. However, the effect of salinity 14 to 16 mmhos/cm was statistically non significant in the Ca : Na content of the stem.

4.2.3.3.1.9 Ca + Mg + K : Na

Leaves : A pronouncedly decrease in Ca + Mg + K : Na content of the leaves with each increment of salinity levels was observed (Table 87).

Roots : Though there was decrease in Ca + Mg + K : Na due to higher salinity levels but it was greater at salinity 4 and 20 mmhos/cm as compared to their respective lower treatment.

Stem : The Ca + Mg + K : Na content of the stem was significantly decreased when salinity was raised upto 14 mmhos/cm. Salinity level 14 and 16 mmhos/cm was found similar in this regards.

4.2.3.3.2 Micronutrient content of leaves, roots and stem

4.2.3.3.2.1 Zinc

Leaves : The data presented in Table 87 revealed that the Zn content of the leaves decreased significantly with the every increase of salinity level. The lowest Zn content was recorded under high level of salinity.

Table 87: Effect of salinity on macronutrient ratios of Ca:Na, Ca+Mg+K:Na and micronutrient contents of leaves, roots and stem of Markingnut

Treatments	Ca/Na	Ca+Mg+K/Na	Micronutrient in ppm			
			Zn	Fe	Mn	Cu
			Leaves			
Control	3.15	9.80	99.43	1612.58	201.89	127.11
4 mmhos/cm	2.32	7.38	88.50	1451.95	176.83	114.15
8 mmhos/cm	1.23	4.46	67.82	1403.28	151.10	91.38
12 mmhos/cm	0.72	2.55	66.00	1398.13	118.16	72.70
14 mmhos/cm	0.48	1.75	48.99	1190.81	92.35	54.44
16 mmhos/cm	0.28	1.04	39.33	908.37	75.18	39.79
20 mmhos/cm	0.13	0.55	20.19	761.83	59.48	29.20
S.E. ±	0.070	0.241	2.972	34.294	4.256	4.881
C.D.at 5%	0.213	0.731	9.016	104.030	12.991	14.806
			Roots			
Control	9.26	10.82	229.03	1694.49	115.57	139.80
4 mmhos/cm	3.37	7.46	185.03	1625.43	136.09	115.39
8 mmhos/cm	2.48	4.90	190.33	1428.18	98.19	89.35
12 mmhos/cm	2.23	4.65	175.88	1250.23	74.67	73.66
14 mmhos/cm	1.79	3.57	106.10	1193.05	70.41	71.66
16 mmhos/cm	1.32	2.56	77.35	862.07	59.61	52.00
20 mmhos/cm	0.95	1.82	39.53	576.30	21.25	27.43
S.E. ±	0.684	1.396	15.941	43.217	5.089	3.667
C.D. at 5%	2.074	4.537	48.356	131.097	15.437	11.124
			Stem			
Control	4.98	8.56	93.58	1519.45	81.56	136.27
4 mmhos/cm	3.51	5.98	90.18	1430.10	78.12	120.13
8 mmhos/cm	2.17	3.58	78.92	1357.51	70.10	102.83
12 mmhos/cm	1.37	2.08	59.68	1110.38	58.38	87.33
16 mmhos/cm	0.84	1.40	50.19	908.18	43.19	72.19
20 mmhos/cm	0.73	1.15	45.31	798.66	35.42	42.48
20 mmhos/cm	0.35	0.55	28.48	439.10	18.71	21. 19
S.E. ±	0.092	0.092	2.507	45.214	2.341	3.859
C.D. at 5%	0.278	0.278	7.605	137.155	7.103	11.760

Roots : The Zn content was decreased due to salinity levels but severe effect was noticed at salinity of 16 and 20 mmhos/cm.

Stem : The Zn content of the stem was estimated highest in the control plant which was significant to the rest of the treatments except 4 mmhos/cm and 14 mmhos/cm as compared to their preceeding treatments.

4.2.3.3.2.2 Iron

Leaves : A Striking decrease in Fe content of the leaves was noticed at salinity from 12 to 20 mmhos/cm (Table 87).

Roots : The Fe content of the roots was severely decreased at 8 and 14 mmhos/cm and onwards salinity.

Stem : The salinity levels at 12 and 20 mmhos/cm resulted in to higher decrease of Fe content of stem.

4.2.3.3.2.3 Manganese

Leaves : The Mn content of the leaves decreased significantly with each incremental level of salinity over previous salinity levels (Table 87).

Roots : The Mn content of the roots was decreased significantly upto 12 mmhos/cm but non significantly after salinity level 14 mmhos/cm.

Stem : A significant decrease in Mn content of the stem was observed with every increase salinity levels except 4 mmhos/cm compared to control. The effect was more pronounced at 20 mmhos/cm.

4.2.3.3.2.4 Copper

Leaves : A significant reduction in Cu content of leaves was observed from salinity levels 4 to 14 mmhos/cm (Table 87).

Roots : The data revealed that Cu content in roots was significantly reduced upto 12 mmhos/cm. However, the effect of salinity 12 and 14 mmhos/cm were similar, but they gave more Cu content than higher level of salinity (i.e. 16 and 20 mmhos/cm).

Stem : A progressive and significant decrease in Cu content of the stem was seen with the increased level of salinity. But the effect was to a greater extent at salinity from 14 to 20 mmhos/cm.

4.2.4 Soapnut

4.2.4.1 Effect on plant height

Periodic observations on the height of soapnut plants expressed in per cent increase over the initial observation under different salinity levels are presented in Table 88. It is evident from the data that plant height decreased throughout the period of investigation except 300 days after planting with the first levels of salinity itself. The salinity levels 16 and 20 mmhos/cm showed similar decrease in plant height at 60 and 120 days after planting but showed significant

decrease in plant height at 180 days after planting. The plants were dried at 300 days after planting due to these higher salinity levels. Severest effect at 180 days after planting was at the heighest levels of salinity. At the termination of experiment it was observed that the plant height decreased with increase salinity upto 12 mmhos/cm.

4.2.4.2 Effect on number of leaves

The data in Table 88 showed that with the first level of salinity itself the number of leaves decreased during the entire period except 240 days after planting. Salinity 16 and 20 mmhos/cm showed injurious symptom and plant died after 300 and 240 days respectively. At 300 days the decreased number of leaves were observed with increased salinity. However, there was no difference between 16 to 20 mmhos/cm upto 180 days of platnting.

4.2.4.3 Effect on stem diameter

It is evident from the data (Table 88) that the stem diameter of control plant was the highest and it decreased consistently with the increased salinity at the 300 days after planting. Similar was the trend when the stem diameter increased to 240 days after planting.

Table 88: Effect of salinity on percentage increase in plant height, number of leaves and stem diameter of Soapnut

Treatments	Days after planting					
	60	120	180	240	300	360
			Plant Height			
Control	19.23	56.07	92.14	158.33	196.15	211.54
4 mmhos/cm	15.30	48.15	79.47	135.12	175.83	187.83
8 mmhos/cm	11.11	46.15	66.23	124.00	152.44	161.63
12 mmhos/cm	9.10	42.85	57.25	111.43	137.00	141.83
14 mmhos/cm	8.60	34.82	50.10	100.23	128.20	131.83
16 mmhos/cm	7.50	31.14	46.43	81.07	-	-
20 mmhos/cm	6.10	25.00	38.46	-	-	-
S.E. ±	0.474	2.148	1.894	3.810	7.999	6.055
C.D. at 5%	1.438	6.516	5.746	11.759	25.184	17.078
			Number of leaves			
Control	37.81	74.48	180.43	211.61	297.63	363.75
4 mmhos/cm	33.38	66.62	160.52	193.60	271.68	332.60
8 mmhos/cm	33.35	57.62	146.67	170.79	243.79	293.68
12 mmhos/cm	32.71	50.42	119.92	142.54	207.61	278.20
14 mmhos/cm	28.76	45.81	18.49	100.52	162.33	190.49
16 mmhos/cm	16.33	31.42	62.50	75.30	-	-
20 mmhos/cm	14.55	30.41	55.68	-	-	-
S.E. ±	1.084	1.031	3.950	5.854	5.242	8.453
C.D. at 5%	3.288	3.009	11.983	18.039	16.517	26.635
			Stem diameter			
Control	64.44	140.38	183.81	216.67	253.33	272.33
4 mmhos/cm	44.42	121.33	151.37	180.24	210.34	227.30
8 mmhos/cm	43.33	120.18	140.22	165.24	183.97	192.18
12 mmhos/cm	42.22	99.25	122.78	143.30	151.24	156.82
14 mmhos/cm	38.14	92.25	108.18	118.10	125.64	130.20
16 mmhos/cm	36.64	66.67	78.12	83.31	-	-
20 mmhos/cm	31.09	50.18	70.53	-	-	-
S.E. ±	1.699	3.718	2.972	3.178	8.492	6.766
C.D. at 5%	5.135	11.273	9.014	9.794	26.749	21.319

More or less similar trend was noted at 180 days after planting. Although salinity 14 and 16 mmhos/cm behaved similarly at 60 days after planting.of The depressive effect of 16 mmhos/cm was evident from 120 days after planting.

4.2.4.3a Effect on leaflets

The number of leaf lets decreased at all growth stages when salinity was raised to 8 mmhos/cm except at 120 days of planting. The salinity 4 mmhos/cm and control plant gave maximum leaf lets throughout the experimentation. More or less similar trend was observed in salinity 12 and 14 (problematic soils) at 180 days after planting and onward period.

4.2.4.4 Effect on plant spread

The data pertaining to the plant spread under various salinity levels are presented in Table 89 indicated that there was significant decrease in plant spread with every increase of salinity level.

4.2.4.5 Effect on leaf area

From the Table 89, it is seen that the total leaf area per plant decreased significantly with each incremental level except salinity at 12 to 14 mmhos/cm. The effects were more pronounced at 16 and 20 mmhos/cm salinity levels.

Table 88a: Effect of salinity on percentage increase in leaflets of Soapnut

Treatments	Days after planting					
	60	120	180	240	300	360
	Number of leaflets					
Control	34.79	69.57	132.66	204.77	277.83	355.87
4 mmhos/cm	31.25	60.18	97.50	173.60	231.37	305.32
8 mmhos/cm	28.56	57.89	85.71	147.06	183.39	235.29
12 mmhos/cm	26.94	52.62	83.89	138.69	157.89	200.73
14 mmhos/cm	20.71	46.67	82.35	138.69	141.58	152.63
16 mmhos/cm	20.70	41.11	75.10	120.54	-	-
20 mmhos/cm	17.83	36.18	70.38	-	-	-
S.E. ±	0.526	1.249	3.206	3.980	5.844	7.414
C.D.at 5%	1.594	3.788	9.726	12.264	18.414	23.360

Table 89: Effect of salinity on plant spread, total leaf area per plant and mortality of Soapnut

Treatments	Plant spread (cm)	Total leaf area (sq.cm.)	Mortality (per cent)
Control	43.17	1540.39	00.00 (00.57)
4 mmhos/cm	40.00	1371.05	00.00 (00.57)
8 mmhos/cm	34.27	1094.71	00.00 (00.57)
12 mmhos/cm	29.10	675.41	48.66 (44.43)
14 mmhos/cm	23.10	631.53	72.66 (58.69)
16 mmhos/cm	20.00	488.60	100.00 (90.00)
20 mmhos/cm	17.17	357.65	100.00 (90.00)
S.E. ±	0.531	36.350	- 1.644
C.D. at 5%	1.793	110.296	- 5.700

The figures in parenthese indicate arcsine transformed value.

4.2.4.6 Effect on plant mortality

The data regarding plant mortality is presented in Table 89 and graphically represented in Fig. 6. The plant under 4 and 8 mmhos/cm levels of salinity did not show any kind of mortality. The mortality symptoms were started from 12 mmhos/cm onwards and 100 per cent mortality was recorded in 16 and 20 mmhos/cm. The mortality symptoms were noted from 150 and 120 days after planting and plant death was occured at 300 and 240 days after planting respectively. The visible symptom of mortality were burning of young leaf margin.

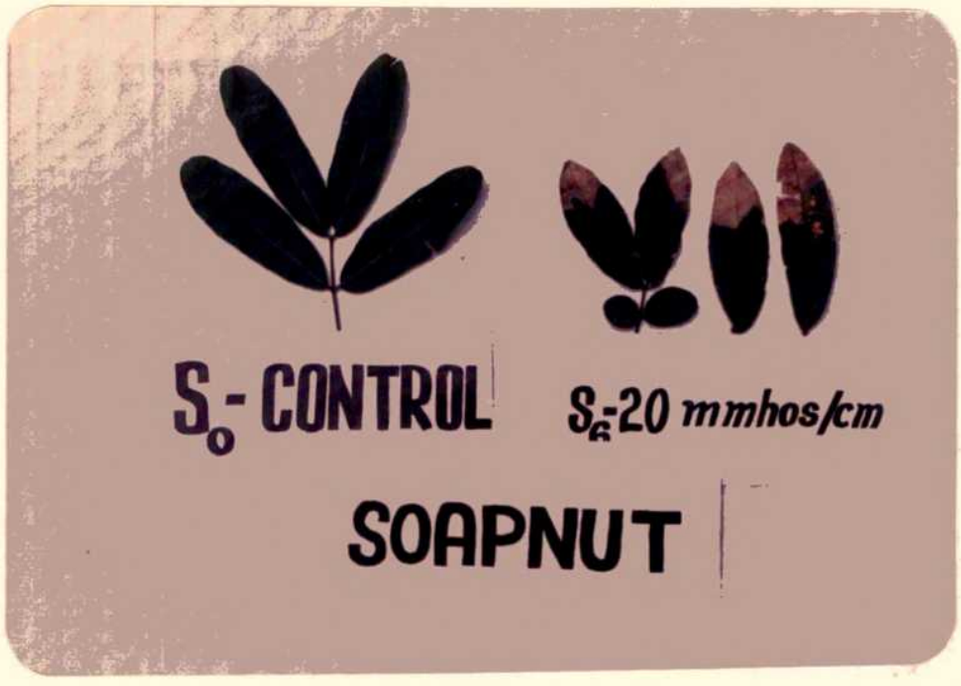


Photo plate No. 35 : Leaf injury caused by 20 mmhos/cm observed 270 days after planting

4.2.4.7 Effect on root length

From the data in Table 90, it is seen that the root length decreased significantly with each incremental level of salinity. Maximum root length was recorded under control plant.

Table 90: Effect of salinity on root length, root volume, number of primary root, number of secondary root and total number of root of Soapnut

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots
Control	58.50	40.70	15.66	363.20	378.86
4 mmhos/cm	55.00	34.10	13.00	224.10	237.10
8 mmhos/cm	41.50	32.50	10.40	186.33	196.73
12 mmhos/cm	33.50	25.50	7.00	143.00	141.00
14 mmhos/cm	32.00	23.27	5.00	75.10	80.10
16 mmhos/cm	29.10	20.50	4.33	52.20	56.33
20 mmhos/cm	27.03	17.10	3.00	40.00	43.00
S.E. ±	0.436	1.550	0.650	7.926	10.047
C.D. at 5%	1.322	3.503	1.669	24.044	30.442

4.2.4.8 Effect on root volume

There was no difference in the root volume under salinity 16 and 20 mmhos/cm. Similarly there was no difference in root volume recorded at salinity levels of 14 and 16 mmhos/cm as well as at 12 and 14 mmhos/cm (Table 90).

4.2.4.9 Effect on number of primary roots

Table 90 showed that the primary roots decreased when the salinity level was increased upto 14 (problematic soil). Lowest number of primary roots were recorded in 20 mmhos/cm, which was similar to next lower salinity level (ie. 16 mmhos/cm).

4.2.4.10 Effect on number of secondary roots

The data presented in Table 90 showed that the secondary roots decreased with the increase in salinity upto 14 mmhos/cm. There was striking difference in the secondary roots under salinity 14 mmhos/cm and above.

4.2.4.11 Effect on total number of roots

The total number of roots decreased with increase in salinity level upto 14 mmhos/cm. The salinity levels 4, 8 and 12 and control plants produced higher total number of roots as compared to rest of treatments (Table 90).

4.2.4.12 Effect on fresh weight of whole plant

On perusal of the data in Table 91, it is seen that with the increase in each salinity level there was consistent fall in fresh weight of whole plant. There was more depressive effect on fresh weight of whole plant after salinity of 14 mmhos/cm.

4.2.4.13 Effect on fresh weight of root

The first salinity level 4 mmhos/cm showed similar effect on fresh weight of root as compared to control and 8 mmhos/cm. The highest two salinity levels also behaved similarly.

Table 91: Effect of salinity on fresh and dry weight of whole plant, root and top of Soapnut.

Treatments	Fresh weight of whole plant	Fresh weight of root	Fresh weight of top	Dry weight of whole plant	Dry weight of root	Dry weight of top
Control	312.43	103.33	289.10	120.34	31.51	88.83
4 mmhos/cm	280.40	93.30	187.10	111.60	29.40	82.20
8 mmhos/cm	242.20	89.00	163.20	98.57	27.52	71.05
12 mmhos/cm	152.43	59.10	93.33	76.22	27.22	49.00
14 mmhos/cm	126.66	53.16	73.50	65.16	25.93	39.23
16 mmhos/cm	72.18	22.08	50.10	52.13	22.88	29.25
20 mmhos/cm	35.05	12.50	22.55	22.23	8.75	13.48
S.E.±	5.019	4.595	3.113	2.705	0.910	2.095
C.D. at 5%	15.225	13.942	9.432	6.285	2.791	8.354

4.2.4.14 Effect on fresh weight of top

The data on fresh weight of top as affected by different salinity levels are presented in Table 91. A sharp drop in the fresh weight of top was observed from 12 mmhos/cm which was significantly different from rest of the higher levels of salinity.

4.2.4.15 Effect on dry weight of whole plant

The data regarding the dry weight of whole plant (Table 91 and Fig. 7) showed that the drop in dry weight of whole plant was observed from 12 mmhos/cm onward. The highest drop in dry weight of whole plant was observed at 20 mmhos/cm which was different from other levels.

4.2.4.16 Effect on dry weight of root

The data in Table 91 indicated that upto salinity 14 mmhos/cm there was no adverse effect. However, severe effect was noted at 20 mmhos/cm.

4.2.4.17 Effect on dry weight of top

A significant reduction in dry weight of top was recorded at 8 mmhos/cm and above (Table 91). At highest salinity level of 20 mmhos/cm very adverse effect was observed.

4.2.4.2 Physiological parameters

4.2.4.1 Effect of salinity on chlorophyll content of leaves

From the data (Table 92) it is seen that the total chlorophyll content of leaves declined with the increasing salinity levels. The total chlorophyll content was higher under control and 4 mmhos/cm as



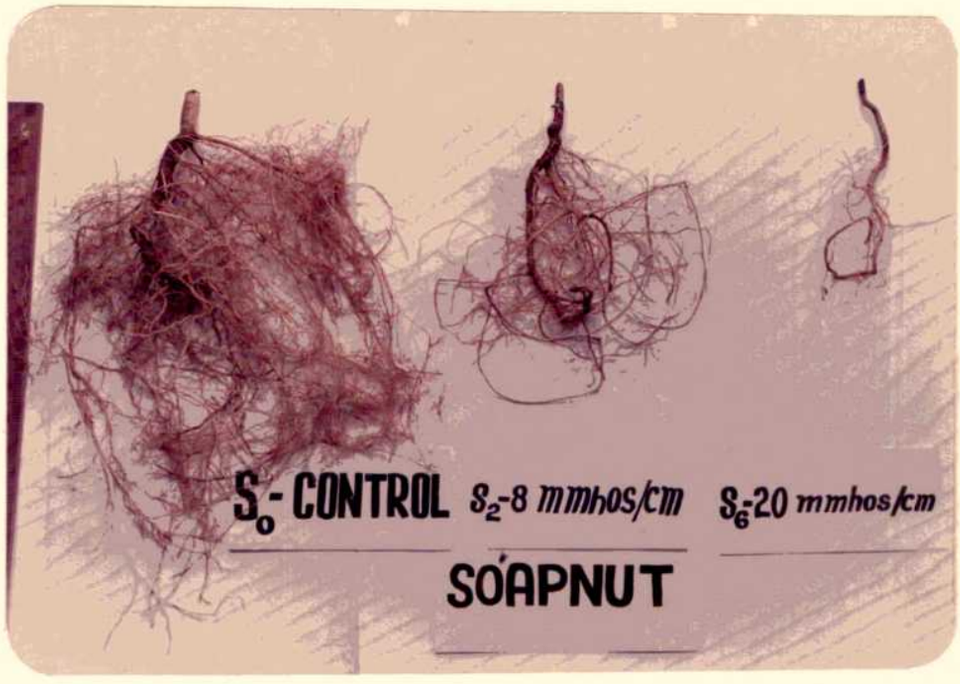


Photo plate No. 36 : Effect of salinity showing depression of shoot and root growth and complete death of plant

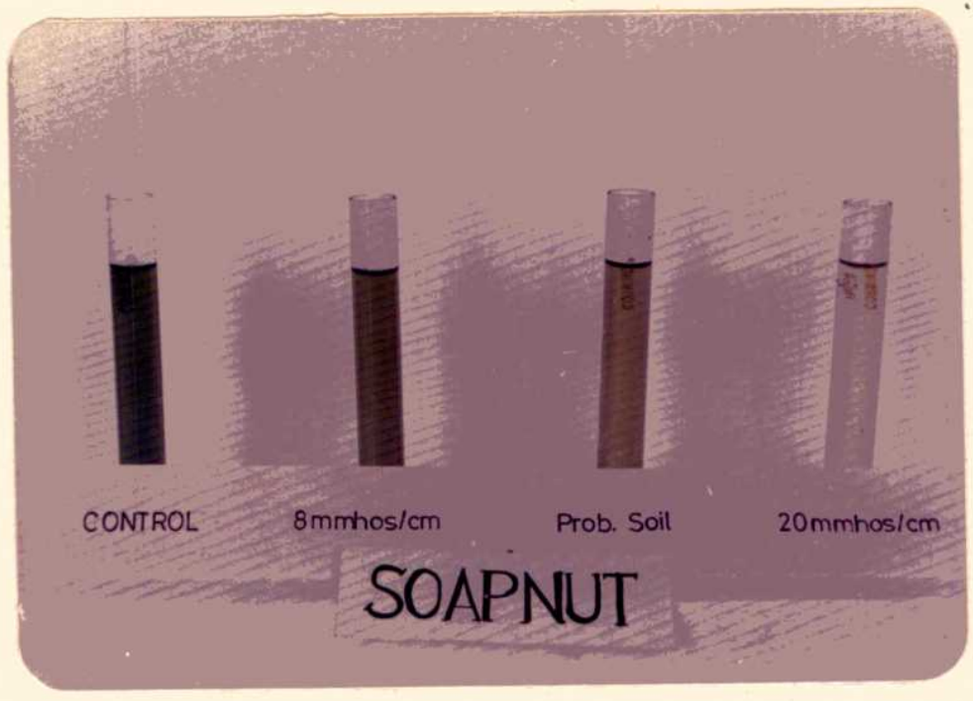


Photo plate No. 37 : Effect of salinity levels showing gradual change in chlorophyll content in Soapnut

compare to rest of treatments. Chlorophyll 'a' and 'b' recorded similar in case of salinity levels 14 and 16 mmhos/cm as well as 12 and 14 mmhos/cm.

Table 92: Effect of salinity on chlorophyll content of leaves, number of stomata per unit area and rate of trnaspiration of Soapnut

Treatments	Chlorophyll			Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
	'a'	'b'	Total		
	mg/g				
		Leaves			
Control	0.6397	1.0240	1.6637	24.00	0.0582
4 mmhos/cm	0.6133	1.0003	1.6136	25.00	0.0480
8 mmhos/cm	0.6050	0.3690	0.9730	25.33	0.0564
12 mmhos/cm	0.3947	0.5340	0.9287	29.66	0.0464
14 mmhos/cm	0.3300	0.4250	0.7550	32.00	0.0464
16 mmhos/cm	0.2620	0.3513	0.6133	35.33	0.0378
20 mmhos/cm	0.0832	0.0360	0.1797	40.66	0.0365
S.E. ±	0.023	0.040	0.063	1.391	0.0012
C.D.at 5%	0.084	0.121	0.191	4.239	0.0042

4.2.4.2.2 Effect on number of stomata

The data in Table 92 and Fig. 8 indicated that there was increasing of stomata with the increase in salinity. The lowest number of stomata was recorded under control plant.

4.2.4.2.3 Effect on rate of trnaspiration

The data regarding rate of trnaspiration are presented in Table 92 and shown graphically in Fig. 8 which indicated that control plants were on highest rate of trnaspiration but decreased when the salinity was artificially raised.

4.2.4.3 Effect of salinity on chemical composition

The data on chemical composition of leaves, roots and stem in soapnut as influenced by different salinity levels are reported in Table 93 and 94.

4.2.4.3.1 Macronutrient content of leaves roots, and stem

4.2.4.3.1.1 Nitrogen

Leaves : The N content (Table 93) of leaves was found to be consistently decreased with the increase in salinity levels. The N content was high in 4 mmhos/cm salinity and control plant than rest of treatments.

Roots : The N content of roots was decreasedwith the increase of the salinity but with negligible differences.

Stem : The N content of stem was significantly low at the higher salinity level (i.e. at 16 and 20 mmhos/mc) as compare to rest of previous treatments.

Table 93: Effect of salinity on macronutrient content (percentage of leaves, roots and stem of Soapnut

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	3.02	2.63	2.35	2.20	1.37	0.59	0.23
4 mmhos/cm	2.79	2.45	2.32	1.94	1.22	0.74	0.27
8 mmhos/cm	2.60	2.18	2.05	1.69	0.98	0.96	0.31
12 mmhos/cm	2.49	1.93	1.73	1.32	0.91	0.62	0.36
14 mmhos/cm	2.22	1.78	1.48	1.04	0.68	0.41	0.40
16 mmhos/cm	2.13	1.48	1.06	0.97	0.34	0.24	0.60
20 mmhos/cm	2.04	0.98	0.55	0.62	0.18	0.13	0.98
S.E. ±	0.027	0.062	0.071	0.056	0.041	0.032	0.041
C.D. at 5%	0.081	0.188	0.217	0.170	0.124	0.098	0.126
			Roots				
Control	2.18	2.20	1.78	1.64	1.83	0.43	0.25
4 mmhos/cm	1.62	2.15	1.70	1.53	1.01	0.55	0.31
8 mmhos/cm	1.60	2.15	1.63	1.36	0.98	0.79	0.35
12 mmhos/cm	1.54	1.91	1.50	1.24	0.86	0.64	0.40
14 mmhos/cm	1.50	1.60	1.43	1.16	0.75	0.52	0.45
16 mmhos/cm	1.35	1.25	1.38	0.87	0.59	0.47	0.46
20 mmhos/cm	1.12	0.88	1.03	0.54	0.26	0.21	0.52
S.E. ±	0.122	0.057	0.041	0.052	0.044	0.037	0.015
C.D. at 5%	0.340	0.174	0.124	0.158	0.133	0.113	0.045
			Stem				
Control	2.38	0.98	1.65	1.56	0.60	0.23	0.11
4 mmhos/cm	2.18	0.90	1.53	1.45	0.48	0.37	0.20
8 mmhos/cm	1.96	0.81	1.23	1.32	0.40	0.42	0.28
12 mmhos/cm	1.82	0.64	0.82	1.05	0.32	0.35	0.33
14 mmhos/cm	1.80	0.38	0.57	0.84	0.30	0.30	0.39
16 mmhos/cm	1.26	0.30	0.48	0.41	0.22	0.25	0.44
20 mmhos/cm	0.94	0.12	0.25	0.37	0.10	0.12	0.48
S.E. ±	0.062	0.028	0.046	0.050	0.015	0.016	0.012
C.D. at 5%	0.188	0.084	0.140	0.151	0.047	0.050	0.035

4.2.4.3.1.2 Phosphorus

Leaves : From the data (Table 93) it is seen that the P declined when salinity level was raised upto 12 mmhos/cm. There was no difference in the P content of leaves under salinity 12 and 14 mmhos/cm.

Roots : The P content of the roots was significantly decreased when the salinity was raised from 12 and mmhos/cm and above. Lowest P content was recorded under salinity 20 mmhos/cm.

Stem : There was no difference in P content of the stem in salinity level 14 and 16 mmhos/cm. However, lowest P content was recorded under 20 mmhos/cm which was different from its lower level to a greater extent.

4.2.4.3.1.3 Potassium

Leaves : The K content (Table 93) of leaves was significantly reduced from 8 mmhos/cm onward. The higher level of salinity i.e. 16 and 20 mmhos/cm showed more decline effects.

Roots : The root K content decreased with increased in salinity with a more or less equal differences.

Stem : The K content of the stem decreased with the increased salinity from 8 to 14 mmhos/cm. At 20 mmhos/cm salinity the effect was highly noticiable.

4.2.4.3.1.4 Calcium

Leaves : The Ca content of the leaves was decreased significantly on increasing the salinity upto 14 mmhos/cm (Table 93). There was no difference in effect of problematic soil (14 mmhos/cm)and 16 mmhos/cm.

Roots : The lowest root Ca was recorded under higher level of salinity.

Stem : The lowest Ca content was noted under 20 mmhos/cm which was similar to 16 mmhos/cm. The salinity level 8, 12, and 14 mmhos/cm were statistically different.

4.2.4.3.1.5 Magnesium

Leaves : Except salinity 8 to 12 mmhos/cm, differences in Mg content of leaves were significant (Table 93).

Roots : The Mg content of roots was remarkebly increased at in salinity at 16 to 20 mmhos/cm.

Stem : The Mg content of stem showed progressively decreased with the increase in salinity except salinity between 12 to 14 mmhos/cm.

4.2.4.3.1.6 Sulphur

Leaves : The S content (Table 93) of leaves was recorded highest at salinity levels 8 mmhos/cm whereas lowest S content was recorded at 20 mmhos/cm.

Roots : The S content of root was increased with increased salinity levels upto 8 mmhos/cm. Further increase in salinity levels after 12 mmhos/cm onward the S content was decreased.

Stem : There was also increase in S content of the stem when salinity was increased upto 8 mmhos/cm. The S content was decreased with maximum magnitude at salinity 20 mmhos/cm.

4.2.4.3.1.7 S-odium

Leaves : The Na content of leaves was increased with the increase of salinity (Table 93). However, the increase was larger at 14 mmhos/cm and above salinity levels.

Roots : The effect of problematic soil (14mmhos/cm) and salinity level of 16 mmhos/cm as well as 8 and 12 mmhos/cm were similar in effects.

Stem : The stem Na content increased significantly with a more or less constant increase with the increase in salinity.

4.1.4.3.1.8 Ca : Na

Leaves : The salinity levels 14 and 16 mmhos/cm and 16 and 20 mmhos/cm showed similar effects in Ca : Na content of leves. But it decreased significantly due to salinity at 4 to14 mmhos/cm (Table 94).

Roots : The Ca : Na content of roots was highest in control plant. There was no difference in Ca : Na content of roots in 8 and 12 mmhos/cm and 14 and 16 mmhos/cm.

Stem : The Ca : Na content of the stem was highest in control plant than rest of the treatments. However, at very first level of salinity the ratio was reducted to a greater magnitude.

4.2.4.3.1.9 Ca + Mg + K : Na

Leaves : A consistent and significant decrease in Ca + Mg + K : Na with increase in salinity upto 12 mmhos/cm was noted (Table 94).

Roots : There was significant reduction in Ca+Mg+K:Na of roots with increase salinity upto 12 mmhos/cm. The lowest ratio was estimated under 20 mmhos/cm.

Stem : In general Ca + Mg + K : Na of stem decreased with the increase of salinity levels with more or less equal quantity. The effect of first salinity level was highly noticiable.

4.2.4.3.2 Micronutrient contents of leaves, roots and stem

4.2.4.3.2.1 Zinc

Leaves : The data presented in Table 94 revealed that the Zn content of leaves decreased highly and significantly

Table 94: Effect of salinity on macronutrient ratios of Ca:Na, Ca+Mg+K:Na and micronutrient contents of leaves, roots and stem of Soapnut

Treatments	Ca/Na	Ca+Mg+K/Na	Micronutrient in ppm			
			Zn	Fe	Mn	Cu
			Leaves			
Control	9.57	25.68	169.50	1397.75	339.52	129.98
4 mmhos/cm	7.19	20.33	155.59	1208.13	314.68	102.10
8 mmhos/cm	5.48	15.26	121.56	1149.93	273.10	98.22
12 mmhos/cm	3.67	11.01	98.35	957.04	267.67	77.81
14 mmhos/cm	2.40	9.53	71.88	812.13	228.61	77.17
16 mmhos/cm	1.48	3.64	51.54	798.54	208.19	55.83
20 mmhos/cm	0.65	1.37	19.38	501.87	176.92	42.70
S.E. ±	0.383	0.969	5.182	38.025	7.226	2.981
C.D. at 5%	1.163	2.940	15.719	115.348	21.920	9.043
			Roots			
Control	6.59	17.87	120.67	1787.77	143.60	95.54
4 mmhos/cm	4.95	14.71	113.53	1494.50	126.38	92.93
8 mmhos/cm	3.81	11.40	94.94	1418.96	108.56	94.07
12 mmhos/cm	3.11	9.01	76.40	1333.16	107.90	71.02
14 mmhos/cm	2.71	7.78	60.13	1254.84	89.68	64.47
16 mmhos/cm	1.94	6.66	57.42	1040.94	80.18	50.89
20 mmhos/cm	1.03	3.48	23.13	698.37	49.87	29.18
S.E. ±	0.251	0.471	4.227	45.201	3.922	2.800
C.D. at 5%	0.763	1.429	12.824	137.116	11.897	8.493
			Stem			
Control	14.53	35.45	51.51	1429.14	76.01	70.80
4 mmhos/cm	7.31	17.47	45.41	1393.35	71.40	65.48
8 mmhos/cm	4.74	10.61	30.16	1208.11	59.15	59.16
12 mmhos/cm	3.29	6.75	27.27	1009.26	43.93	40.32
14 mmhos/cm	2.16	4.41	20.03	927.53	38.43	29.35
16 mmhos/cm	1.61	3.21	13.52	713.89	30.54	20.25
20 mmhos/cm	0.76	1.50	4.84	550.31	14.68	12.74
S.E. ±	0.705	1.614	3.570	36.972	3.364	2.225
C.D. at 5%	2.139	4.896	10.829	112.154	10.206	6.750

with each incremental level of salinity. The most striking depressive effect was observed from 12 mmhos/cm and above.

Roots : It is obvious from the data (Table 94) that Zn content of leaves decreased significantly with increase in salinity from 8 to 14 mmhos/cm.

Stem : There was significant decrease in Zn of stem upto the salinity level 8 mmhos/cm. The highest decline was observed at 20 mmhos/cm.

4.2.4.3.2.2 Iron

Leaves : The Fe content of the leaves was estimated highest in control plant which was significant to rest of the treatments (Table 94).

Roots : The Fe content of roots decreased significantly at 14 to 20 mmhos/cm.

Stem : There was a sharp decline in Fe content in stem was recorded at 16 mmhos/cm and above. The 4 mmhos/cm and control plant showed similar effect.

4.2.4.3.2.3 Manganese

Leaves : Lowest Mn content of the leaves was noticed under highest salinity level (Table 94). The salinity 8 and 12 mmhos/cm and 14 and 16 mmhos/cm behaved statistically similar way.

Roots : Minimum N was noted under 20 mmhos/cm, which was significantly low as compared to salinity 16 mmhos/cm.
Stem : The salinity 14 mmhos/cm behaved similarly with that of 12 and 16 mmhos/cm.

4.2.4.3.2.4 Copper

Leaves : Significantly lowest Cu content of the leaves was noted under higher salinity levels. There were similar effect in Cu content of leaves at salinity level 4 and 8 mmhos/cm and 8 and 12 mmhos/cm (Table 94).
Roots : The Cu content of the roots was estimated highest in controlled plant, which was similar to 4 mmhos/cm. Highest salinity level i.e. 20 mmhos/cm exhibited lowest Cu content of roots which was significantly different from that of 16 mmhos/cm.
Stem : There was a significant decrease in Cu content of stem with every increased level of salinity. The lowest Cu content of stem was recorded under 20 mmhos/cm.

4.2.5 Phalsa

4.2.5.1 Effect of plant height

The periodic height observations of phalsa plants expressed in per cent increase over the initial observation under different salinity levels are given in Table 95. The salinity level at 4 mmhos/cm

and control were statistically similar throughout the period except 180 and 360 days after planting and they showed more plant height as compare to 8 and 12 mmhos/cm. The adverse effect was recorded right from 60 days after planting when the salinity was raised from 8 mmhos/cm. The data further revealed that the effect of 16 and 20 mmhos/cm were significantly different during the entire course of investigation except 120 days after planting.

4.2.5.2 Effect on number of leaves

The results in Table 95 showed that there was no difference between control plant and salinity level 4 mmhos/cm at 240 days and onward planting days during the course of investigation. They showed superior performance in number of leaves than rest of other salinity levels. Similarly the salinity levels of 4 and 8 mmhos/cm were similar upto 120 and at 360 days after planting. The number of leaves were adversly decreased when the salinity was increased from 16 to 20 mmhos/cm compared to other lower levels of salinity.

4.2.5.3 Effect on stem diameter

The data indicated that the stem diameter in control and 4 mmhos/cm was similar at

Table 95: Effect of salinity on percentage increase in plant height, number of leaves and stem diameter of Phalsa

Treatments	Days after planting					
	60	120	180	240	300	360
			Plant height			
Control	25.00	90.91	168.12	304.55	635.55	762.17
4 mmhos/cm	25.10	88.88	152.38	295.24	619.08	712.83
8 mmhos/cm	20.00	73.83	127.21	227.36	375.67	470.81
12 mmhos/cm	18.18	62.50	127.10	207.83	280.62	341.11
14 mmhos/cm	18.18	61.90	112.73	200.00	272.12	300.00
16 mmhos/cm	14.29	52.39	105.26	147.91	-	-
20 mmhos/cm	12.30	50.33	94.74	121.04	-	-
S.E. ±	0.572	1.582	2.840	6.984	21.954	9.568
C.D. at 5%	1.736	4.799	8.599	21.189	69.173	30.149
			Number of leaves			
Control	62.50	125.57	242.85	437.50	714.27	742.86
4 mmhos/cm	57.14	100.84	200.18	431.90	683.31	700.18
8 mmhos/cm	55.14	100.09	162.83	371.43	568.43	633.33
12 mmhos/cm	37.50	85.71	126.32	285.71	431.14	371.43
14 mmhos/cm	28.57	50.42	100.26	228.57	274.76	257.14
16 mmhos/cm	25.50	35.50	100.18	171.43	-	-
20 mmhos/cm	20.93	32.83	75.34	114.30	-	-
S.E. ±	1.576	4.895	5.864	11.820	28.783	27.353
C.D. at 5%	4.780	4.853	17.787	34.223	90.690	86.186
			Stem diameter			
Control	35.55	100.89	150.41	200.17	233.48	292.66
4 mmhos/cm	32.35	86.65	140.15	180.89	220.93	279.64
8 mmhos/cm	31.39	80.18	133.33	180.86	200.10	216.52
12 mmhos/cm	30.77	50.63	110.11	166.67	180.25	190.63
14 mmhos/cm	30.21	45.83	83.29	123.28	150.76	158.99
16 mmhos/cm	30.20	42.37	83.20	100.73	-	-
20 mmhos/cm	20.10	36.32	66.80	82.43	-	-
S.E. ±	1.228	2.807	3.675	5.118	4.499	8.157
C.D. at 5%	3.726	8.515	11.147	15.526	14.175	25.700

various growth stages except 120 and 240 days after planting. Similarly the stem diameter in salinity 4 and 8 mmhos/cm was similar during the entire course of the investigation except 300 and 360 days after planting. The salinity levels 16 and 20 mmhos/cm showed more growth depression and they were different from other in all growth periods except 120 days after planting.

4.2.5.4 Effect on plant spread

The data regarding the plant spread under different salinity levels (Table 96) showed that the plants under 8 and 12 mmhos/cm as well as 16 and 20 mmhos/cm were statistically similar. The maximum plant spread was recorded under control plants followed by 4 mmhos/cm.

4.2.5.5 Effect on leaf area

It is evident from Table 96 that significant decrease was seen in total leaf area per plant with each subsequent salinity level over the previous lower level. Severe effects of salinity was noticed from salinity of 14 mmhos/cm and above.

Table 96: Effect of salinity on plant spread, total leaf area per plant and mortality of Phalsa

Treatments	Plant spread (cm)	Total leaf area (sq.cm.)	Mortality (per cent)
Control	62.50	4135.72	00.00 (00.57)
4 mmhos/cm	55.10	3464.51	00.00 (00.57)
8 mmhos/cm	41.17	2266.43	00.00 (00.57)
12 mmhos/cm	38.05	2051.95	27.33 (31.50)
14 mmhos/cm	25.33	1233.00	61.66 (51.94)
16 mmhos/cm	20.15	957.66	100.00 (90.00)
20 mmhos/cm	19.00	770.20	100.00 (90.00)
S.E. ±	1.456	44.122	- 1.121
C.D. at 5%	4.416	133.843	- 3.401

The figures in parenthese indicate transformed percentage value in to arcsine value.

4.2.5.6 Effect on plant mortality

The data regarding plant mortality has been given in Table 96 and shown graphically in Fig. 6. The salinity levels 4 and 8 mmhos/cm did not show any kind of mortality symptom. Mortality was noticed under 12 mmhos/cm and 100 per cent mortality was recorded in 16 to 20 mmhos/cm salinity. The mortality symptoms were noted under both salinity levels from 150 days after planting. The salinity levels 16 and 20 mmhos/cm showed burning of leaf margin and drying of shoot tip.

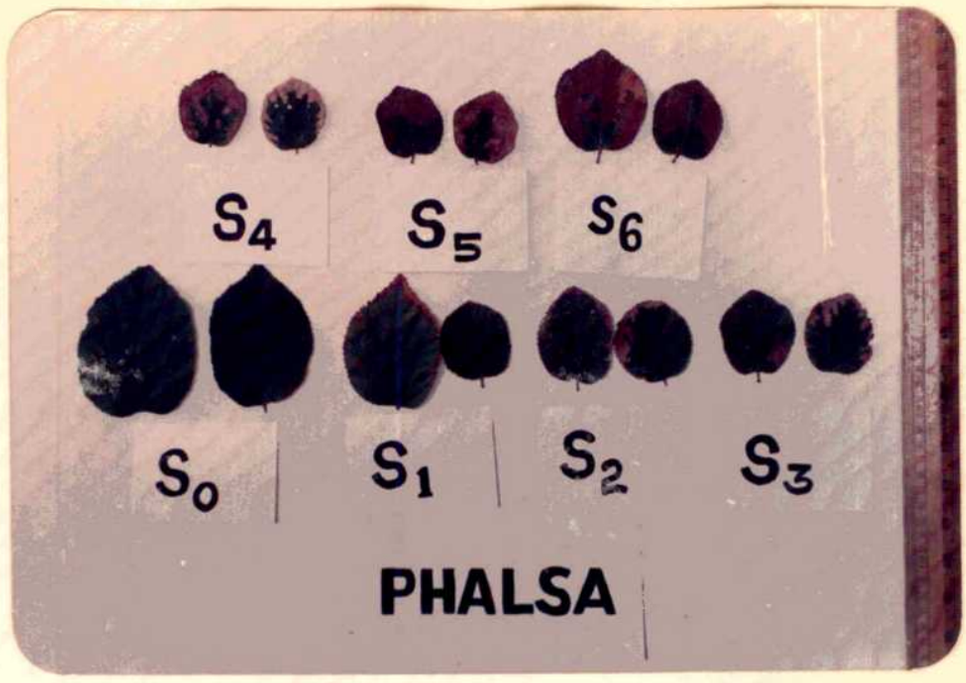




Photo plate No. 38 : Leaf injury caused by salinity S_1 (4 mmhos/cm S_2 (8 mmhos/cm), S_3 (12 mmhos/cm), S_4 (14 mmhos/cm), S_5 (16 mmhos/cm) and S_6 (20 mmhos/cm) and depressed root growth

4.2.5.7 Effect on root length

The data pertaining to the root length under various salinity levels presented in Table 97 revealed that the salinity of 12 mmhos/cm resulted into significant reduction in root length as compared to its lower and higher salinity levels. However, the extent of root length reduction was greater at 20 mmhos/cm.

4.2.5.8 Effect on root volume

The data in Table 97 showed that the root volume at salinity level of 14 mmhos/cm significantly reduced as compared to its next lower and higher salinity levels.

Table 97: Effect of salinity on root length, root volume number of primary root, number of secondary root, total number of root and number of branches of Phalsa

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots	Number of branches
Control	40.00	30.70	17.50	94.10	211.60	6.33
4 mmhos/cm	37.50	28.10	14.50	78.40	92.91	6.00
8 mmhos/cm	36.20	26.50	13.10	72.00	85.10	5.10
12 mmhos/cm	28.36	23.00	10.20	61.00	71.00	5.00
14 mmhos/cm	26.10	19.50	8.33	57.33	65.66	5.00
16 mmhos/cm	26.70	15.50	6.70	40.21	46.91	4.10
20 mmhos/cm	24.10	14.05	6.20	28.20	33.40	3.50
S.E. ±	0.951	1.091	0.905	3.432	2.420	1.563
C.D. at 5%	2.885	3.310	2.742	10.410	7.341	NS

4.2.5.9 Effect on number of primary roots

The very first salinity level i.e. 4 mmhos/cm was different from control but was found similar to 8 mmhos/cm. The salinity levels from 14 to 20 mmhos/cm were similar and showed less number of primary roots as compared to rest of the treatments.

4.2.5.10 Effect on number of secondary roots

Similarly the salinity of 4 mmhos/cm though deviated significantly in reduction of secondary roots from control but behaved similar to 8 mmhos/cm. There was also significant reduction due to salinity from 14 to 20 mmhos/cm.

4.2.5.11 Effect on total number of roots

The total number of roots decreased significantly with the increased salinity levels except salinity between 12 to 14 mmhos/cm. The effect was remarkably noticed at the start of first salinity level.

4.2.5.11a Effect on number of branches

The data in Table 97 showed that though there was increase in number of branches with the increase of salinity levels, the differences were statistically non-significant from each other.

4.2.5.12 Effect on fresh weight of whole plant

The data presented in Table 98 indicated that there was highly significant decrease in fresh weight of whole plant due to every increased salinity level. The most stiking depressive effect was observed from 16 mmhos/cm.

Table 98: Effect of salinity on fresh and dry weight of whole plant, root and top of Phalsa.

Treatments	Fresh weight of whole plant	Fresh weight of root	Fresh weight of top	Dry weight of whole plant	Dry weight of root	Dry weight of top
Control	104.33	38.83	65.50	39.68	10.43	29.25
4 mmhos/cm	94.10	35.00	59.10	34.87	9.32	25.55
8 mmhos/cm	68.70	32.50	36.20	27.79	9.03	18.76
12 mmhos/cm	46.38	18.85	27.53	22.25	8.21	14.04
14 mmhos/cm	40.33	15.33	25.00	20.05	7.05	13.00
16 mmhos/cm	26.48	11.15	15.33	15.10	6.36	8.74
20 mmhos/cm	20.33	8.00	12.33	14.01	5.31	8.70
S.E. ±	1.595	1.241	1.231	0.670	0.440	0.341
C.D. at 5%	4.858	3.858	3.733	2.032	1.336	1.035

4.1.5.13 Effect on fresh weight of root

The pronounced and significant reduction of fresh weight of root was noticed at 20 mmhos/cm salinity as compared to its lower levels (Table 98).

4.1.5.14 Effect on fresh weight of top

The fresh weight was significantly reduced upto the salinity 12 mmhos/cm (Table 98). More depressive effect was observed at 8 and 16 mmhos/cm of salinity.

4.2.5.15 Effect on dry weight of whole plant

The data on dry weight of whole plant as influenced by various salinity levels presented in Table 98 and shown in Fig. 10 indicated significant decline in dry weight of whole plant upto the salinity 12 mmhos/cm

4.2.5.16 Effect on dry weight of root

The data in Table 98 indicated that more or less similar differences in dry weight of root was observed due to increased salinity levels.

4.2.5.17 Effect on dry weight of top

It is obvious from the data (Table 98) that most depressive effect of salinity was found at 16 mmhos/cm but was started from 8 mmhos/cm, it was statistically similar to 20 mmhos/cm.

4.2.5.2 Physiological parameters

4.2.5.2.1 Effect of salinity on chlorophyll content of leaves

The chlorophyll 'a', 'b' and total was

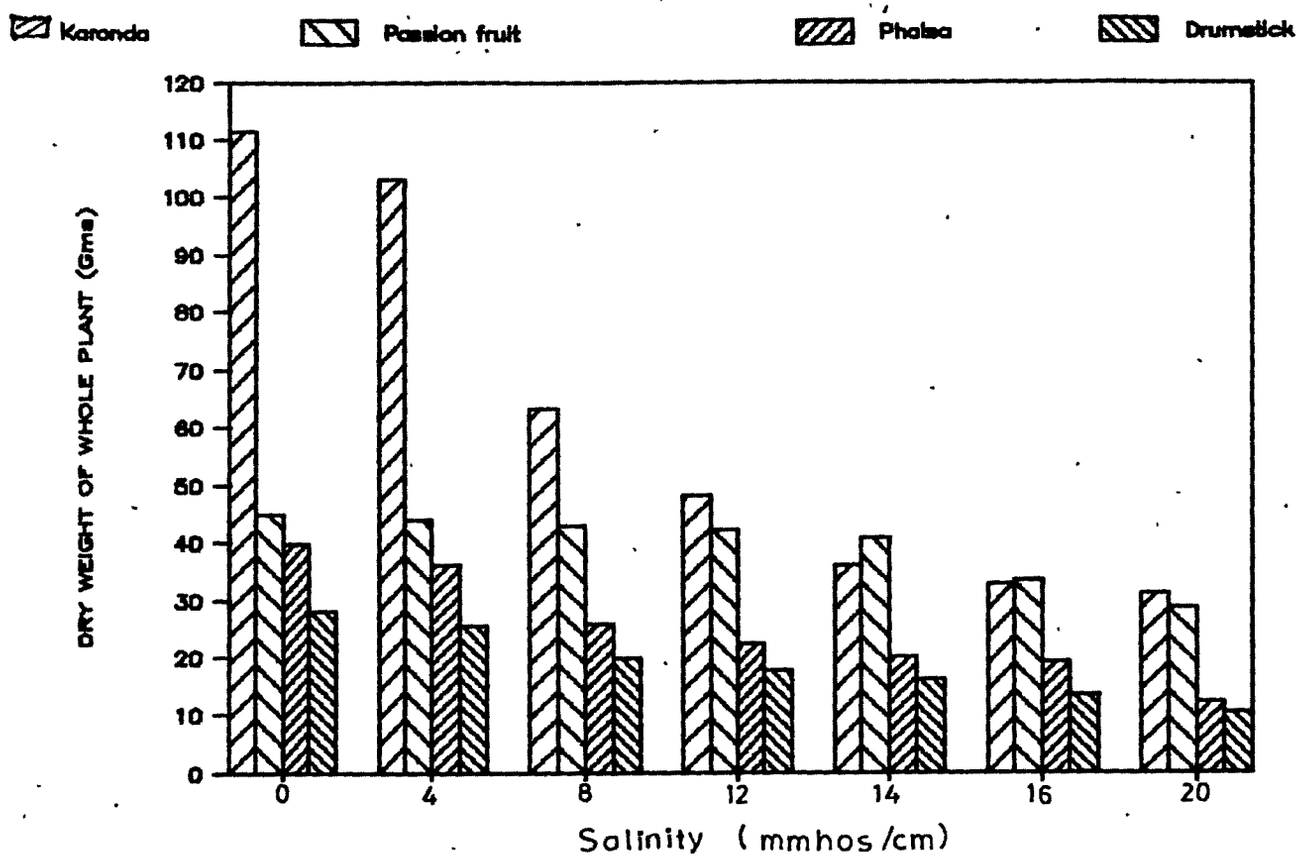


Fig 10. Effect of salinity on dry matter accumulation in Karonda, Passion fruit, Phalsa and Drumstick at the time of harvest



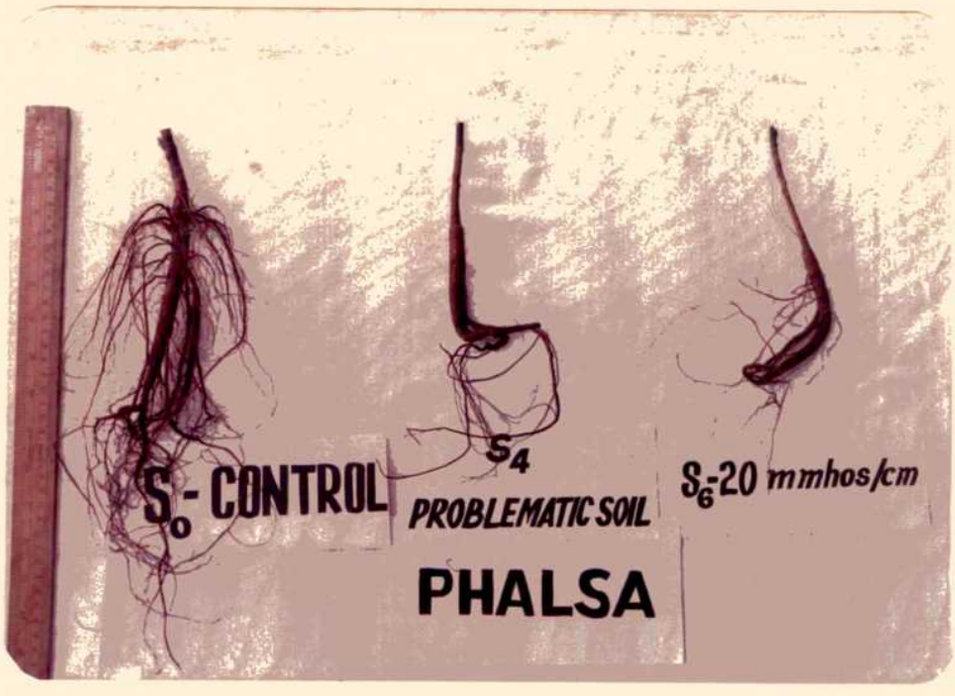


Photo plate No. 39 : Effect of salinity S_4 (problematic soil) and S_6 (20 mmhos/cm) on shoot and root growth of Phalsa noticed 9 months after planting

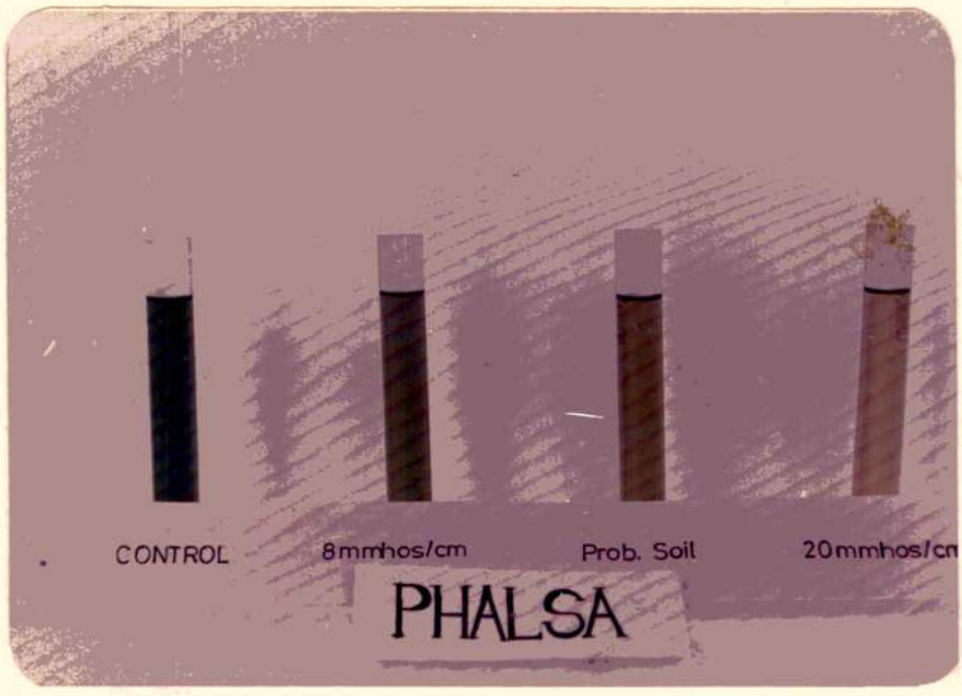


Photo plate No. 40 : Effect of salinity levels showing gradual change in chlorophyll content in Phalsa

statistical similar at 4 mmhos/cm of salinity as compare to control. The results due to 8 mmhos/cm were different for 'a' chlorophyll but were similar in for total chlorophyll compre to its lower salinity.

Table 99: Effect of salinity on chlorophyll content of leaves, Number of stomata per unit area and rate of trnaspiration of Phalsa

Treatments	Chlorophyll			Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
	'a'	'b'	Total		
	mg/g				
		Leaves			
Control	1.3647	1.3220	2.6867	20.00	0.0254
4 mmhos/cm	1.3237	1.2457	2.5693	26.66	0.0239
8 mmhos/cm	0.4700	0.4600	0.9300	31.35	0.0235
12 mmhos/cm	0.4050	0.3360	0.7410	37.00	0.0221
14 mmhos/cm	0.3980	0.3070	0.7050	40.00	0.0208
16 mmhos/cm	0.2720	0.2637	0.5342	42.33	0.0195
20 mmhos/cm	0.2460	0.2100	0.4640	46.67	0.0179
S.E. ±	0.017	0.059	0.072	1.894	0.0005
C.D. at 5%	0.052	0.100	0.220	5.745	0.0017

4.2.5.2.2 Effect on number of stomata

Thedata in Table 99 and Fig. 8 indicated that there was trend of increase number of stomata with the increase in salinity level. The salinity 12, 14 and 16 mmhos/cm were at par from each other in number of stomata.

4.2.5.2.3 Effect on rate of transpiration

Though there was decrease in rate of transpiration to corresponding increase of salinity levels, the differences were more of less similar.

4.2.5.3 Effect of salinity on chemical composition

The data on chemical composition of leaves, roots and stem of phalsa as affected by different salinity levels are noted in Table 100 and 101.

4.2.5.3.1 Macronutrient content of leaves, roots and stem

4.2.5.3.1.1 Nitrogen

Leaves : The N content (Table 100) of leaves decreased due to increase in salinity, but with a more or less equal magnitude.

Roots : The root N significantly decreased with the increased salinity except in 14 to 16 mmhos/cm.

Stem : Significant reduction N content of stem was observed when salinity level was raised from 12 to 20 mmhos/cm.

4.2.5.3.1.2 Phosphorus

Leaves : The P content of leaves was statistically reduced due to salinity at 8 and 12 mmhos/cm. Similarly

Table 100: Effect of salinity on macronutreiht content (percentage) of leaves, roots and stem of Phalsa

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	2.92	1.38	2.05	1.96	1.00	0.45	0.30
4 mmhos/cm	2.68	1.35	1.98	1.92	0.91	0.47	0.34
8 mmhos/cm	2.38	1.05	1.97	1.52	0.88	0.58	0.35
12 mmhos/cm	2.32	0.92	1.86	1.28	0.88	0.58	0.35
14 mmhos/cm	2.30	0.67	1.85	1.20	0.52	0.39	0.39
16 mmhos/cm	1.93	0.55	1.78	1.13	0.30	0.32	0.41
20 mmhos/cm	1.72	0.22	1.25	0.73	0.22	0.17	0.47
S.E. ±	0.123	0.042	0.063	0.047	0.031	0.015	0.012
C.D. at 5%	0.373	0.128	0.206	0.142	0.095	0.045	0.035
			Roots				
Control	3.18	1.38	1.73	1.76	1.30	0.30	0.70
4 mmhos/cm	3.00	1.06	1.67	1.59	1.18	0.39	0.76
8 mmhos/cm	2.68	0.93	1.55	1.49	0.92	0.51	0.80
12 mmhos/cm	2.21	0.90	1.50	1.28	0.84	0.36	0.88
14 mmhos/cm	1.86	0.88	1.43	1.20	0.73	0.34	0.95
16 mmhos/cm	1.76	0.80	1.28	1.15	0.58	0.30	1.10
20 mmhos/cm	1.48	0.63	0.90	0.98	0.53	0.18	1.22
S.E. ±	0.056	0.029	0.049	0.049	0.021	0.020	0.020
C.D. at 5%	0.169	0.087	0.148	0.148	0.062	0.061	0.056
			Stem				
Control	3.08	1.32	2.13	0.92	0.84	0.46	0.10
4 mmhos/cm	3.01	1.13	2.03	0.81	0.79	0.43	0.15
8 mmhos/cm	2.78	0.95	1.90	0.76	0.65	0.38	0.27
12 mmhos/cm	2.53	0.63	1.83	0.52	0.53	0.30	0.28
14 mmhos/cm	2.08	0.55	1.60	0.38	0.39	0.28	0.30
16 mmhos/cm	1.68	0.50	1.29	0.30	0.25	0.20	0.49
20 mmhos/cm	1.12	0.32	0.92	0.16	0.15	0.11	0.56
S.E. ±	0.088	0.030	0.047	0.026	0.017	0.013	0.019
C.D. at 5%	0.260	0.091	0.143	0.073	0.053	0.038	0.058

the salinity of 20 mmhos/cm was highly effective in decrease of P content of leaves(Table 100)

Roots : The root P was significantly low at salinity 4 and 20 mmhos/cm as compared to their earlier treatments.

Stem : There was a decrease in P content of stem with the successive increase in salinity but the reductions were statistically similar at salinity from 12 to 16 mmhos/cm.

4.2.5.3.1.3 Potassium

Leaves : Significant and most striking effect in K content of leaves was observed at salinity 20 mmhos/cm(Table 100)

Roots : A significantly low K content of root was observed at 16 and 20 mmhos/cm as compare to rest of treatments.

Stem : Similar to root, the K content of stem was significantly low at salinity 14 to 20 mmhos/cm.

4.2.5.3.1.4 Calcium

Leaves : The Ca content (Table 100) of leaves significantly and highly decreased at salinity of 8 and 20 mmhos/cm as compared to their next lower salinity.

Roots : The salinity upto 12 mmhos/cm showed significant decrease in Ca content of roots (Table 100). The highest level of salinity also behaved differently.

Stem : There was no significant decrease in Ca content of stem in salinity 4 to 8 mmhos/cm. In rest of the salinity levels significant reduction in Ca content of stem was observed.

4.2.5.3.1.5 Magnesium

Leaves : The data presented in Table 100 indicated that Mg content of leaves was decreased significantly due to salinity from 8 to 16 mmhos/cm. There was no difference in Mg content of leaves recorded under 4 to 8 mmhos/cm and 16 to 20 mmhos/cm.

Roots : The Mg content of roots declined significantly with increasing levels of salinity except from 16 to 20 mmhos/cm.

Stem : The plant under control and 4 mmhos/cm recorded similar difference in Mg content of the stem but were significantly higher from rest of the treatments.

4.2.5.3.1.6 Sulphur

Leaves : The S content (Table 100) of leaves was found to be increased with increase in level of salinity upto 8 mmhos/cm. However, beyond that limit the S content of leaves declined significantly.

Roots : It was interesting to note that with increase in salinity level N content of leaves was found to be

increased upto salinity level of 8 mmhos/cm. However, beyond this the N content of roots was found to be declined.

Stem : The stem S was decreased significantly with increasing levels of salinity except from 12 to 14 mmhos/cm.

4.2.5.3.1.7 Sodium

Leaves : The Na content of leaves increased with the increase in salinity level (Table 100). The leaf Na was high in higher salinity levels than control.

Roots : Maximum and significantly higher Na was observed in roots in salinity 14 to 16 mmhos/cm.

Stem : The Na content of stem was increased highly at 14 mmhos/cm and above salinity.

4.2.5.3.1.8 Ca : Na

Leaves : There was a significant reduction in Ca : Na with increased salinity levels except 14 to 16 mmhos/cm.

Roots : There was a significant reduction in Ca : Na of roots with each incremental level of salinity.

Stem : There was higher and significant decrease in Ca :Na of stem due to salinity upto 8 mmhos/cm.

4.2.5.3.1.9 Ca + Mg + K : Na

Leaves : A corresponding decrease (Table 101) in Ca + Mg + K : Na with the increase in salinity was recorded

except in salinity from 12 to 16 mmhos/cm. The 20 mmhos/cm salinity level gave significantly low ratio than rest of the treatments.

Roots : Every increased salinity showed significantly low Ca + Mg + K : Na ratio of roots.

Stem : The stem Ca + Mg + K : Na decreased severely at salinity of 14 mmhos/cm but thereafter the decrease was statistically similar.

4.2.5.3.2 Micronutrient contents of leaves, roots and stem

4.2.5.3.2.1 Zinc

Leaves : The salinity level of 8 mmhos/cm showed significant decrease in Zn content of the leaves compared to its lower (4 mmhos/cm) and higher (12 mmhos/cm) salinity. More decline was noted at higher salinity (20 mmhos/cm) (Table 101).

Roots : Statistically the salinity levels from 4 to 12 mmhos/cm and 14 to 16 mmhos/cm were equal in effect.

Stem : Only salinity 4 mmhos/cm and 20 mmhos/cm resulted into significant decrease in Zn content of the stem compared to rest of the treatments.

Table 101: Effect of salinity on macronutrient ratios of Ca:Na, Ca+Mg+K:Na and micronutrient contents of leaves, roots and stem of Phalsa

Treatments	Ca / Na	Ca+Mg+K / Na	Micronutrient in ppm			
			Zn	Fe	Mn	Cu
		Leaves				
Control	6.55	16.76	58.32	1751.80	305.80	131.99
4 mmhos/cm	5.64	14.16	56.06	1604.28	303.28	114.15
8 mmhos/cm	4.23	12.35	41.59	1373.16	266.32	91.14
12 mmhos/cm	3.46	10.64	33.19	1319.38	246.98	89.37
14 mmhos/cm	3.07	9.16	30.08	1118.45	233.78	85.84
16 mmhos/cm	2.75	8.34	25.83	983.10	220.52	72.56
20 mmhos/cm	1.57	4.63	15.10	650.58	171.89	30.09
S.E. ±	0.111	0.347	1.695	43.650	5.915	5.726
C.D. at 5%	0.338	1.093	5.143	132.411	17.944	17.369
		Roots				
Control	2.51	6.78	31.65	1113.78	168.40	58.50
4 mmhos/cm	2.09	5.84	24.88	1081.51	111.43	45.00
8 mmhos/cm	1.75	4.84	24.51	1048.49	107.42	36.20
12 mmhos/cm	1.45	4.11	23.96	1018.49	103.97	34.20
14 mmhos/cm	1.29	3.53	19.69	953.36	98.80	32.33
16 mmhos/cm	1.04	2.73	18.08	936.40	88.39	30.10
20 mmhos/cm	1.81	1.97	14.46	855.63	71.81	21.74
S.E. ±	0.021	0.076	0.720	10.498	2.985	2.300
C.D. at 5%	0.063	0.232	2.185	31.844	9.054	6.921
		Stem				
Control	9.50	39.37	46.63	1246.33	87.00	80.92
4 mmhos/cm	5.66	24.80	40.83	1148.64	80.00	74.48
8 mmhos/cm	2.84	12.32	32.62	1010.51	70.62	61.07
12 mmhos/cm	2.08	11.54	29.50	863.88	67.37	49.35
14 mmhos/cm	1.19	8.28	23.91	702.57	58.00	35.39
16 mmhos/cm	0.62	3.80	20.24	689.32	47.13	25.38
20 mmhos/cm	0.28	2.20	10.37	499.59	28.40	12.38
S.E. ±	0.561	2.105	1.609	27.326	2.609	2.888
C.D. at 5%	1.703	6.383	4.881	82.892	7.913	8.760

4.2.5.3.2.2 Iron

Leaves : There was highly significant reduction in Fe content of leaves due to higher concentration of salinity except salinity from 8 to 12 mmhos/cm.

Roots : The Fe content of root was similar in salinity from 8 to 12 and 14 to 16 mmhos/cm. Lowest Fe content of the roots was recorded under 20 mmhos/cm which was statistically different to next lower salinity.

Stem : There was pronounced decrease in Fe content of stem with every increase in salinity from 8 to 20 mmhos/cm.

4.2.5.3.2.3 Manganese

Leaves : It is observed from the data (Table 101) that Mn content of leaves was decreased significantly due to salinity at 8 mmhos/cm. However, lowest Mn estimate was seen under 20 mmhos/cm, which was significantly different as compared to rest salinity levels.

Roots : The Mn content of the roots was sharply reduced at 4 mmhos/cm salinity. Further reductions were more or less equal.

Stem : The salinity from 14 to 20 mmhos/cm showed significant decrease of Mn content of the stem.

4.2.5.3.2.4 Copper

Leaves : The Cu content of the leaves was low and more striking at 20 mmhos/cm levels as compared to other treatments (Table 101).

Roots : The first salinity level showed higher reduction in Cu content of the roots. However, the salinity of 8 to 16 mmhos/cm were similar in effects regarding the Cu content of the root.

Stem : Though salinity at 4 mmhos/cm was similar to control in effect on Cu content of the stem. But the next higher salinity levels were resulted into significantly low Cu content of the stem.

4.2.6 Karonda

4.2.6.1 Effect on plant height

Periodic observation on height of karonda plant expressed in the per cent increase over the initial observation under various salinity levels are given in Table 102. The plants were severely affected at 16 and 20 mmhos/cm and they recorded less plant height as compared to control and other levels during the entire course of investigation. Similarly, the plant height in 4 and mmhos/cm and control was similar at various growth stages. The salinity levels 12 to 14 right from 120 days after planting showed significant decrease in plant height.

Table 102: Effect of salinity on percentage increase in plant height, number of leaves and stem diameter of Karonda

Treatments	Days after planting					
	60	120	180	240	300	360
			Plant height			
Control	45.53	143.67	236.89	400.11	483.00	541.00
4 mmhos/cm	42.86	140.75	221.43	397.00	477.43	515.75
8 mmhos/cm	26.45	133.71	205.59	373.11	457.00	492.00
12 mmhos/cm	20.68	125.67	188.24	308.83	371.19	415.20
14 mmhos/cm	16.23	92.80	130.47	250.75	303.46	343.82
16 mmhos/cm	16.40	81.58	115.21	215.00	261.67	294.54
20 mmhos/cm	13.03	66.51	99.59	188.35	228.24	255.09
S.E. ±	1.507	3.669	5.715	7.731	10.899	12.893
C.D. at 5%	4.572	11.131	17.316	23.424	33.061	39.065
			Number of leaves			
Control	121.43	331.11	626.00	856.86	1088.15	1115.21
4 mmhos/cm	117.33	324.33	594.43	831.14	1074.11	1100.00
8 mmhos/cm	110.14	308.44	571.20	817.68	1023.00	1063.51
12 mmhos/cm	107.14	295.00	525.77	800.80	909.29	949.08
14 mmhos/cm	90.40	275.07	481.00	754.33	834.00	870.11
16 mmhos/cm	75.18	258.53	453.04	671.00	729.57	764.67
20 mmhos/cm	67.81	244.15	414.15	605.67	662.33	691.00
S.E. ±	2.746	5.057	9.654	12.012	18.856	24.978
C.D. at 5%	8.331	15.541	29.286	36.396	57.200	75.772
			Stem diameter			
Control	80.39	141.34	266.10	353.25	445.11	481.33
4 mmhos/cm	66.64	137.00	233.23	351.10	440.00	473.10
8 mmhos/cm	60.15	125.81	210.44	315.33	419.33	438.00
12 mmhos/cm	50.33	121.33	206.00	287.07	351.33	382.27
14 mmhos/cm	38.86	100.53	171.50	271.35	343.27	367.00
16 mmhos/cm	33.32	83.45	150.10	240.33	305.13	327.11
20 mmhos/cm	833.10	76.67	128.41	221.17	257.00	275.00
S.E. ±	1.972	2.646	5.602	6.872	9.012	14.123
C.D. at 5%	5.981	8.025	16.974	20.822	27.306	42.792

4.2.6.2 Effect on number of leaves

The number of leaves were decreased when increase of salinity throughout the periods of investigation (Table 102). The salinity 16 and 20 mmhos/cm significantly reduced the number of leaves at all days after planting except 60 and 120 days. The salinity levels of 4 mmhos/cm and control were statistically similar during all the growth stages except at 180 days after planting. After 240 days of planting the salinity levels viz. from 12 to 20 mmhos/cm, there was significant reduction in number of leaves.

4.2.6.3 Effect on stem diameter

The result showed (Table 102) that stem diameter decrease when the salinity was increased artificially during the course of investigation. The stem diameter in salinity 4 mmhos/cm and control was similar at all growth stages except 60 and 180 days after planting. The adverse effects were noted in greater amount when the salinity was increased at 20 mmhos/cm. The effect of 12 to 14 mmhos/cm (problematic soils) were not different from each other at 240 days and above.

4.2.6.4 Effect on plant spread

The control plant, salinity 4 and 8 mmhos/cm were statistically similar and they had greater spread than the rest of the treatments. The effect at 20 mmhos/cm was in a highly reduced state and was similar to salinity of 16 mmhos/cm(Table 103).

4.2.6.5 Effect on leaf area

It is evident from Table 103 that the total leaf area per plant was found to be reduced in greater way due to each subsequent level of salinity. The most stiking depressive effect was noted under 14 mmhos/cm and above. The low total leaf area per plant was recorded under 20 mmhos/cm.

Table 103: Effect of salinity on plant spread, total leaf area per plant and mortality of Karonda

Treatments	Plant spread (cm)	Total leaf area (sq.cm.)	Mortality (per cent)
Control	66.17	4314.16	00.00 (00.57)
4 mmhos/cm	63.33	3739.45	00.00 (00.57)
8 mmhos/cm	63.00	3540.10	00.00 (00.57)
12 mmhos/cm	54.70	3039.45	00.00 (00.57)
14 mmhos/cm	43.20	2129.61	10.66 (19.37)
16 mmhos/cm	34.17	1876.50	26.33 (30.85)
20 mmhos/cm	31.00	1332.34	40.33 (30.85)
S.E. ±	2.923	48.811	- 1.221
C.D. at 5%	8.856	148.055	- 3.401

The figures in parenthese indicate transformed percentage value in to arcsine value.





Photo plate No. 41 : Effect of salinity showing reduced leaf area under S_6 (20 mmhos/cm) and depressed growth with blackening or roots under problematic soil (S_4) observed 12 months after planting

4.2.6.6 Effect on plant mortality

The data regarding plant mortality given in Table 103 and shown in Fig. 6 indicated that the plants at salinity levels 4, 8 and 12 mmhos/cm did not show any kind of mortality symptoms. The mortality symptoms were started from 14 mmhos/cm. The plant mortality was not seen between salinity level of 16 and 20 mmhos/cm. The younger leaves of the plants were associated with yellow colour at highest salinity after 300 days of platning.

4.2.6.7 Effect on root length

The root length was significantly but constently decreased at every next higher salinity level upto 14 mmhos/cm (Table 104).

4.2.6.8 Effect on root volume

From the Table 104 it was noticed that the salinity levels like 8 and 14 were found effective in significant decrease of root volume compared to their respective higher levels but at the same time their effects compared to lower salinity levels were statistically similar.

4.2.6.9 Effect on number of primary roots

Except salinity at 12 mmhos/cm all other levels exhibited non significant decreases in primary roots.

4.2.6.10 Effect on number of secondary roots

Only the salinity level of 14 mmhos/cm (problematic soils) was found effective in significant reducing the number of secondary roots.

Table 104: Effect of salinity on root length, root volume, number of primary root, number of secondary root, total number of root and branches of Karonda

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots	Number of branches
Control	60.80	57.10	20.10	305.00	325.10	16.60
4 mmhos/cm	58.00	53.10	17.03	288.00	305.03	15.00
8 mmhos/cm	53.00	49.20	15.10	253.30	268.40	13.00
12 mmhos/cm	48.10	40.50	12.50	238.50	251.00	12.60
14 mmhos/cm	40.33	36.00	11.00	177.20	188.20	12.10
16 mmhos/cm	31.10	30.50	10.00	110.60	120.60	11.30
20 mmhos/cm	26.20	27.00	8.33	97.33	105.00	11.33
S.E. ±	1.264	1.555	0.810	7.131	8.000	0.724
C.D. at 5%	3.803	4.503	2.472	21.606	24.268	2.195

4.2.6.11 Effect on total number of roots

The effect of salinity on total number of roots was as similar as of secondary roots (Table 104). As compared to control the total roots were three times less in highest level of salinity.

4.2.6.11a Effect of number of branches

The data in Table 104 indicated that number of branches decreased with increase in salinity level, but differences were more or less equal.

4.2.6.12 Effect on fresh weight of whole plant

It is evident from Table 105 that the fresh weight of whole plant was suddenly declined at salinity of 8 mmhos/cm and continued upto 16 mmhos/cm. But last two higher salinity levels were not different from each other in effect.

4.2.6.13 Effect on fresh weight of root

The trend of salinity effect on fresh weight of root was most similar as evidenced on fresh weight of root (Table 105).

4.2.6.14 Effect on fresh weight of top

There was continuous decrease in fresh weight of top due to each higher salinity level. However, at the increasing salinity levels the effect was also became in a increasing way.

4.2.6.15 Effect on dry weight of whole plant

The data regarding dry weight of whole plant in Table 105 and Fig. 10 showed the depressive effect

at every increased salinity except salinity at 16 to 20 mmhos/cm.

Table 105 : Effect of salinity on fresh and dry weight of whole plant, root and top of Karonda

Treatments	Fresh weight of whole plant (g)	Fresh weight of root (g)	Fresh weight of top (g)	Dry weight of whole plant (g)	Dry weight of root (g)	Dry weight of top (g)
Control	290.76	95.10	195.66	111.46	35.15	76.31
4 mmhos/cm	265.70	87.10	178.60	103.17	32.62	70.57
8 mmhos/cm	157.66	53.33	104.33	62.91	20.14	42.77
12 mmhos/cm	107.67	37.00	70.67	48.18	15.68	32.50
14 mmhos/cm	78.30	27.00	61.30	35.74	11.78	23.99
16 mmhos/cm	59.33	20.33	39.00	33.69	10.88	22.81
20 mmhos/cm	51.37	18.20	33.17	29.17	9.90	19.27
S.E. ±	4.572	1.357	3.261	1.861	0.519	1.353
C.D. at 5%	13.869	4.116	.892	5.644	1.574	4.104

4.2.6.16 Effect on dry weight of root

The dry weight of root was reduced significantly due to salinity raised upto 14 mmhos/cm (Table 105).

4.2.6.17 Effect on dry weight of top

It was observed from Table 105 that the higher levels of salinity like 14, 16 and 20 mmhos/cm did not show any statistical difference on dry weight



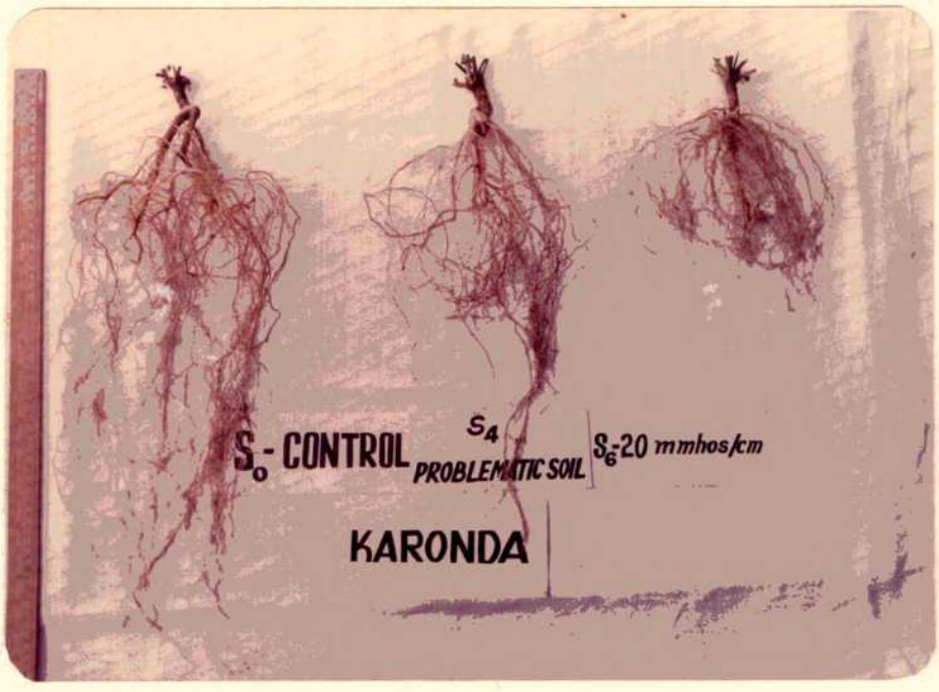


Photo plate No. 42 : Effect of salinity showing decreased number of leaves, plant growth and roots in karonda at the time of termination of experiment

of top. However the earlier salinity levels showed significant decrease in dry weight of top.

4.2.6.2 Physiological parameters

4.2.6.2.1 Effect of salinity on chlorophyll content of leaves

There was significant difference in chlorophyll 'a', 'b' and total in control and first level of salinity. But beyond salinity 8 mmhos/cm there was not any difference in chlorophyll content.

Table 106: Effect of salinity on chlorophyll content of leaves, number of stomata per unit area and rate of transpiration of Karonda

Treatments	Chlorophyll			Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
	'a'	'b'	Total		
		Leaves			
Control	0.9600	1.3070	2.2670	13.33	0.0362
4 mmhos/cm	0.6150	0.8863	1.5013	19.66	0.0295
8 mmhos/cm	0.4370	0.6050	1.0420	19.33	0.0287
12 mmhos/cm	0.4317	0.5870	1.0187	24.66	0.0264
14 mmhos/cm	0.3770	0.5068	0.8830	28.33	0.0250
16 mmhos/cm	0.3497	0.4740	0.8237	31.33	0.0237
20 mmhos/cm	0.3350	0.4240	0.7590	36.00	0.0231
S.E. ±	0.031	0.038	0.069	1.589	0.0003
C.D. at 5%	0.094	0.117	0.210	4.819	0.0011

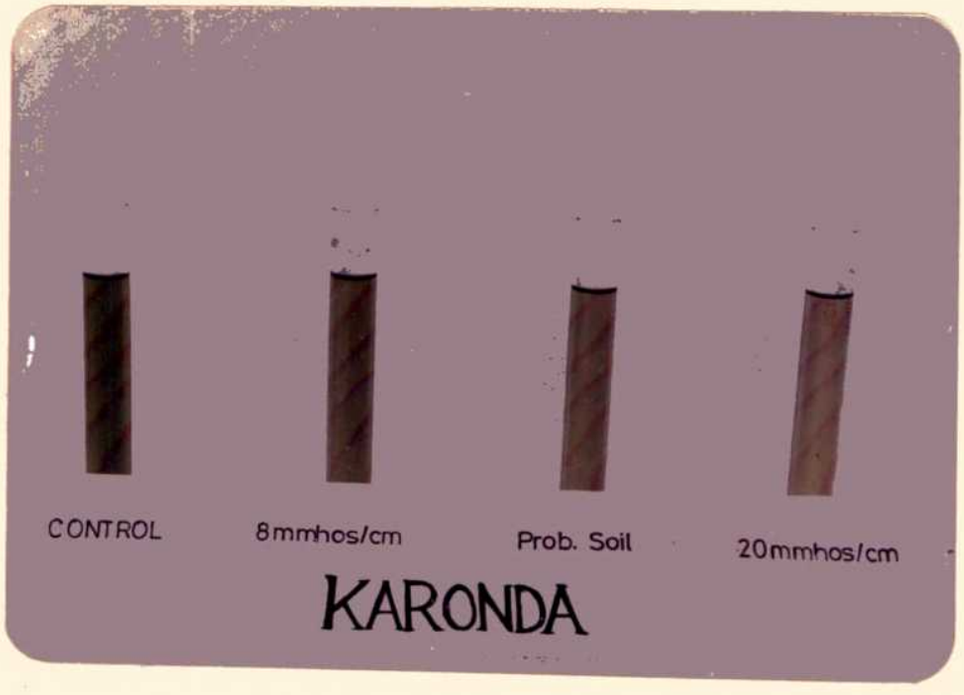


Photo plate No. 43 : Effect of salinity levels showing gradual change in chlorophyll content in Karonda

4.2.6.2.2 Effect on number of stomata

It is observed from Table 106 and Fig.8 that the number of stomata showed increasing trend with corresponding increase of salinity level. More number of stomata was recorded at 20 mmhos/cm, which was similar to its next lower level of salinity.

4.2.6.2.3 Effect on rate of trnaspiration

A decreasing trend of rate of trnaspiration was noticed due to increasing of salinity level (Table 106 and Fig. 8). But the rate of transpiration was significantly decreased in salinity from 8 to 16 mmhos/cm.

4.2.6.3 Effect of salinity on chemical composition

The data on chemical composition of leaves, roots and stem in Karonda as influenced by different salinity levels are presented in Table 107 and 108.

4.2.6.3.1 Macronutrient content of leaves, roots and stem

4.2.6.3.1.1 Nitrogen

Leaves : The results in Table 107 indicated that N content of leaves significantly decreased with increased salinity levels upto 12 mmhos/cm. The effect in leaves N content were at par in salinity levels from 12 to 16 mmhos/cm.

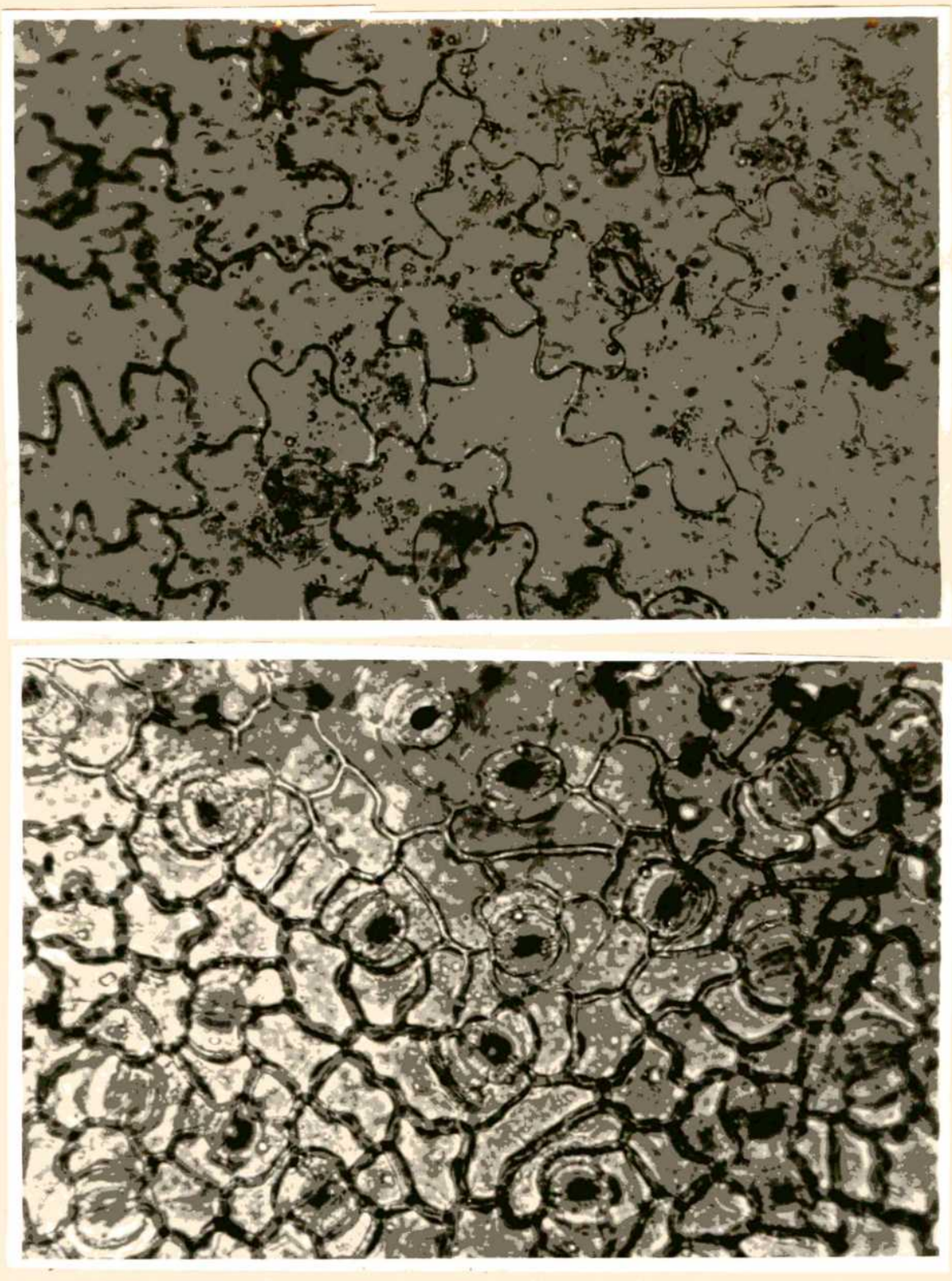


Photo plate No. 44 : Effect of salinity 20 mmhos/cm on density of stomata number compared to control in Karonda

Roots : Except salinity 4 mmhos/cm and control all other higher salinity levels resulted significant decrease in N content of roots.

Stem : The trend of salinity effect in stem N content was mostly similar to that of root (Table 107).

4.2.6.3.1.2 Phosphorus

Leaves : The P content of leaves was severely affected at salinity 4 mmhos/cm. Similarly the effect was more pronounced in salinity from 14 to 20 mmhos/cm (Table 107).

Roots : The P-content of root significantly decreased in all salinity levels except in salinity 4 to 8 mmhos/cm.

Stem : There was constent increase in P content of stem due to different levels of salinity. But the decrease beyond 14 mmhos/cm was significant.

4.2.6.3.1.3 Potassium

Leaves : The K content of leaves decreased significantly with high magnitude in salinity from 8 to 20 mmhos/cm (Table 107).

Roots : The root K content was high in salinity at 4 mmhos/cm and control plant than other salinity levels. However, the differences were significant except in salinity 8 to 12 mmhos/cm.

Table 107: Effect of salinity on macronutrient content (percentage) of leaves, roots and stem of Karonda

Treatments	N	P	K	Ca	Mg	SS	Na
			Leaves				
Control	2.63	1.47	2.05	2.04	1.20	0.36	0.33
4 mmhos/cm	2.17	1.32	1.93	1.80	0.94	0.40	0.35
8 mmhos/cm	1.82	1.02	1.85	1.52	0.82	0.51	0.50
12 mmhos/cm	1.62	1.00	1.55	1.40	0.53	0.54	0.62
14 mmhos/cm	1.55	0.89	1.26	1.20	0.50	0.59	0.89
16 mmhos/cm	1.50	0.71	1.07	1.08	0.48	0.33	1.34
20 mmhos/cm	1.28	0.52	0.81	0.77	0.40	0.31	1.65
S.E. ±	0.052	0.028	0.043	0.043	0.031	0.031	0.046
C.D. at 5%	0.157	0.086	0.131	0.131	0.095	0.039	0.140
			Roots				
Control	2.77	1.18	1.78	1.84	1.27	0.30	0.40
4 mmhos/cm	2.62	1.08	1.70	1.80	1.13	0.41	0.45
8 mmhos/cm	2.32	1.05	1.58	1.60	0.89	0.51	0.46
12 mmhos/cm	1.97	0.93	1.57	1.52	0.72	0.72	0.47
14 mmhos/cm	1.74	0.79	1.50	1.28	0.49	0.61	0.50
16 mmhos/cm	1.48	0.63	1.43	0.92	0.41	0.30	0.61
20 mmhos/cm	1.04	0.48	1.28	0.58	0.19	0.18	0.64
S.E. ±	0.059	0.021	0.022	0.051	0.037	0.018	0.013
C.D. at 5%	0.180	0.065	0.066	0.156	0.111	0.055	0.039
			Stem				
Control	2.96	0.80	2.10	1.20	0.85	0.20	0.17
4 mmhos/cm	2.79	0.70	1.90	1.13	0.73	0.36	0.26
8 mmhos/cm	2.54	0.68	1.63	0.98	0.62	0.44	0.35
12 mmhos/cm	2.12	0.52	1.35	0.80	0.49	0.50	0.49
14 mmhos/cm	1.89	0.49	1.32	0.70	0.39	0.59	0.63
16 mmhos/cm	1.31	0.33	1.22	0.65	0.30	0.20	0.75
20 mmhos/cm	0.81	0.13	0.89	0.37	0.15	0.16	0.89
S.E. ±	0.072	0.026	0.048	0.036	0.021	0.025	0.017
C.D. at 5%	0.220	0.079	0.146	0.110	0.064	0.077	0.051

Stem : There was no any hard differences in salinity from 12 to 16 mmhos/cm. But at highest salinity level, the decrease in K content of stem was at a greater extent.

4.1.6.3.1.4 Calcium

Leaves : The Ca content of leaves was highly and significantly decreased in salinity from 14 mmhos/cm and above.

Roots : The Ca content of roots was pronounced and significantly decreased when salinity was raised from 12 to 20 mmhos/cm(Table 107).

Stem : The plants under control and salinity of 4 mmhos/cm and salinity from 12 to 16 mmhos/cm exhibited similar differences in Ca content of stem.

4.1.6.3.1.5 Mangnesium

Leaves : The Mg content of leaves was statistically similar under 12, 14 and 16 mmhos/cm as well as 16 to 20 mmhos/cm. The plants under 4 and 8 mmhos/cm and control recorded significantly higher Mg content in the leaves (Table 107).

Roots : The Mg content of roots was reduced significantly when salinity levels were increased upto 14 mmhos/cm. The decline was more pronounced at 20 mmhos/cm.

Stem : The Mg content of stem was decreased with every increase of salinity levels. The more striking depressive effect was noted under 20 mmhos/cm

4.1.6.3.1.6 Sulphur

Leaves : The data presented in Table 107 indicated that there was increase in S content of leaves with the salinity increased upto 14 mmhos/cm. Further increase in salinity levels from 16 to 20 mmhos/cm was statistically similar.

Roots : The trend of S content was increasing upto salinity level of 12 mmhos/cm with significant effect.

Stem : The sulphur content of stem only decreased significantly due to increasedlevels of salinity from 16 to 20 mmhos/cm. The increase was found upto 14 mmhos/cm.

4.2.6.3.1.7 Sodium

Leaves : The Na content of leaves was increased at every increase of salinity level (Table 107). Maximum Na content of leaves was recorded under 20 mmhos/cm which was also different from its two lower levels.

Roots : Though there was increase in Na content of root due to various levels of salinity, it was more or leds equal.

Stem : The Na content of stem was increased at every increased salinity level.

4.2.6.3.1.8 Ca : Na

Leaves : There was significant decrease in Ca : Na of leaves with every increase of salinity level. The control plant showed significantly high Ca : Na than all salinity levels.

Roots : Except control and 4 mmhos/cm and salinity of 8 to 12 mmhos/cm all other salinity levels affected significantly the Ca : Na ratio of roots.

Stem : With the increase in salinity upto 12 mmhos/cm the Ca : Na significantly decreased in roots. Low ratio was recorded under 20 mmhos/cm, which was similar to 16 mmhos/cm.

4.2.6.3.1.9 Ca + Mg + K : Na

Leaves : It is evident from the data (Table 108) that there was a progressive decrease in Ca + Mg + K : Na with the increase in salinity. Plant under 12 and 14 mmhos/cm showed only non significant decrease of ratio.

Roots : Except salinity level of 8 and 12 all other salinity levels showed significant decrease of ratio in roots.

Table 108: Effect of salinity on marconutrient ratios of Ca : Na, Ca + Mg + K : Na and micronutrient contents of leaves, roots and stem of Karonda

Treatments	Ca / Na	Ca+Mg+K / Na	Micronutrient in ppm			
			Zn	Fe	Mn	Cu
			Leaves			
Control	6.18	16.05	67.87	1728.59	417.01	118.58
4 mmhos/cm	5.01	13.00	57.77	1722.60	402.65	89.43
8 mmhos/cm	3.03	8.38	46.57	1688.34	368.90	65.48
12 mmhos/cm	2.32	3.78	41.39	1374.70	347.40	64.59
14 mmhos/cm	1.36	3.34	38.88	1212.43	327.40	26.55
16 mmhos/cm	0.84	2.07	37.52	1177.79	315.95	23.00
20 mmhos/cm	0.47	1.20	33.62	809.10	268.87	20.35
S.E. ±	0.095	0.244	1.220	46.551	5.993	3.906
C.D. at 5%	0.287	0.740	4.700	141.210	18.179	11.848
			Roots			
Control	4.61	12.23	50.18	1592.27	168.88	53.89
4 mmhos/cm	4.07	10.55	48.37	1546.16	161.98	49.16
8 mmhos/cm	3.48	8.72	42.05	1537.92	157.39	45.13
12 mmhos/cm	3.25	8.14	42.03	1422.64	155.42	38.95
14 mmhos/cm	2.56	6.58	39.81	1347.95	144.67	33.39
16 mmhos/cm	1.51	4.32	33.91	1105.32	134.41	29.21
20 mmhos/cm	0.91	3.20	31.07	893.37	130.73	9.89
S.E. ±	0.142	0.210	1.248	31.458	1.264	2.306
C.D. at 5%	0.431	0.637	3.785	95.427	3.835	6.994
			Stem			
Control	7.13	24.70	53.33	1233.64	153.25	66.90
4 mmhos/cm	4.35	14.49	50.42	1103.69	151.76	61.88
8 mmhos/cm	2.82	9.26	32.49	1063.86	121.36	52.15
12 mmhos/cm	1.65	5.45	29.10	803.75	97.09	48.40
14 mmhos/cm	1.11	3.81	28.44	798.35	72.65	34.30
16 mmhos/cm	0.86	2.89	12.39	541.41	69.56	21.33
20 mmhos/cm	0.22	1.59	13.48	401.47	32.33	8.60
S.E. ±	0.230	0.825	1.850	57.707	5.339	2.422
C.D. at 5%	0.699	2.503	5.613	175.051	16.196	7.348

Stem : Ca + Mg + K : Na content of roots in control was highest. This ratio was lower under salinity 20 mmhos/cm, which was similar to that under salinity 14 and 16 mmhos/cm.

4.2.6.3.2 Micronutrient content of leaves, roots and stem

4.2.6.3.2.1 Zinc

Leaves : The salinity upto 12 mmhos/cm showed significant decrease in Zn content of leaves (Table 108). Lowest Zn content of leaves under 20 mmhos/cm was observed and significant from that of salinity 16 mmhos/cm.

Roots : Zn content of roots decreased with increased salinity levels. Lowest Zn content of roots was noted under 20 mmhos/cm, which was similar to next lower salinity level (i.e. 16 mmhos/cm).

Stem : The salinity at 4 mmhos/cm and control plant showed maximum Zn content of stem but both were similar. Further increase in the level of salinity the Zn content of the stem decreased with a non significant effect.

4.2.6.3.2.2 Iron

Leaves : It was observed from the data in Table 108 that Zn content of leaves decreased with the increase in salinity. The most striking depressive effect was at

20 mmhos/cm, which was however, statistically significant from that of salinity 16 mmhos/cm.

Roots : The salinity levels of 16 and 20 mmhos/cm were significantly different from their earlier salinity levels.

Stem : The Fe content of stem was high in the control, 4 and 8 mmhos/cm salinity levels as compared to rest of the treatments. A more pronounced decrease was noticed when salinity was raised from 12 to 20 mmhos/cm.

4.2.6.3.2.3 Mangnese

Leaves : The Mn content of leaves was significantly low between salinity 8 and 12 mmhos/cm (Table 108).

Roots : The Mn content of roots was high in the control and 4 mmhos/cm level as compared to rest of the treatments. However, the problematic soil exhibited significant differences compared to its lower and higher salinity levels.

Stem : Mn content of stem significantly decreased with the increased salinity from 4 to 12 mmhos/cm. Lowest Mn content of stem was estimated under 20 mmhos/cm and was significantly differed to that of 16 mmhos/cm.

4.2.6.3.2.4 Copper

Leaves : The results in Table 108 indicated that the Cu content of leaves was most striking in salinity 4 mmhos/cm. Thereafter there was corresponding decrease with a small magnitude. Again at salinity of 14 mmhos/cm decline was larger as compared to its lower level.

Roots : The decrease in Cu content of root was slow upto 16 mmhos/cm of salinity but it was too severe decline at 20 mmhos/cm.

Stem : The salinity levels from 12 to 20 mmhos/cm resulted into high and significant reduction in Cu content of stem (Table 108). The Cu content estimated in salinity 20 mmhos/cm was too less compared to all other levels.

4.2.7 passion fruit

4.2.7.1 Effect on plant height

The periodic height observation of passion fruit plants expressed in per cent increase over the initial observation under different salinity levels are given in Table 109. The salinity level at 4 mmhos/cm and control were similar throughout the period except at 60, 120 and 300 days after planting. However, they showed significantly more plant height as compare to

other treatments. The adverse effect was recorded right from 60 days after planting when the salinity was raised to 20 mmhos/cm. The data further revealed that the effect of 4 and 8 mmhos/cm and 16 and 20 mmhos/cm were statistically and significantly different during the entire course of investigation.

4.2.7.2 Effect on number of leaves

The data in Table 109 further showed that the number of leaves was significantly reduced during the entire period of investigation when the salinity was raised to 20 mmhos/cm. The lower number of leaves were recorded under 20 mmhos/cm, which were similar to next lower salinity level (i.e. 16 mmhos/cm at 60 days after planting. The salinity levels 8 and 12 mmhos/cm were statistically similar during all growth stages except 360 days after planting, but they were superior to 16 and 20 mmhos/cm.

4.2.7.3 Effect on stem diameter

On perusal of the data in Table 109, it was seen that with the increase in every salinity level except 16 mmhos/cm at 180 days after planting, there was consistent and significant fall in stem diameter during the entire course of investigation.

Table 109: Effect of salinity on percentage increase in plant height, number of leaves and stem diameter of Passion fruit

Treatments	Days after planting					
	60	120	180	240	300	360
			Plant height			
Control	122.50	247.50	438.46	474.00	697.44	751.40
4 mmhos/cm	122.10	242.82	401.93	531.17	631.16	673.16
8 mmhos/cm	113.64	212.20	340.90	425.00	533.33	545.75
12 mmhos/cm	109.42	213.95	302.95	393.24	485.37	506.43
14 mmhos/cm	98.12	209.76	295.37	370.02	-	-
16 mmhos/cm	88.88	202.63	275.10	355.26	-	-
20 mmhos/cm	75.18	182.50	248.84	-	-	-
S.E. ±	1.809	2.639	7.504	10.242	21.529	9.773
C.D. at 5%	5.488	8.006	22.782	31.561	70.209	31.872
			Number of leaves			
Control	83.35	147.05	300.00	547.06	890.59	1047.06
4 mmhos/cm	81.25	125.50	225.81	460.37	775.18	898.75
8 mmhos/cm	60.18	88.24	152.44	323.53	470.88	575.48
12 mmhos/cm	58.82	86.87	133.33	273.32	423.33	446.67
14 mmhos/cm	37.50	68.75	93.75	150.93	-	-
16 mmhos/cm	23.53	62.50	70.57	118.75	-	-
20 mmhos/cm	16.67	27.87	44.44	-	-	-
S.E. ±	2.513	4.952	8.830	16.668	34.311	36.475
C.D. at 5%	7.624	15.020	26.772	51.363	111.894	118.949
			Stem diameter			
Control	45.83	99.49	193.33	280.55	347.00	373.15
4 mmhos/cm	42.10	90.72	180.10	257.18	304.49	320.78
8 mmhos/cm	38.92	80.33	140.44	200.59	235.45	247.40
12 mmhos/cm	35.33	60.14	100.33	140.14	160.95	167.49
14 mmhos/cm	29.51	50.30	83.33	120.34	-	-
16 mmhos/cm	23.80	40.83	60.67	78.60	-	-
20 mmhos/cm	20.22	33.32	55.95	-	-	-
S.E. ±	0.826	2.383	4.323	5.520	12.180	9.629
C.D. at 5%	2.507	7.228	13.114	17.009	42.003	31.403

The salinity levels 14 and 16 mmhos/cm showed more growth depression and they were significantly different from each other during various growth stages. Most striking effect was started at 240 days after planting in salinity level 16 mmhos/cm. The plants after 240 days could not survive.

4.2.7.4 Effect on plant spread

Table 110 showed that the plant spread decreased significantly due to the salinity levels increased from 12 to 20 mmhos/cm. There was no difference in the plant spread under 4 and 8 mmhos/cm as well as 8 and 12 mmhos/cm.

Table 110: Effect of salinity on plant spread, total leaf area per plant and mortality of passion fruit

Treatments	Plant spread (cm)	Total leaf area (sq.cm.)	Mortality (per cent)
Control	31.10	10669.42	00.00 (00.57)
4mmhos/cm	26.50	10654.54	00.00 (00.57)
8 mmhos/cm	24.37	10590.53	50.66 (45.57)
12 mmhos/cm	23.50	7069.53	78.66 (62.72)
14 mmhos/cm	21.00	4411.01	100.00 (90.00)
16 mmhos/cm	18.20	2200.67	100.00 (90.00)
20 mmhos/cm	15.00	1505[illegible].52	100.00 (90.00)
S.E. ±	0.735	391.430	- 1.047
C.D. at 5%	2.228	1187.56	- 3.176

The figures in parenthese indicate trnasformed percentage value in to arcsine value.

4.2.7.5 Effect on leaf area

The data regarding total leaf area per plant under various salinity levels given in Table 110, indicated that most striking depressive effect was noted from 12 mmhos/cm. However, the total leaf area per plant was statistically similar in salinity upto 8 mmhos/cm.

4.2.7.6 Effect on plant mortality

The data on plant mortality as influenced by various salinity levels is presented in Table 110. and graphically in Fig. 6. The plant under 4 mmhos/cm level of salinity did not show any kind of mortality. The mortality symptoms were started from 8 mmhos/cm and onward and 100 per cent mortality was recorded in 14, 16 and 20 mmhos/cm. The mortality symptoms were noted under 20 mmhos/cm level from 120 days after planting and plant death was occured at 240 days after planting. The salinity levels from 14 to 20 mmhos/cm showed yellowing of old leaves, severe defoliatio and then drying of tender shoot tip.

4.2.7.7 Effect on root length

It is obvious from data in Table 111, the depressive effect of salinity was noticed from 16 mmhos/cm and the root length reduction was greater at 20 mmhos/cm.



Photo plate No. 45 : Effect of various salinity levels as seen by the yellowing of leaves 270 days after planting.

4.2.7.8 Effect on root volume

There was significant decrease in root volume upto the salinity level of 14 mmhos/cm. But the root volume in higher salinity levels like 14, 16 and 20 mmhos/cm did not differ from each other statistically.

Table 111: Effect of salinity on root length, root volume, number of primary root, number of secondary root and total number of root of passion fruit

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secondary roots	Total number of roots
Control	20.00	21.00	10.00	53.30	62.30
4 mmhos/cm	18.50	17.50	7.33	29.00	36.33
8 mmhos/cm	17.67	13.50	5.50	22.00	27.50
12 mmhos/cm	15.33	10.10	4.10	15.07	19.17
14 mmhos/cm	14.10	8.00	4.00	10.00	14.00
16 mmhos/cm	13.00	6.50	3.33	8.10	11.43
20 mmhos/cm	10.33	6.20	3.00	8.66	11.66
S.E. ±	0.843	0.600	0.820	1.433	3.010
C.D. at 5%	2.557	1.818	2.484	4.341	9.120

4.2.7.9 Effect on number of primary roots

The initial salinity level itself showed high reduction in number of primary roots, however, the effect of increased salinity levels beyond this limit were not so different from each other (Table 111).

4.2.7.10 Effect on number of secondary roots

Though there was highly significant depression effect on secondary roots in the first four lower levels, the higher salinity levels like 14, 16 and 20 mmhos/cm significantly similar from each other.

4.2.7.11 Effect on total number of roots

The control plants recorded maximum total number of root as compare to rest of the treatments (Table 111). The total roots were severely reduced at very first level of salinity. However, the higher levels were not so effective.

4.2.7.12 Effect on fresh weight of whole plant

The data regarding fresh weight of whole plant given in Table 112, revealed significantly low fresh weight of whole plant at 16 mmhos/cm and above. But more pronounced effect was observed at salinity of 12 mmhos/cm

4.2.7.13 Effect on fresh weight of root

There were mostly non significantly decreases in fresh weight of root as influenced by various salinity levels.

4.2.7.14 Effect on fresh weight of top

The salinity 16 and 20 mmhos/cm resulted into the significant decrease in fresh weight of top as compared to rest of salinity levels (Table 112).

Table 112: Effect of salinity on fresh and dry weight of whole plant, root and top of passion fruit

Treatments	Fresh weight of whole plant	Fresh weight of root	Fresh weight of top	Dry weight of whole plant	Dry weight of root	Dry weight of top
Control	114.00	18.50	95.50	48.83	8.72	40.11
4 mmhos/cm	108.50	17.00	91.50	46.88	7.20	39.68
8 mmhos/cm	105.53	14.10	91.43	40.85	5.55	35.30
12 mmhos/cm	85.34	11.67	73.67	39.30	5.30	34.00
14 mmhos/cm	80.83	10.83	70.00	34.59	4.00	30.59
16 mmhos/cm	52.30	7.83	44.47	30.57	4.30	26.27
20 mmhos/cm	42.54	5.67	37.87	28.00	3.50	24.50
S.E. ±	1.950	1.024	1.733	0.664	0.330	0.560
C.D. at 5%	5.947	3.105	5.257	2.013	0.991	1.697

4.2.7.15 Effect on dry weight of whole plant

The dry weight of whole plant was steadly but significantly decreased at every increased salinity level as indicated in Table 112 and Fig. 10.



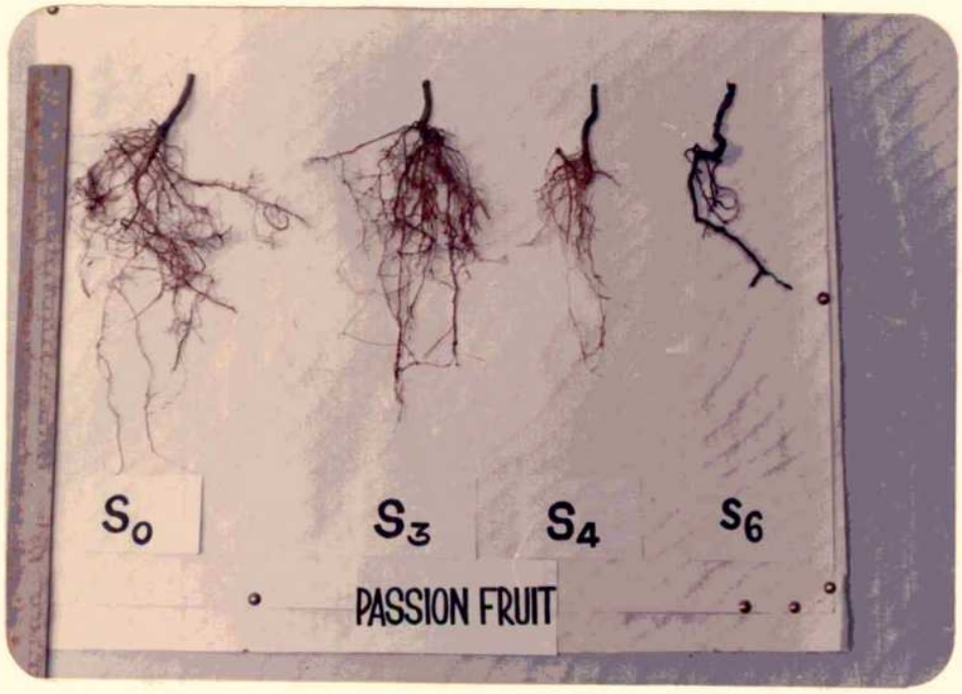


Photo plate No. 46 : Effect of salinity levels on shoot and root growth 240 days after planting

4.2.7.16 Effect on dry weight of root

There was decrease in dry weight of root with the corresponding increased salinity levels but differences were more or less equal from each other (Table 112).

4.2.7.17 Effect on dry weight of top

It is obvious from the data in Table 112 that significantly depressive effect of salinity was started from 12 mmhos/cm. The decrease was more pronounced under salinity 20 mmhos/cm as compared to control plants.

4.2.7.2 Physiological parameters

4.2.7.2.1 Effect of salinity on chlorophyll content of leaves

The data in Table 113 indicated that chlorophyll 'a', 'b' and total decreased but non significantly in salinity levels of 16 and 20 mmhos/cm. The initial salinity level was found differing from control and its next higher salinity level in respect of chlorophyll content.

4.2.7.2.2 Effect on number of stomata

The data on number of stomata in Table 113 and Fig. 8 indicated that there was a increasing trend

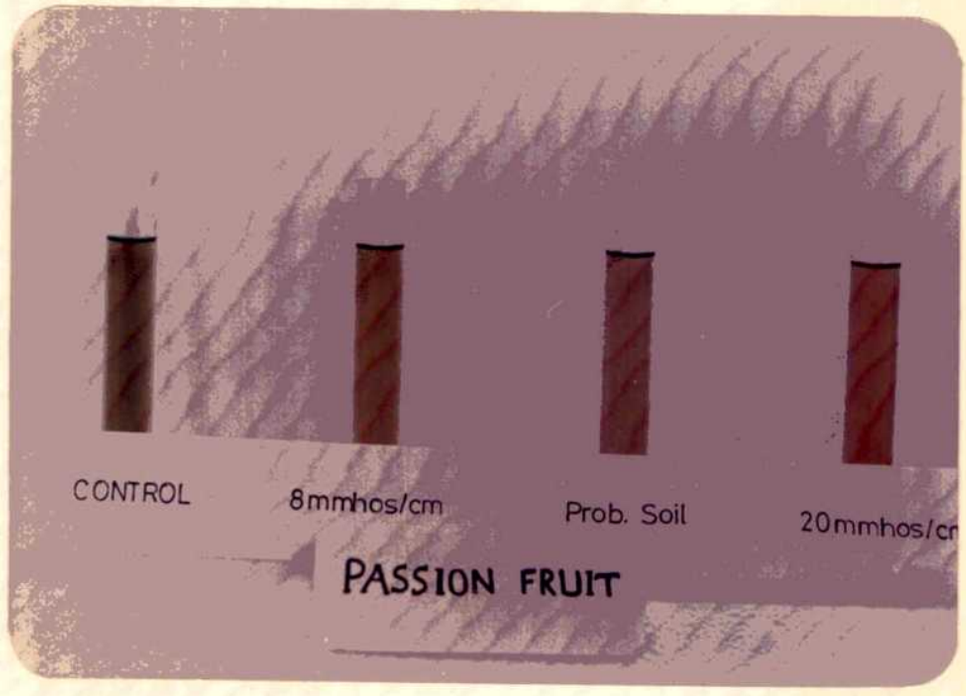


Photo plate No. 47 : Effect of salinity levels showing gradual change in chlorophyll content in Passion fruit

of stomata with increasedsalinity. But differences were at par upto the salinity level of 12 mmhos/cm. In highest level of salinity, the stomata number was near about three times more as compare to control.

Table 113: Effect of salinity on chlorophyll content of leaves, number of stomata per unit area and rate of trnaspiration of passion fruit

Treatments	Chlorophyll			Number of stomata (40 x)	Rate of trnaspiration $gH_2O/cm^2/hr$
	'a'	'b'	Total		
	mg/g				
		Leaves			
Control	0.751	1.0907	1.8417	11.67	0.0264
4 mmhos/cm	0.617	0.8680	1.4850	14.00	0.0257
8 mmhos/cm	0.436	0.6050	1.0417	15.33	0.0242
12 mmhos/cm	0.395	0.5110	0.09060	15.33	0.0232
14 mmhos/cm	0.360	0.4080	0.7740	22.66	0.0222
16 mmhos/cm	0.251	0.2697	0.5240	27.33	0.0213
20 mmhos/cm	0.234	0.2413	0.4760	35.00	0.0199
S.E. ±	0.016	0.029	0.043	1.464	0.0003
C.D. at 5%	0.048	0.089	0.130	4.441	0.0011

4.2.7.2.3 Effect on rate of trnaspiration

The results on rate of trnaspiration as incluenced by various salinity levels presented in Table 113 and shown in Fig. 8 indicated a decreased trend of rate of trnaspiration with the increased salinity levels but mostly with non significant effect with each other.

4.2.7.3 Effect of salinity on chemical composition

The data on chemical composition of leaves, roots and stem of passion fruit as affected by various salinity levels are presented in Table 114 and 115.

4.2.7.3.1 Macronutrient content of leaves, roots and stem

4.2.7.3.1.1 Nitrogen

Leaves : The N content of leaves was significantly decreased due to salinity levelsat 4, 12 and 16 mmhos/cm compared to their immediate next lower salinity levels (Table 114).

Roots : The N content of the roots was decreased due to different salinity levels. However the decrease was statistically non significant due to salinity at 4 and 14 mmhos/cm compare to their earlier treatment. Beyond the salinity level of 14 mmhos/cm, the N content of the roots was significantly decreased.

Stem : There was decreasing trend of N content of stem with increasing salinity levels. But the salinity at 12 mmhos/cm was found statistically similar to its immediate lower and higher level of salinity in effect.

Table 114: Effect of salinity on macronutrient (percentage) of leaves, roots and stem of Passion fruit

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	3.89	1.28	0.98	1.48	1.08	0.42	0.59
4 mmhos/cm	3.73	1.24	0.90	1.35	0.98	0.74	0.62
8 mmhos/cm	3.43	1.12	0.81	1.16	0.72	0.90	0.94
12 mmhos/cm	2.98	0.82	0.65	0.87	0.50	0.80	1.32
14 mmhos/cm	2.77	0.55	0.60	0.81	0.34	0.79	1.54
16 mmhos/cm	2.43	0.30	0.48	0.40	0.29	0.53	1.73
20 mmhos/cm	1.98	0.13	0.19	0.28	0.13	0.28	1.89
S.E. ±	0.072	0.026	0.031	0.033	0.029	0.047	0.051
C.D. at 5%	0.219	0.070	0.096	0.101	0.074	0.142	0.154
			Roots				
Control	2.50	0.55	0.63	1.40	0.94	0.27	0.28
4 mmhos/cm	2.29	0.48	0.55	1.18	0.86	0.34	0.52
8 mmhos/cm	1.98	0.35	0.53	0.92	0.70	0.49	0.54
12 mmhos/cm	1.65	0.35	0.42	0.88	0.67	0.37	0.60
14 mmhos/cm	1.54	0.30	0.33	0.64	0.43	0.32	0.60
16 mmhos/cm	1.26	0.28	0.25	0.58	0.36	0.20	0.61
20 mmhos/cm	0.99	0.15	0.12	0.39	0.28	0.13	0.74
S.E. ±	0.084	0.015	0.013	0.066	0.022	0.014	0.021
C.D. at 5%	0.254	0.044	0.041	0.200	0.066	0.042	0.065
			Stem				
Control	2.70	0.80	0.54	2.00	1.06	0.37	0.25
4 mmhos/cm	2.46	0.76	0.50	1.72	0.79	0.49	0.32
8 mmhos/cm	2.21	0.62	0.38	1.56	0.61	0.57	0.67
12 mmhos/cm	2.04	0.55	0.30	1.16	0.48	0.46	0.98
14 mmhos/cm	2.88	0.39	0.25	0.94	0.48	0.37	1.25
16 mmhos/cm	1.43	0.30	0.23	0.76	0.29	0.30	1.35
20 mmhos/cm	1.21	0.14	0.11	0.35	0.15	0.18	1.48
S.E. ±	0.048	0.018	0.013	0.056	0.026	0.015	0.042
C.D. at 5%	0.144	0.055	0.040	0.171	0.080	0.046	0.129

4.2.7.3.3.2 Phosphorus

Leaves : The P content of the leaves decreased at every incremental level of salinity (Table 114). But the decrease of P content was statistically significant when the salinity level was raised from 8 to 20 mmhos/cm.

Roots : The salinity levels also resulted into decrease of P content of roots. However, salinity levels between 8 and 12 mmhos/cm and 14 and 16 mmhos/cm behaved similarly.

Stem : The significant decrease in P content of the stem was noticed right from low level of salinity (4 mmhos/cm) to higher level of salinity (20 mmhos/cm).

4.2.7.3.3.3 Potassium

Leaves : In the absence of salinity levels and when it was raised upto 14 mmhos/cm there was decrease in K content of the leaves, it was statistically non significant. But after salinity level of 14 mmhos/cm and upto 20 mmhos/cm, there was significant decrease in K content of the leaves (Table 114).

Roots : The K content of the roots decreased but non significantly due to salinity levels between 4 to 8 mmhos/cm. The higher levels of salinity (i.e. from 12 to 20 mmhos/cm) showed significant decrease in K content of the roots.

Stem : The K content of the stem was also decreased due to various salinity levels, but the no salinity and salinity level of 4 mmhos/cm and salinity levels of 14 and 16 mmhos/cm behaved equally in K content of the stem.

4.2.7.3.3.4 Calcium

Leaves : Except salinity levels between 12 and 14 mmhos/cm, the Ca content of the leaves was decreased significantly (Table 114). The lowest Ca content of the leaves was observed at salinity level of 20 mmhos/cm.

Roots : The salinity levels upto 8 mmhos/cm affected into significant decrease of Ca content of the roots. Similarly when the salinity was raised to 14 mmhos/cm (problematic soil), the decrease was also statistically significant compare to its next lower salinity level.

Stem : The entire levels of salinity as compare to control showed significant decrease of Ca content of the stem.

4.2.7.3.3.5 Magnesium

Leaves : In salinity levels of 14 and 16 mmhos/cm, the Mg content of the leaves was non significant. But the lower and higher levels of salinity other than the above showed significant decrease of Mg content of the leaves (Table 114).

Roots : At the same time the Mg content of the root was non significant. The decrease of the Mg content of the root was not significant between salinity levels 8 and 12 mmhos/cm. From problematic soil to highest level of salinity, there was severe decrease in Mg content of the roots.

Stem : The Mg content of the stem also showed non significant decrease due to salinity levels of 12 to 14 mmhos/cm. Rest of the salinity levels resulted into significant decrease of Mg content of the stem.

4.2.7.3.3.6 Sulphur

Leaves : The trend of S content of the leaves affected by salinity levels was reverse as compare to other macronutrient content i.e. there was increase in S content of the leaves upto 8 mmhos/cm. The lowest S content was noticed at highest level of salinity.

Roots : The results of S content of the roots were changed due to salinity levels. Upto the salinity levels of 8 mmhos/cm, there was significant increase in S content of the roots. But after the salinity level of 12 to 20 mmhos/cm, the S content of the roots was decreased significantly.

Stem : The trend of S content of the stem due to different salinity level was as similar to that of roots.

4.2.7.3.3.7 Sodium

Leaves : The Na content of the leaves due to salinity levels from 4 to 20 mmhos/cm was increased significantly. The increase was appriciably high at highest level of salinity as compare to control. Actually from no salinity to salinity at 4 mmhos/cm, the results were similar (Table 114).

Roots : The differences of Na content of the roots due to salinity levels from 4 to 16 mmhos/cm were statistically at par to each other even though there was increase in Na content of the roots.

Stem : The result of Na content of the stem in control and salinity level of 4 mmhos/cm and salinity levels between 14 and 16 mmhos/cm showed were similar. The rest of the salinity levels showed significant increase in Na content of the stem.

4.2.7.3.3.8 Ca : Na

Leaves : There was consistant decrease in Ca : Na ratio due to every incremental level of salinity. However the decrease observed was significant between salinity level 8 to 12 and 14 to 16 mmhos/cm (Table 115).

Roots : The Ca : Na content of the roots was suddenly decreased due to salinity level of 4 mmhos/cm from control.

but after the salinity level from 4 to 20 though there was decrease in Ca : Na content of the roots. It was statistically non significant from each other.

Stem : Similarly tremendous decrease was observed in Ca : Na content of stem when salinity levels were raised upto 12 mmhos/cm. There after due to salinity levels the decrease was there, but it was within the statisticaly limit.

4.2.7.3.3.9 Ca + Mg + K : Na

Leaves : The Ca + Mg + K : Na ratio decreased significantly due to every increase in salinity levels. But it was worth to say that the decrease of Ca + Mg + K : Na ratio of the leaves was abberuptly reduced when the salinity level was shifted from 4 to 8 mmhos/cm (Table 115).

Roots : The Ca + Mg + K : Na ratio of the roots was reduced due to every additional level of salinity. But it was interesting to note here that a initial level of salinity showed higher decrease of Ca + Mg + K : Na of roots as compare to control.

Stem : Most stiking effect of salinity of Ca + Mg + K : Na of stem was observed due to incremental levels of salinity. Upto 12 mmhos/cm there was drastick reduction in Ca + Mg + K : Na content of the stem at 4 mmhos/cm.

Table 115: Effect of salinity on macronutrient ratios of Ca : Na, Ca + Mg + K : Na and micronutrient contents of leaves, roots and stem of passion fruit.

Treatments	Ca / Na	Ca+Mg+K / Na	Micronutrient in ppm			
			Zn	Fe	Mn	Cu
			Leaves			
Control	2.55	6.11	65.10	898.95	125.22	78.10
4 mmhos/cm	2.22	5.32	58.88	818.09	113.10	71.13
8 mmhos/cm	1.28	2.99	45.20	711.43	85.37	49.38
12 mmhos/cm	0.58	1.53	40.24	598.35	59.92	35.10
14 mmhos/cm	0.52	1.10	37.07	439.30	27.32	34.39
16 mmhos/cm	0.23	0.68	20.76	401.38	23.97	22.12
20 mmhos/cm	0.15	0.31	11.30	259.38	18.62	18.57
S.E. ±	0.090	0.209	2.184	22.813	4.763	2.978
C.D. at 5%	0.272	0.633	6.624	69.411	14.448	9.034
			Roots			
Control	5.43	11.16	95.36	1777.62	148.20	56.63
4 mmhos/cm	2.26	4.72	90.83	1754.57	143.60	51.32
8 mmhos/cm	1.70	3.98	69.30	1720.45	137.61	49.55
12 mmhos/cm	1.46	3.30	58.64	1674.35	120.62	44.25
14 mmhos/cm	1.06	2.33	50.11	1361.79	92.83	36.28
16 mmhos/cm	0.94	1.94	35.45	1230.85	70.08	30.15
20 mmhos/cm	0.39	0.92	19.75	1124.51	30.44	11.50
S.E. ±	0.288	0.648	3.215	27.295	5.117	3.717
C.D. at 5%	0.873	1.965	9.751	82.797	15.522	11.276
			Stem			
Control	8.10	14.56	70.81	1595.03	203.91	65.30
4 mmhos/cm	4.18	9.76	65.35	1435.13	198.34	58.18
8 mmhos/cm	2.34	4.83	53.82	1393.83	173.21	49.25
12 mmhos/cm	1.18	1.99	41.21	1195.10	152.10	35.91
14 mmhos/cm	0.75	1.34	36.43	1050.03	121.73	28.85
16 mmhos/cm	0.56	0.95	30.10	892.55	88.32	27.33
20 mmhos/cm	0.24	0.40	14.33	632.32	50.16	15.18
S.E. ±	0.263	0.586	2.173	42.312	4.948	1.949
C.D. at 5%	0.797	1.777	6.592	128.353	15.010	5.912

4.2.7.3.2 Micronutrients content of leaves, roots and stem

4.2.7.3.2.1 Zinc

Leaves : The Zn content of the leaves (Table 115) was decreased because of additional levels of salinity. But the salinity effects between 4 to 8 mmhos/cm and after 14 mmhos/cm were statistically significant.

Roots : Actually the initial level of salinity (i.e. 4 mmhos/cm) and control and salinity levels of 12 and 14 mmhos/cm did not differ statistically in Zn content of the roots. But appreciably least Zn content of the roots was observed at salinity level of 20 mmhos/cm.

Stem : The salinity levels from 12 to 16 mmhos/cm were statistically similar in decrease of Zn content of the stem. All other salinity levels recorded significant decreases in Zn content of the stem.

4.2.7.3.2.2 Iron

Leaves : The Fe content of the leaves declined in a tremendous way due to raising of salinity level from 4 to 20 mmhos/cm, except salinity levels of 14 to 16 mmhos/cm (Table 115).

Roots : Usually the raising of salinity upto 12 mmhos/cm from control the decrease of Fe content of the root was

non significant. But after problematic soil the decrease was significant.

Stem : The raising of salinity levels from 4 to 8 mmhos/cm though showed significant decrease of iron content of stem as compare to control, they were at par to each other. But higher levels of salinity from 12 to 20 mmhos/cm were seen to be affecting significant decrease in Fe content of the stem.

4.2.7.3.2.3 Manganese

Leaves : Statistically there was no hardly any difference between control and salinity level 4 mmhos/cm and salinity levels from 14 to 20 mmhos/cm, even though there was gradual decrease in Mn content of the leaves (Table 115).

Roots : Similarly, the control, salinity levels 4 and 8 mmhos/cm behaved similarly in decrease of Mn content of the roots. But the raising of salinity from 8 to 20 mmhos/cm, the Mn content of the roots was significantly reduced.

Stem : Except control and initial level of salinity, all other salinity levels showed significant decrease in Mn content of stem. More pronounced decrease was observed after salinity of 14 mmhos/cm.

4.2.7.3.2.4 Copper

Leaves : Statistically non significant decrease was observed in control and salinity 4 mmhos/cm, salinity 12 and 14 mmhos/cm and salinity at 16 to 20 mmhos/cm in Ca content of the leaves (Table 115).

Roots : There was decrease in Cu content of the roots but non significantly due to the raising of salinity upto 8 mmhos/cm. Similarly due to salinity levels from 12 to 16 mmhos/cm showed non significant decrease from each other in Cu content.

Stem : Except salinity levels between 14 to 16 mmhos/cm all other levels showed significant decrease in Cu content of the stem.

4.2.8 Drumstick

4.2.8.1 Effect on plant height

Periodic observation on height of drumstick plant expressed in the per cent increase over the initial observation under various salinity levels are presented in Table 116. The depressive effect due to salinity was seen at 240 and 300 days in 4 mmhos/cm salinity level. Although plants in all treatments survived till 240 days after planting the plant under salinity 20 mmhos/cm were died at 300 days after planting. There were significant

Table 116: Effect of salinity on percentage increase in plant height, number of leaves and stem diameter of Drumstick

Treatments	Days after planting					
	60	120	180	240	300	360
			Plant height			
Control	30.97	82.76	210.00	436.62	762.58	809.15
4 mmhos/cm	30.10	81.48	192.10	384.44	601.12	783.87
8 mmhos/cm	25.00	55.58	155.56	343.40	585.26	639.23
12 mmhos/cm	20.88	36.09	154.55	327.35	536.84	583.511
14 mmhos/cm	20.68	30.47	143.33	280.58	455.44	536.86
16 mmhos/cm	15.63	26.41	107.89	208.53	323.90	-
20 mmhos/cm	13.98	22.84	71.88	129.74	-	-
S.E. ±	1.024	2.656	6.221	14.110	18.716	14.229
C.D. at 5%	3.107	8.058	18.870	42.802	57.675	44.832
			Number of leaves			
Control	87.50	187.50	330.89	487.50	650.71	720.71
4 mmhos/cm	75.89	157.07	328.57	485.71	614.23	675.50
8 mmhos/cm	75.33	125.57	285.17	381.50	543.51	590.24
12 mmhos/cm	55.66	91.83	212.50	325.89	487.50	517.50
14 mmhos/cm	42.50	88.89	187.50	303.90	350.57	377.37
16 mmhos/cm	28.57	71.43	150.00	271.49	288.18	-
20 mmhos/cm	12.50	50.50	83.83	150.70	-	-
SE ±	2.727	4.804	8.590	14.583	16.839	17.368
C.D. at 5%	8.273	14.574	26.058	44.237	53.890	54.694
			Stem diameter			
Control	44.44	100.35	177.81	230.33	310.33	344.45
4 mmhos/cm	33.33	80.55	155.66	202.22	266.65	289.33
8 mmhos/cm	28.50	72.56	144.44	191.11	255.44	277.78
12 mmhos/cm	22.22	55.56	110.50	158.89	233.33	250.56
14 mmhos/cm	20.05	50.53	103.53	147.79	200.34	214.24
16 mmhos/cm	20.00	40.43	88.89	113.33	144.44	-
20 mmhos/cm	18.38	38.35	60.65	91.11	-	-
S.E. ±	1.124	2.176	3.888	4.451	7.023	4.994
C.D. at 5%	3.499	6.600	11.799	13.503	21.641	15.736

differences between salinity 12 to 14 mmhos/cm (problematic soil) were noted only from trnasplanting of 240 days onwards. Salinity level 20 mmhos/cm showed severest depressive effect from 180 days after planting.

4.2.8.2 Effect on number of leaves

The data presented in Table 116 indicated that there was no hardly any difference in number of leaves between the control and salinity at 4 mmhos/cm from 180 days onwards. Adverse effect was recorded right from 120 days after the planting when the salinity was raised to 8 mmhos/cm. Plants under 16 mmhos/cm were survived upto about 10 months. The data further revealed that the effects of 16 to 20 mmhos/cm was significantly different from each other during the entire course of investigation.

4.2.8.3 Effect on stem diameter

The results in Table 116 showed that the stem diameter decreased when the salinity was increased artificially during the entire course of the investigation. The data further revealed that the stem diameter under 4 and 8 mmhos/cm were similar at 180 days after planting and above. Lowest stem diameter was recorded in

the highest salinity level (i.e. 20 mmhos/cm) which was significantly different in 180 and above days after planting.

4.2.8.4 Effect on plant spread

The effect of salinity on plant spread is given in Table 117. The control plants exhibited largest plant spread followed by salinity 4 and 8 mmhos/cm. There was hardly any difference between the effect of problematic soil (14 mmhos/cm) and salinity 16 mmhos/cm. The lower plant spread was recorded under 20 mmhos/cm which was however significantly different from that of 16 mmhos/cm.

Table 117: Effect of salinity on plant spread, total leaf area per plant and mortality of Drumstick

Treatments	Plant spread (cm)	Total leaf area (sq.cm.)	Mortality (per cent)
Control	53.20	6041.11	00.00 (00.57)
4 mmhos/cm	46.55	5627.94	00.00 (00.57)
8 mmhos/cm	38.00	4944.86	00.00 (00.57)
12 mmhos/cm	30.17	3131.61	35.66 (36.87)
14 mmhos/cm	25.17	2743.00	85.33 (67.45)
16 mmhos/cm	23.20	2250.71	100.00 (90.00)
20 mmhos/cm	19.17	1606.53	100.00 (90.00)
S.E. ±	0.737	52.555	- 1.930
C.D. at 5%	2.417	139.427	- 5.850

The figures in parenthese indicate trnasformed percentage value in to arcsine value.

4.2.8.5 Effect on leaf area

The depressive effect of salinity on total leaf area was seen right from the salinity 4 mmhos/cm, which continued upto 20 mmhos/cm. The most striking depressive effect was recorded under 12 mmhos/cm.

4.2.8.6 Effect on plant mortality

The data regarding plant mortality has been given in Table 117 and graphically represented in Fig. 6, which indicated that no mortality was observed upto 8 mmhos/cm. Mortality was noticed under 12 mmhos/cm and 100 per cent mortality was recorded under 16 to 20 mmhos/cm.

Salinity 20 mmhos/cm started showing the mortality symptoms right from 180 days after planting. While the mortality symptom was recorded under 16 mmhos/cm was started from 210 days after planting, and it was completely dried when it attained 360 days of age. However, in case of the 20 mmhos/cm, plant death occured at 300 days after planting. The both salinity levels showed yellowing effect of leaf and sever defoliation of leaves.

4.2.8.7 Effect on root length

The data pertaining to the root length under various salinity level is presented in Table 118.

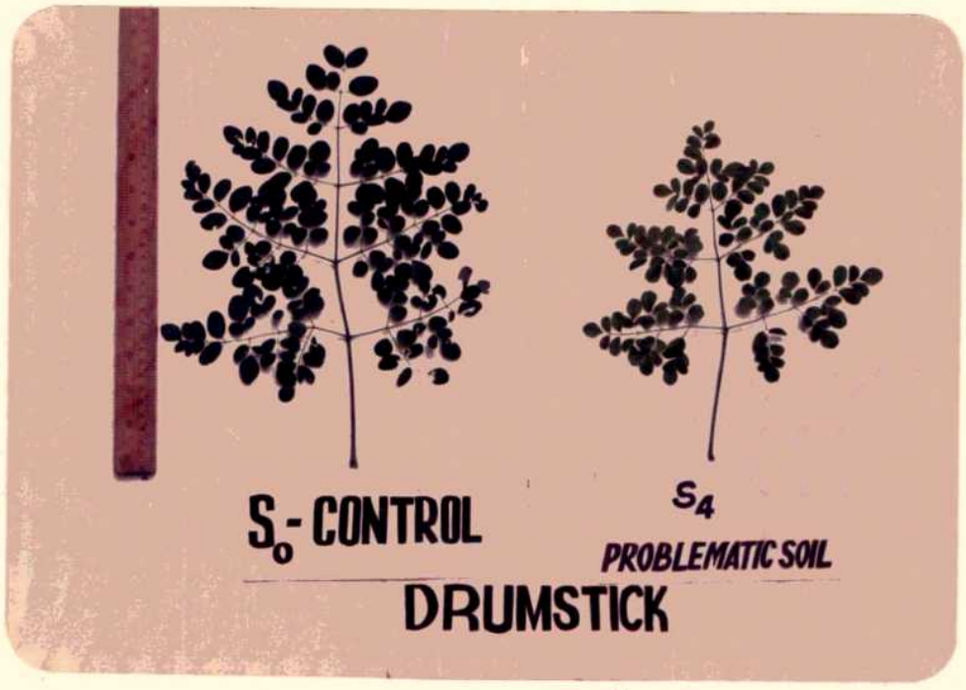


Photo plate No. 48 : Salinity effect causing yellowing and reduced leaf area as observed under problematic soil 270 days after planting

There was decrease in root length with the increase in salinity but not consistant. Minimum root length was recorded under 20 mmhos/cm, which was statistically not different from 16 mmhos/cm.

Table 118 : Effect of salinity on root length, root volume, number of primary root, number of secondary root and total number of root of Drumstick

Treatments	Root length (cm)	Root volume (ml)	Number of primary roots	Number of secon-dary roots	Total number of roots	Roots dia-meter (mm)
Control	20.20	40.50	8.55	10.00	18.55	12.50
4 mmhos/cm	19.00	37.10	7.00	8.20	15.20	12.00
8 mmhos/cm	17.33	32.10	4.00	5.50	9.50	9.60
12 mmhos/cm	16.50	30.50	3.33	4.20	7.53	9.30
14 mmhos/cm	16.70	22.20	3.00	4.00	7.00	7.00
16 mmhos/cm	14.00	13.50	2.10	3.10	5.20	5.50
20 mmhos/cm	13.50	12.00	2210	2.00	3.10	4.00
S.E. ±	0.911	1.091	0.173	0.810	0.624	0.748
C.D. at 5%	2.763	3.310	0.524	2.454	1.890	2.269

4.2.8.8 Effect on root volume

The data in Table 118 showed that there was no difference in root volume in treatments 12 and 14 mmhos/cm as well as 16 and 20 mmhos/cm. The maximum root volume was recorded under controlled plant followed by that of salinity 4 mmhos/cm.

4.2.8.9 Effect on number of primary roots

The number of primary roots decreased with the increased salinity levels in general (Table 118). The salinity levels 12 adn 14 and 14 and16 mmhos/cm were similar and showed more number of primary roots as compare to higher levels of salinity (i.e. 16 and 20 mmhos/cm).

4.2.8.10 Effect on number of secondary roots

The data in Table 118 showed that the significant reduction in secondary roots was recorded in the case of the salinity at 8 mmhos/cm compared to 4 mmhos/cm. Minimum number of secondary roots were recorded at salinity level 20 mmhos/cm.

4.2.8.11 Effect on total number of roots

The total number of roots decreased with the every increase in salinity levels except 12 to 14 mmhos/cm (Table 118). The highest level of salinity was recorded 6 time less total number of roots as compare to control plants.

4.2.8.11a Effect on root diameter

The data presented in Table 118 showed that the root diameter decreased markedly when the salinity was increased to 8 mmhos/cm.

4.2.8.12 Effect on fresh weight of whole plant

The data presented in Table 119 indicated that the fresh weight of whole plant was decreased significantly with increase in salinity upto 8 mmhos/cm. A sharp drop in the fresh weight of whole plant was observed from 8 mmhos/cm which was different from 12 mmhos/cm. Significant and lower fresh weight of whole plant was recorded at 16 and 20 mmhos/cm compared to problematic soil.

Table 119 : Effect of salinity on fresh weight and dry weight of whole plant, root and top of Drumstick

Treatments	Fresh weight of whole plant	Fresh weight of root	Fresh weight of top	Dry weight of whole plant	Dry weight of root	Dry weight of top
Control	110.76	37.66	73.10	27.82	10.55	17.27
4 mmhos/cm	106.00	36.00	70.00	27.46	10.26	17.50
8 mmhos/cm	70.76	24.66	46.10	19.49	7.40	12.51
12 mmhos/cm	47.17	16.00	31.17	17.61	6.70	10.91
14 mmhos/cm	41.50	15.00	26.50	16.24	6.70	9.54
16 mmhos/cm	27.70	11.20	16.50	14.92	5.72	9.20
20 mmhos/cm	19.81	7.66	12.15	11.99	3.90	8.09
S.E. ±	3.049	1.215	2.052	1.283	0.503	0.634
C.D. at 5%	9.250	3.686	6.224	3.892	1.526	1.923

4.2.8.13 Effect on fresh weight of root

Though a sharp drop in fresh weight of root was observed in salinity of 12 mmhos/cm, it was statistically similar in effect to 14 mmhos/cm (Table 119).

4.2.8.14 Effect on fresh weight of top

The salinity at 8 mmhos/cm showed more pronounced decrease in fresh weight of top. Similarly the effect was still higher in decrease at salinity 16 mmhos/cm.

4.2.8.15 Effect on dry weight of whole plant

The continuous decrease in dry weight of whole plant with increasing salinity level was observed but the differences were more or less similar to each other.

4.2.8.16 Effect on dry weight of root

A significant and high in magnitude drop in dry weight of root was noticed at salinity of 8 mmhos/cm and 20 mmhos/cm. In rest of the salinity levels the effect was slow.

4.2.8.17 Effect on dry weight of top

The decrease in dry weight of top was more and significant at salinity of 8 mmhos/cm compared to



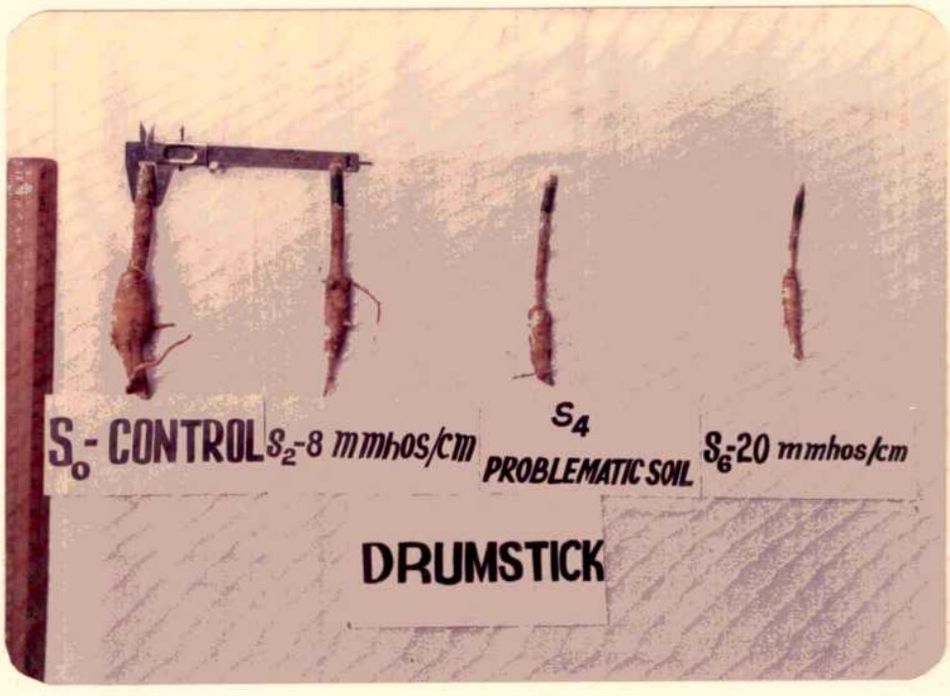


Photo plate No. 49 : Depressed shoot, stem diameter and root growth as affected by salinity levels 240 days after planting



Photo plate No. 50 : Effect of salinity levels showing gradual change in chlorophyll content in Drumstick

4 mmhos/cm. In other salinity levels the decrease was not so prominant.

4.2.8.2 Physiological parameters

4.2.8.2.1 Effect of salinity on chlorophyll content of leaves

From perusal of the data (Table 120) it is evident that the salinity levels 4 mmhos/cm and control produced satatistically similar 'a', 'b' and total chlorophyll. The salinity level 8 mmhos/cm was found to be statistically different in 'a', 'b' and total chlorophyll content.

Table 120: Effect of salinity on chlorophyll content of leaves, number of stomata per unit area and rate of trnaspiration of Drumstick

Treatments	Chlorophyll			Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
	'a'	'b'	Total		
	mg/g				
			Leaves		
Control	1.0950	1.2513	2.3463	23.20	0.0149
4 mmhos/cm	1.0473	1.2337	2.2800	22.20	0.0169
8 mmhos/cm	0.8660	1.0573	1.9233	17.80	0.0174
12 mmhos/cm	0.5637	0.7350	1.2987	14.30	0.0177
14 mmhos/cm	0.4647	0.6830	1.1487	12.66	0.0188
16 mmhos/cm	0.4020	0.6058	1.0000	11.00	0.0192
20 mmhos/cm	0.3410	0.5287	0.8687	10.10	0.0193
S.E. ±	0.028	0.025	0.056	0.984	0.0002
C.D. at 5%	0.094	0.089	0.117	2.985	0.0006

4.2.8.2.2 Effect on number of stomata

It is observed from Table 120 and Fig. 8 that the number of stomata decreased with the increase in salinity levels. A significantly more number of stomata was recorded under salinity level 4 mmhos/cm followed by that of salinity 8 mmhos/cm. As compare to control plant, the total number of stomata was two times decreased at salinity level at 20 mmhos/cm.

4.2.8.2.3 Effect on rate of trnaspiration

The rate of trnaspiration was significantly higher in salinity 12 mmhos/cm as compared to problematic soil but was similar to salinity level of 8 mmhos/cm.

4.2.8.3 Effect of salinity on chemical composition

The data on chemical composition of leaves, roots and stem as affected by different salinity levels are reported in Table 121 and 122.

4.2.8.3.1 Macronutrient content of leaves, roots and stem

4.2.8.3.1.1 Nitrogen

Leaves : The result of N content of leaves due to increased levels of salinity showed significant decrease from each other (Table 121).

Roots : The salinity levels 4 and 12 mmhos/cm and salinity levels 14 and 16 mmhos/cm behaved similarly in N content of the roots. At salinity level of 20 mmhos/cm the lowest N was observed in roots as compared to the control and low salinity levels.

Stem : The salinity levels between 4 to 8 mmhos/cm and from 12 to 20 mmhos/cm showed significant decrease in N content of the stem. The salinity level 8 to 12 mmhos/cm behaved similarly.

4.2.8.3.1.2 Phosphorus

Leaves : The initial level of salinity and control showed no statistical difference in P content of the leaves, but every higher salinity level from 8 to 20 mmhos/cm showed significant decrease in P content (Table 121).

Roots : The decrease in P content of the roots in control soil and every increased salinity soil showed significant decrease from each other.

Stem : The P content of the stem was also decreased significantly due to different salinity levels except that of 12 to 14 mmhos/cm levels.

4.2.8.3.1.3 Potassium

Leaves : There was decrease in K content of the leaves as affected due to different salinity levels (Table 121), but it was gradual. However, salinity at 8 mmhos/cm was

Table 121: Effect of salinity on macronutrient content (percentage) of leaves, roots and stem of Drumstick

Treatments	N	P	K	Ca	Mg	S	Na
			Leaves				
Control	3.39	2.32	2.81	1.72	0.67	0.48	0.25
4 mmhos/cm	3.18	2.15	2.68	1.64	0.60	0.96	0.41
8 mmhos/cm	2.97	2.02	2.32	1.51	0.41	1.32	0.44
12 mmhos/cm	2.72	1.73	1.88	1.20	0.37	1.09	0.48
14 mmhos/cm	2.49	1.38	1.75	1.12	0.36	0.82	0.61
16 mmhos/cm	2.35	0.80	1.55	0.99	0.34	0.52	0.63
20 mmhos/cm	2.12	0.36	1.50	0.73	0.24	0.33	0.72
S.E. ±	0.040	0.073	0.116	0.037	0.014	0.052	0.015
C.D. at 5%	0.121	0.221	0.351	0.113	0.041	0.158	0.044
			Roots				
Control	2.48	1.79	2.55	1.96	1.54	0.32	0.24
4 mmhos/cm	2.19	1.60	2.38	1.79	1.42	0.48	0.39
8 mmhos/cm	1.83	1.48	2.30	1.48	1.28	0.82	0.65
12 mmhos/cm	1.76	1.21	1.89	1.20	0.98	0.53	0.99
14 mmhos/cm	1.48	0.92	1.73	0.92	0.62	0.32	1.19
16 mmhos/cm	1.48	0.70	1.43	0.70	0.48	0.29	1.19
20 mmhos/cm	0.95	0.42	0.93	0.38	0.19	0.12	1.36
S.E. ±	0.062	0.049	0.067	0.053	0.049	0.039	0.039
C.D. at 5%	0.187	0.147	0.147	0.161	0.149	0.117	0.119
			Stem				
Control	3.38	1.35	2.88	1.24	1.90	0.89	0.12
4 mmhos/cm	3.25	1.20	2.71	1.17	1.70	0.72	0.18
8 mmhos/cm	2.89	0.92	2.32	0.88	1.38	0.67	0.20
12 mmhos/cm	2.69	0.76	1.89	0.84	1.00	0.60	0.23
14 mmhos/cm	2.32	0.72	1.55	0.71	0.73	0.39	0.35
16 mmhos/cm	1.98	0.53	1.26	0.60	0.70	0.26	0.48
20 mmhos/cm	1.29	0.16	0.89	0.30	0.28	0.13	0.59
S.E. ±	0.092	0.041	0.069	0.044	0.063	0.023	0.016
C.D. at 5%	0.279	0.125	0.209	0.133	0.191	0.071	0.048

significantly different from its lower and higher salinity levels.

Roots : The salinity levels 4 and 8 mmhos/cm did not show any statistical difference in K content of the roots. But all other salinity levels decreased the K content of the roots significantly.

Stem : There was no any high difference in K content of the stem because of control and salinity soil of 4 mmhos/cm. But the decrease in K content of the stem was severe in salinity levels from 12 to 20 mmhos/cm.

4.2.8.3.1.4 Calcium

Leaves : Except salinity of 12 to 14 mmhos/cm the differences in Ca content of leaves were statistically different from each other.

Roots : A gradual and significant decrease in Ca content of the roots was noticed when the salinity level was raised from 4 to 20 mmhos/cm (Table 121).

Stem : The control and salinity levels from 4 to 14 mmhos/cm indicated non significant decrease in Ca content of the stem. However, there was highly significant decrease in higher salinity levels.

4.2.8.3.1.5 Magnesium

Leaves : The salinity levels from 8 to 16 mmhos/cm resulted into non significant decrease of Mg content of

the leaves (Table 121). The highest salinity levels showed least Mg content of the leaves.

Roots : Except control and salinity level of 4 mmhos/cm, other higher concentration of salinity showed significant difference in Mg content of the roots. The decrease was toosevere between salinity level of 8 and 12 mmhos/cm and salinity levels of 14 and 16 mmhos/cm.

Stem : The Mg content of the stem was non significantly decreased due to salinity levels of 14 and 16 mmhos/cm. All other salinity levels showed significant decrease. There was maximum decrease when salinity levels were raised from 12 to 14 mmhos/cm.

4.2.8.3.1.6 Sulphur

Leaves : There was significant increase in S content of the leaves when the salinity levels were raised from 4 to 12 mmhos/cm (Table 121). However, the further higher levels of salinity showed significant decrease in S content of the leaves.

Roots : The S content of the roots was found increased significantly upto the salinity levels of 8 mmhos/cm. The higher levels of salinity (i.e. 14 and 16 mmhos/cm) did not show statistical decrease in S content of the roots.

Stem : The result of S content of the stem due to salinity levels were continuously decreasing trend, but after problematic soil the decrease was severe.

4.2.8.3.1.7 Sodium

Leaves : The Na content of the leaves was increased with every increased level of salinity, but the differences were at par upto the salinity level of 16 mmhos/cm (Table 121).

Roots : Similar increase in Na content of the roots was notice due to every incremental level of salinity. However, the increase was significant and maximum when the salinity levels were raised from 4 to 14 mmhos/cm.

Stem : The Na content of the stem increased but non significantly in salinity levels of 4 and 8 mmhos/cm. But the shift of increase was higher when the salinity levels were raised from 12 to 20 mmhos/cm.

4.2.8.3.1.8 Ca : Na

Leaves : There was consistant and significant decrease in Ca : Na content of the leaves due to salinity levels from 4 to 14 mmhos/cm (Table 122). The salinity levels 14 and 16 mmhos/cm behaved equally. The decrease in Ca : Na ratio of leaves was immediately noticed even at initial level of salinity.

Roots : The effect of decrease in Ca:Na ratio of root was statistically non significant in almost all levels of salinity except salinity level of 4 to 8 mmhos/cm. However, the differences were higher in magnitude due to increase salinity level from 4 to 12 mmhos/cm. The lowest ratio of Ca : Na in root was noticed under 20 mmhos/cm.

Stem : The ratio of Ca : Na was suddently decreased from that of control due to first level of salinity (4 mmhos/cm). Similarly, the significant decrease was noticed in salinity levels of 12 and 14 mmhos/cm. The salinity levels from problematic soil (14 mmhos/cm) to 20 mmhos/cm behaved almost similarly. Under highest salinity the high reduced ratio of Ca : Na in stem was noted

4.2.8.3.1.9 Ca + Mg + K : Na

Leaves : The Ca + Mg + K : Na ratio of the leaves was severely decreased at the start of salinity level(4 mmhos/cm). Upto the salinity level of 12 mmhos/cm the decrease in Ca + Mg + K : Na ratio was significant. Beyond this salinity level the differences were within the

statistical limit. The ratio was more than six times less under highest salinity compare to control.

Roots : The control and salinity under 4 mmhos/cm, salinity level of 8 and 12 mmhos/cm and salinity levels from 12 to 20 mmhos/cm behaved with statistically similar differences of Ca + Mg + K : Na ratio in roots. Compare to all salinity levels under salinity level of 8 mmhos/cm the drastic reduction in the ratio was observed.

Stem : Appriciable reduction in Ca + Mg + K : Na ratio of stem was noticed when the salinity levels were increased right from 4 to 14 mmhos/cm. Thereafter the decrease was there but it was non significant. The severe reduction of the ratio in stem was immediately noticed under the salinity of 4 mmhos/cm. Compare to control under highest salinity level the ratio was decreased more than 24 times.

4.2.8.3.2 Micronutrient content of leaves, roots and stem

4.2.8.3.2.1 Zinc

Leaves : The decrease of Zn content of the leaves was observed on par from each other due to the salinity levels from 8 to 14 mmhos/cm (Table 122). The reduction in Zn content of the leaves was maximum when the salinity level was raised from 4 to 8 mmhos/cm and 14 and 16 mmhos/cm.

Roots : There was no statistical difference in Zn content of the roots due to control and salinity level of 4 mmhos/cm, beyond this initial level, the other higher levels of salinity showed significant decreases in Zn content of the roots. However the decrease was to a greater extent at highest levels of salinity (i.e. 20 mmhos/cm) compare to its preceeding levels of salinity.

Stem : The salinity level from 12 to 16 mmhos/cm were found on par to each other in decreasing the Zn content of the stem. But the decrease was maximum when salinity levels were raised upto 8 mmhos/cm and salinity levels from 16 to 20 mmhos/cm.

4.2.8.3.2.2. Iron

Leaves : The Fe content of the leaves was decreased due to subsequent increase in salinity levels. However, the

Table 122: Effect of salinity on macronutrient ratios of Ca:Na, Ca+Mg+K:Na and micronutrient contents of leaves, roots and stem of Drumstick

Treatments	Ca / Na	Ca+Mg+K / Na	Micronutrient in ppm			
			Zn	Fe	Mn	Cu
			Leaves			
Control	6.66	21.41	53.89	1158.95	97.65	45.13
4 mmhos/cm	4.00	12.00	52.44	1127.60	83.18	40.83
8 mmhos/cm	3.45	9.65	33.19	1083.13	70.65	31.34
12 mmhos/cm	2.41	6.44	30.23	983.73	60.33	20.35
14 mmhos/cm	1.86	5.60	28.48	819.13	49.86	18.71
16 mmhos/cm	1.52	4.88	18.59	773.56	32.31	17.70
20 mmhos/cm	1.02	3.59	8.59	773.41	19.736	12.40
S.E. ±	0.136	0.737	1.856	43.786	2.516	1.239
C.D. at 5%	0.413	2.236	5.632	132.623	7.632	3.758
			Roots			
Control	6.10	16.90	65.33	1205.95	78.12	70.53
4 mmhosØcm	4.80	14.88	65.10	1198.91	71.23	69.84
8 mmhos/cm	2.34	8.36	59.78	1016.97	64.34	58.29
12 mmhos/cm	1.22	4.12	46.11	835.85	58.19	39.49
14 mmhos/cm	0.77	2.74	35.90	692.65	48.82	37.17
16 mmhos/cm	0.59	2.18	27.56	549.65	29.52	28.13
20 mmhos/cm	0.28	1.11	6.74	116.93	8.33	8.93
S.E. ±	0.544	1.495	2.497	42.270	4.230	2.759
C.D. at 5%	1.650	4.435	7.575	128.224	12.817	8.368
			Stem			
Control	10.52	51.06	43.86	1398.18	103.47	37.26
4 mmhos/cm	6.64	31.20	38.25	1209.24	89.30	30.50
8 mmhos/cm	4.03	22.61	29.40	1089.36	74.98	29.32
12 mmhos/cm	3.66	16.23	20.42	989.65	53.16	20.38
14 mmhos/cm	2.03	8.57	18.15	810.64	41.12	15.17
16 mmhos/cm	1.26	5.29	14.77	796.57	29.82	12.44
20 mmhos/cm	0.51	2.49	6.06	539.27	15.81	6.50
S.E. ±	0.394	2.015	1.591	34.797	3.371	1.434
C.D. at 5%	1.196	6.111	4.825	105.556	10.226	4.350

decrease was most apparent when salinity levels were raised from 12 to 16 mmhos/cm (Table 122).

Roots : No statistical difference was observed between control and salinity level of 4 mmhos/cm in Fe content of the roots, but there after significant decrease was there in Fe content of the roots. However the effects were most striking between salinity levels of 16 and 20 mmhos/cm.

Stem : The Fe content of the stem significantly decreased due to the salinity level of 8 mmhos/cm. But at highest salinity level, the Fe content of the stem was reduced to a maximum extent as compared to its immediate preceeding salinity levels.

4.2.8.3.2.3 Manganese

Leaves : There was consistant and significant decrease in Mn content of the leaves at every incremental level of salinity upto 14 mmhos/cm. But the next higher levels of salinity (i.e. 16 and 20 mmhos/cm) showed tremendous decrease in Mn content of the leaves (Table 122).

Roots : The decrease in Mn content of the roots were almost at par to each other upto the salinity level of 14 mmhos/cm. But the salinity levels of 16 and 20 mmhos/cm resulted higher decrease in Mn content of the roots.

Stem : There was sudden decrease in Mn content of the stem even at initial level of salinity as compared to control. The effect was also noticeable between salinity level of 8 to 12 mmhos/cm and 14 to 16 mmhos/cm.

4.2.8.3.2.4 Copper

Leaves : There was no statistically difference in Cu content of the leaves due to salinity levels from 12 to 16 mmhos/cm (Table 122). But the earlier lower and highest level of salinity showed striking effect.

Roots : The control and salinity level of 4 mmhos/cm and salinity level of 12 and 14 mmhos/cm behaved in a similar manner in Cu content of the roots. Maximum decrease was observed at salinity level of 12 as compared to its preceeding salinity level, but the reduction was still immediate preceeding level of salinity.

Stem : The result on Cu content of the stem due to salinity levels of 4 to 8 mmhos/cm and salinity levels of 14 to 16 mmhos/cm were statistically equal even though there was continuous decrease. The Cu content of the stem was found to be decreased significantly at salinity levele of 12 to 20 mmhos/cm from their immediate preceeding level of salinity.

4.2.4 The estimated ratios of sodium

The results on estimated sodium ratios of leaves and roots (Table 122a) indicated that with the increase of salinity levels, there was increase in this ratio in fruit crop species like markingnut, soapnut, karonda and passion fruit. Further the ratio was more than unity in highest salinity indicating thereby higher deposition of sodium in leaves compare to roots. In these crops the sodium ratio of stem and root was also more than one which indicated higher amount of sodium in stem compare to roots. However, among these crops except karonda the plants were not survived. This indicated that karonda has its resistance against salinity. In fruit crops viz. phalsa and drumstick the sodium ratio in leaves and stem was less than one even if in high salinity condition but plants could not survived indicating even a low concentration of sodium causes plant injury which leads to death of the plants and are said to be as medium susceptible to salinity. It was interesting to pointout that even though the sodium concentration in coconut was least of all and the plants were not associated with any sign of mortality showed its highly tolerance to salinity or might be associated with the escape mechanism of salinity resistance.

In cashew there was highest deposition of sodium in leaves and stem and the plants were died at 240 and 300 days after plantig.

Table 122a: Sodium concentration ratio in leaves:root and stem:roots as influenced by varied levels of salinity in different fruit crops.

Fruit crops		Salinity levels in (mmhos/cm)		
		4	14	20
Cashew	L:R	4.34	3.86	3.97
	S:R	2.62	2.71	3.01
	D	-	300	240
Coconut	L:R	1.02	0.68	0.90
	S:R	-	-	-
	D	-	-	-
Markingnut	L:R	0.95	1.81	2.22
	S:R	1.55	0.92	1.11
	D	-	180	180
Soapnut	L:R	0.87	0.87	1.88
	S:R	0.64	0.86	0.92
	D	-	-	-
Phalsa	L:R	0.44	0.41	0.38
	S:R	0.19	0.31	0.45
	D	-	-	300
Karonda	L:R	0.77	1.78	2.57
	S:R	0.57	1.26	1.39
	D	-	-	-
Passion fruit	L:R	2.19	2.56	2.56
	S:R	0.61	2.08	2.00
	D	-	300	240
Drumstick	L:R	1.05	0.51	0.53
	S:R	0.46	0.29	0.43
	D	-	-	300

L:R : Leaves:Roots, S:R : Stem:Root

D : Days after planting.

4.2.5 Response analysis of drymatter under varying salinity levels

The quadratic functions between different levels of salinity and dry matter of different fruit crops were estimated separately. Results of response function were statistically significant and are presented in Table 122b.

4.2.5.1 Cashew

The quadratic relationship between salinity levels and dry matter yield of cashew was highly significant. The coefficient of multiple determination R^2 was 0.9746 explaining thereby 97.46 per cent variation in dry matter yield of cashew due to various level of salinity. The partial regression coefficient attached to the X^2 was negative and highly significant indicating tolerance to salinity level. The maximum tolerable level to salinity was estimated to be 0.29 and the expected yield at this level was 40.07.

4.2.5.2 Coconut

The quadractic function of relationship of various salinity level and dry matter yield of coconut were significant. However the partial regression coefficient could not show significance at 5% level of probably. The R^2 was significant explaining 91.87 per cent variation in dry matter due to salinity.

4.2.5.3 Markingnut

The quadractic functional relationship between various level of salinity and dry matter yield of markingnut was highly significant. The coefficient of multiple determination R^2 was significant explaining 96.60 per cent variation in dry matter yield of markingnut with respect to various level of salinity. The partial regression coefficient attached to linear term was negative and significant indicating consistent decline in dry matter level of markingut with respect to increase in the dose of salinity.

4.2.5.4 Soapnut

The quadratic function in soapnut dry matter yield was significant in presence of various levels of salinity. The coefficient of multiple determination R^2 explained 99.04 per cent variations in dry matter yield in soapnut to various levels of salinity. The partial regression coefficient attached to linear and quadratic term were negative and significant indicating consistant decline with additional increment in the levels of salinity.

4.2.5.5 Phalsa

The quadratic functional relationship in dry matter of phalsa with respect to various levels of

Table 122b: Quadratic response function of salinity on dry matter production

Fruit crop	Intercept b_0	Partial gegression coefficient b_1	Partial regression b_2	Estimated tolerable level of salinity	Estimated dry matter	Coefficient multiple determination R^2	F
Cashew	40.36	0.4532	-0.8736*	0.259	40.47	0.9746**	76.79
	S.E. ±	0.3602	0.0168				
	t	1.2580	-4.3727				
Coconut	691.30	-15.8677	-0.3771			0.9187**	22.61
	S.E.±	13.7930	0.6451				
	t	-1.1504	-0.5845				
Markingnut	24.49	-0.8440 X	0.0037			0.9660**	56.89
	S.E.±	0.2835	0.0132				
	t	-2.9763	0.2543				
Soapnut	124.07	-2.4531 X	-0.1345*			0.9904**	207.27
	S.E.±	1.0135	0.0472				
	t	-2.4195	-2.8370				

Contd.....

Table 122a : Contd....

1.	2.	3.	4.	5.	6.	7.	8.
Phalsa	42.85	-1.2682 X	0.0255			0.9795**	95.68
	S.E.±	0.4082	0.0190				
	t	-4.8210	1.3404				
Karonda	128.36	-9.6335 X	0.2337*			0.9773**	86.13
	S.E.±	1.4790	3.3782				
	t	-6.5732					
Passion fruit	43.53	0.5957	-0.0680*	4.38	44.83	0.9398**	31.27
	S.E.±	0.4407	0.0206				
	t	1.3516	-3.3016				
Drumstick	29.35	-1.1080	0.0081			0.9912**	227.20
	S.E.±	0.1720	0.0008				
	t	-6.4349	1.0173				

No. of observations = 7, *,** significant at 5 and 1 per cent level, respectively.

Y = Estimated dry matter, X = Salinity levels, b_0, b_1, b_2 = Regression coefficient.

salinity was highly significant. The coefficient of multiple determination R^2 was 0.9795 explaining thereby 97.95 per cent variation in phalsa yield with respect of various levels of salinity. The partial regression coefficient attached to linear term was negative and significant. Whereas the partial regression coefficient attached to X^2 was non significant indicating linear decline in yield with respect to level of salinity.

4.2.5.6 Karonda

The quadratic functional relationship in karonda dry matter yield and various levels of salinity was significant giving high value of R^2 0.9773. The coefficient of multiple determination R^2 thus explained 97.73 per cent variation in dry matter of karonda in presence of various levels of salinity. The partial regression coefficient attached to linear term and quadratic were negatively and positively significant indicating thereby decline in yield consistantly.

4.2.5.7 Passion fruit

The quadratic relation between various levels of salinity and passion fruit dry matter yield was highly significant giving high value of R^2 equal to 0.9398. The coefficient of multiple determination R^2 explained

95.98 per cent variations in dry matter yield with respect to various salinity levels. The partial regression coefficient attached to quadratic term X^2 was negative and significant indicating maxima in dry matter. The maximum level of tolerance to salinity was estimated to be 4.38 beyond which the dry matter yield declined significantly with additional increment in the level of salinity. The expected yield and maximum tolerance level estimated were 45.03 and 4.38 salinity level respectively.

4.2.5.8 Drumstick

The quadratic function between various levels of salinity was highly significant giving high value of R^2 0.9912. The coefficient of multiple determination R^2 explained 99.2 per cent variations in dry m matter yield of drumstick with respect to change in the levels of salinity. The partial regression coefficient attached to linear term X was negative and significant indicating consistent decline in dry matter yield of drumstick with respect to levels of salinity.

Conclusions

Out of eight fruit crops only two fruit crops namely cashew and passion fruit exhibited tolerance to levels of salinity extent. Whereas other fruit crops exhibited significant decline in yield due to increasing salinity levels.

4.3 Correlation coefficient among different characters in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in different fruit crops

4.3.1 Cashew

The results on character association in cashew (Table 123) revealed that in presence of both ESP level and salinity conditi on all the character except plant mortality showed highly significant correlation with dry matter production. The results further indicated that the interelatiobship among the characters was also positive and highly significant. Plant mortality was found to be negatively correlated with all the characters.

4.3.2 Coconut

The results on correlation indicated that all the characters except plant mortality showed significant positive correlation with dry matter production in presence of salinity condition. However, the association of all characters with dry matter in presence of ESP level was either weak positive or negative non significant. The characters viz. plant mortality, stomata number and rate of trnaspiration had shown negative correlation with most of the characters. But these three were found to

Table 123: Correlation coefficien. among different morphological characters in presence of exchangeable sodium percentage (ESP) and salinity (ECe, in Cashew

Characte-		Plant height (cm)	Number of leaves	Leaf area (sq.cm.)	Mortality (per cent)	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chloro-phyll (mg/g	Number of stomata (40 x)	Rate of transpi-ration $gH_2O/cm^2/hr$	Dry matter of whole plant
Plant height (cm)	ESP	1.000	0.942**	0.940**	-0.908**	0.899**	0.925**	0.926**	0.899**	0.923**	0.885**	0.875**
	ECe	1.000	0.903**	0.924**	-0.970**	0.745**	0.881**	0.922**	0.908**	0.907**	0.956**	0.867**
Number of leaves	ESP		1.000	0.977**	-0.881**	0.923**	0.964**	0.923**	0.919**	0.909**	0.871**	0.861**
	ECe		1.000	0.927**	-0.884**	0.693	0.926**	0.927**	0.899**	0.931**	0.896	0.844**
Leaf area (sq.cm.)	ESP			1.000	-0.829**	0.905**	0.974**	0.881**	0.884**	0.905**	0.852**	0.812**
				1.000	-0.910**	0.829**	0.960**	0.941**	0.986**	0.866**	0.934**	0.861**
Mortality (per cent)	ESP				1.000	-0.906**	-0.861**	-0.954**	-0.876**	-0.899**	-0.910**	-0.922**
	ECe				1.000	-0.730**	-0.883**	-0.880**	-0.896**	-0.904**	-0.919**	-0.822**
Root length (cm)	ESP					1.000	0.924**	0.879**	0.852**	0.910*	0.832**	0.812**
	ECe					1.000	0.717**	0.778**	0.824**	0.686**	0.826**	0.814**
Total number of roots	ESP						1.000	0.876**	0.866**	0.931**	0.844**	0.802**
							1.000	0.907**	0.934**	0.850**	0.862**	0.809**
Fresh weight of whole plant	ESP							1.000	0.937**	0.900**	0.940**	0.924**
	ECe							1.000	0.909**	0.934**	0.917**	0.929**
Total chloroph-yll (mg/g)	ESP								1.000	0.871**	0.911**	0.914**
	ECe								1.000	0.853**	0.983**	0.856**
Number of sto-mata (40 x)	ESP									1.000	0.873**	0.846**
	ECe									1.000	0.872**	0.876**
Rate of trnas-piration(gH_2O/cm^2/hr)	ESP										1.000	0.924**
	Ece										1.000	0.900

*, ** significant at 5 and 1 per cent, respectively.

Table 124: Correlation coefficient among different morphological characters in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in coconut

Characters		Plant height (cm.)	Number of leaves	Leaf area (sq.cm.)	Mortality (per cent)	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chlorophyll (mg/g)	Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$	Dry matter of whole plant
Plant height (cm)	ESP	1.000	0.729**	0.954**	-0.788**	0.989**	0.992**	0.949**	0.843**	-0.949**	-0.959**	0.006
	ECe	1.000	0.700**	0.976**	-0.849**	0.932**	0.986**	0.961**	0.910**	-0.868**	-0.981**	0.816**
Number of leaves	ESP		1.000	0.645**	-0.633**	0.693**	0.741**	0.667**	0.604**	-0.672**	-0.717**	0.061
	ECe		1.000	0.751**	-0.712**	0.694**	0.750**	0.690**	0.726**	0.676	-0.742**	0.601**
Leaf area (sq.cm.)	ESP			1.000	-0.745**	0.951**	0.954**	0.938**	0.868**	-0.925**	-0.964**	-0.035
				1.000	-0.809**	0.900**	0.985**	0.956**	0.962**	-0.828**	-0.954**	0.814**
Mortality (per cent)	ESP				1.000	-0.783**	-0.764**	-0.859**	-0.627**	0.766**	0.785**	-0.157
	ECe				1.000	-0.915**	-0.823**	-0.821**	-0.674**	0.954**	0.884**	-0.732**
Root length (cm)	ESP					1.000	0.979**	0.946**	0.814**	-0.949**	-0.954**	-0.018**
	ECe					1.000	0.935**	0.929**	0.834**	-0.922**	-0.910**	-0.810**
Total number of roots	ESP						1.000	0.941**	0.815**	-0.958**	-0.966**	0.005
	ECe						1.000	0.969**	0.941**	-0.846**	-0.963**	0.815**
Fresh weight of whole plant	ESP							1.000	0.758**	-0.932**	-0.935**	0.039
	ECe							1.000	0.920**	-0.834**	-0.919**	0.931**
Total chlorophyll (mg/g)	ESP								1.000	-0.706**	-0.805**	-0.022
	ECe								1.000	-0.702**	-0.851**	0.802**
Stomata/unit (40 x)	ESP									1.000	0.923**	0.057
	ECe									1.000	0.980**	-0.713**
Transpiration $gH_2O/cm^2/hr$	ESP										1.000	0.063
	ECe										1.000	-0.758**

*, ** significant at 5 and 1 per cent level, respectively.

be positively related with each other. The interrelationship among other characters was highly and positively significant (Table 124).

4.3.3 Markingnut

In markindnut the character correlation (Table 125) revealed that except plant mortality and number of stomata all other characters showed highly significant and positive correlation with dry matter production both in presence of ESP and salinity levels. Plant mortality showed negative correlation with all the characters except number of stomata. The number of stomata also showed significant negative correlation with most of the characters. The number of stomata and rate of trnaspirations were found to be negatively correlated. Rest of the associations among the characters were positive and highly significant.

4.3.4 Soapnut

The total dry matter production was found to be highly positive and significantly correlated with all the characters except plant mortality and stomata number in presence of ESP and salinity condition. The two characters viz. plant mortality and number of stomata did not show any relation with most of characters. The stomata

Table 126: Correlation coefficient among different morphological characters in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Markingnut

Characters		Plant height (cm)	Number of leaves	Leaf area (sq.cm.)	Mortality (per cent)	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chlorophyll (mg/g)	Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$	Dry matter of whole plant
Plant height (cm)	ESP	1.000	0.959**	0.951**	-0.845**	0.887**	0.909**	0.916**	0.940**	-0.882**	0.898**	0.920**
	ECe	1.000	0.930 *	0.970**	-0.907**	0.759**	0.841**	0.930**	0.887**	-0.881**	0.875**	0.946**
Number of leaves	ESP		1.000	0.951**	-0.809**	0.861**	0.900 *	0.913**	0.940**	-0.908**	0.880**	0.919**
	ECe		1.000	0.970**	-0.918**	0.869**	0.870**	0.959**	0.919**	-0.885**	0.927**	0.952**
Leaf area (sq.cm.)	ESP			1.000	-0.747**	0.903**	0.968**	0.976**	0.947**	-0.869**	0.893**	0.975**
	ECe			1.000	-0.907**	0.847**	0.903**	0.955**	0.911**	-0.895**	0.905**	0.936**
Mortality (per cent)	ESP				1.000	-0.750**	-0.681**	-0.699 *	-0.800**	0.762**	-0.897**	-0.706**
	ECe				1.000	-0.706	-0.741**	-0.937**	-0.928**	0.903**	-0.870**	-0.932**
Root length (cm)	ESP					1.000	0.935**	0.939**	0.820**	-0.841**	0.827**	0.929**
	ECe					1.000	0.845**	0.833**	0.788**	-0.725**	0.891**	0.788**
Fresh weight of whole plant	ESP						1.000	0.992**	0.917**	-0.877**	0.855**	0.989**
	ECe						1.000	0.876**	0.809**	-0.739**	0.813**	0.809**
Total number of roots	ESP							1.000	0.910**	-0.870**	0.863**	0.996**
	ECe							1.000	0.978**	-0.909**	0.880**	0.959**
Total chlorophyll (mg/g)	ESP								1.000	-0.884**	0.894**	0.917**
	ECe								1.000	-0.908**	0.847**	0.942**
Stomata/unit (40 x)	ESP									1.000	-0.820**	-0.874**
	ECe									1.000	-0.859**	-0.906**
Transpiration $gH_2O/cm^2/hr$	ESP										1.000	0.864**
	ECe										1.000	0.890**

*,** significant at 5 and 1 per cent level, respectively.

Table 126: Correlation coefficients among different morphological characters in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Soapnut

Characters		Plant height (cm)	Number of leaves	Leaf area (sq.cm.)	Mortality (per cent)	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chlorophyll (mg/g)	Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$	Dry matter of whole plant
Plant height (cm)	ESP	1.000	0.959**	0.951**	-0.845**	0.887**	0.909**	0.916**	0.940**	-0.882**	0.896**	0.920**
	ECe	1.000	0.930 *	0.970**	-0.907**	0.759**	0.841**	0.930**	0.867**	-0.681**	0.875**	0.946**
Number of leaves	ESP		1.000	0.951**	-0.809**	0.861**	0.900**	0.913**	0.940**	-0.908**	0.880**	0.919**
	ECe		1.000	0.970**	-0.918**	0.869**	0.870**	0.959**	0.919**	-0.885**	0.927**	0.952**
Leaf area (sq.cm.)	ESP			1.000	-0.747**	0.903**	0.968**	0.976**	0.947**	-0.869**	0.893**	0.975**
	ECe			1.000	-0.907**	0.847**	0.903**	0.955**	0.911**	-0.895**	0.905**	0.936**
Mortality (per cent)	ESP				1.000	-0.750**	-0.681**	-0.699**	-0.800**	0.762**	-0.897**	-0.706**
	ECe				1.000	-0.706	-0.741**	-0.937**	-0.928**	0.903**	-0.870**	-0.932**
Root length (cm)	ESP					1.000	0.935**	0.939**	0.820**	-0.841**	0.827**	0.929**
	ECe					1.000	0.845**	0.833**	0.788**	-0.725**	0.891**	0.788**
Total number of roots	ESP						1.000	0.992**	0.917**	-0.877**	0.855**	0.989**
	ECe						1.000	0.876**	0.809**	-0.739**	0.813**	0.809**
Fresh weight of whole plant	ESP							1.000	0.910**	-0.870**	0.863**	0.996**
	ECe							1.000	0.978**	-0.909**	0.880**	0.959**
Total chlorophyll (mg/g)	ESP								1.000	-0.884**	0.894**	0.917**
	ECe								1.000	-0.908**	0.847**	0.942**
Stomata/unit (40 x)	ESP									1.000	-0.820**	-0.874**
	ECe									1.000	-0.859**	-0.906**
Transpiration $gH_2O/cm^2/hr$	ESP										1.000	0.864**
	ECe										1.000	0.890**

*,** significant at 5 and 1 per cent level, respectively.

number also showed negative significant correlation with rate of trnaspiration. The results further indicated that most of the other associations were highly and positively significant with each other in both the conditions (Table 126).

4.3.5 Phalsa

The correlation results in Table 127 showed that most of the character combinations were highly and positively significant. Plant mortality and number of stomata showed negative and highly significant correlation with all the characters. But these two were significantly correlated with each other in presence of both ESP and salinity conditions. The number of stomata was found to be negatively and highly significantly correlated with rate of trnaspiration and dry matter production in both the conditions.

4.3.6 Karonda

In karonda out of 11 characters except plant mortality, stomata number and rate of trnaspiration all others were found to be highly positively and significantly correlated with dry matter production in presence of ESP and salinity levels. The plant mortality and number of stomata did not show any relation with all

Table 127: Correlation coefficient among different morphological characters in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Phalsa

Characters		Plant height (cm)	Number of leaves	Leaf area (sq.cm.)	Mortality (per cent)	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chloro-phyll (mg/g)	Number of stomata (40 x)	Rate of transpi-ration $gH_2O/cm^2/hr$	Dry matter of whole plant
Plant height (cm)	ESP	1.000	0.948**	0.959**	-0.829**	0.906**	0.946**	0.925**	0.880**	-0.911**	0.690**	0.906**
	ECe	1.000	0.973**	0.946**	-0.929**	0.909**	0.908**	0.963**	0.892**	-0.913**	0.905**	0.964
Number of leaves	ESP		1.000	0.972**	-0.809**	0.935**	0.947**	0.959**	0.928**	-0.951**	0.595**	0.971**
	ECe		1.000	0.975**	-0.948**	0.948**	0.925**	0.982**	0.886**	-0.944**	0.900**	0.966**
Leaf area (sq.cm.)	ESP			1.000	-0.721**	0.899**	0.954**	0.986**	0.966**	-0.928**	0.525*	0.950**
	ECe			1.000	-0.877**	0.941**	0.880**	0.993**	0.953**	-0.944**	0.836**	0.981**
Mortality (per cent)	ESP				1.000	-0.794**	-0.752**	-0.667**	-0.636**	0.803**	-0.720**	-0.739**
	ECe				1.000	-0.869**	-0.870**	-0.909**	-0.741**	0.863**	-0.877**	-0.888**
Root length (cm)	ESP					1.000	0.910**	0.878**	0.835**	-0.889**	0.638**	0.914**
	ECe					1.000	0.856	0.942**	0.868**	-0.913**	0.773**	0.895**
Total number of roots	ESP						1.000	0.954**	0.914**	-0.910**	0.623**	0.930**
	ECe						1.000	0.896**	0.795**	-0.881**	0.911**	0.902**
Fresh weight of whole plant	ESP							1.000	0.977**	-0.908**	0.497*	0.966**
	ECe							1.000	0.935**	-0.945	0.862**	0.984**
Total chloro-phyll (mg/g)	ESP								1.000	-0.887**	0.392	0.927**
	ECe								1.000	-0.878**	0.732**	0.938**
Stomata/unit (40 x)	ESP									1.000	-0.602**	-0.909**
	ECe									1.000	-0.831**	-0.946**
Transpiration $gH_2O/cm^2/hr$	ESP										1.000	0.561**
	ECe										1.000	0.866**

*, ** significant at 5 and 1 per cent level, respectively.

Table 128: Correlation coefficient among different morphological characters in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Karonda

Characters		Plant height (cm)	Number of leaves	Total leaf area (sq.cm.)	Mortality (per cent)	Root length (cm)	Total number of roots	Total number of branches	Fresh weight of whole plant	Total chloro-phyll (mg/g	Number of stomata (40 x)	Rate of trans-piration $gH_2O/cm^2/hr$	Dry matter of whole plant
Plant height (cm)	ESP	1.000	0.953**	0.961**	-0.943**	0.836**	0.940**	0.904**	0.923**	0.954**	-0.854**	-0.873**	0.909**
	ECe	1.000	0.965**	0.942**	-0.761**	0.944**	0.933**	0.890**	0.946 *	0.866**	-0.909**	0.935**	0.932**
Number of leaves	ESP		1.000	0.934**	-0.958**	0.788**	0.881**	0.863**	0.902**	0.942**	-0.799**	-0.820**	0.918**
	ECe		1.000	0.988**	-0.638**	0.905**	0.908	0.883**	0.979**	0.941**	-0.910	0.961**	0.960**
Total leaf area (sq.cm.)	ESP			1.000	-0.905**	0.877**	0.988**	0.904**	0.949**	0.952**	-0.911**	-0.824**	0.927**
	ECe			1.000	-0.570**	0.846**	0.854**	0.881**	0.966**	0.959**	-0.869**	0.967**	0.953**
Mortality (per cent)	ESP				1.000	-0.795**	-0.890**	0.858**	-0.904**	-0.970**	0.773**	0.833**	-0.928**
	ECe				1.000	-0.847**	-0.789	-0.680**	-0.606**	-0.486*	0.761**	-0.608**	-0.580**
Root length (cm)	ESP					1.000	0.872**	0.877**	0.928**	0.840**	-0.925**	0.746**	0.867**
	ECe					1.000	0.981**	0.835**	0.889**	0.769**	-0.918**	0.850**	0.858**
Total number of roots	ESP						1.000	0.893**	0.938**	0.950**	-0.909**	-0.864**	0.922**
	ECe						1.000	0.835**	0.891**	0.775**	-0.891**	0.853**	0.855**
Total number of branches	ESP							1.000	0.894**	0.879**	-0.873**	-0.782**	0.881**
	ECe							1.000	0.869**	0.802**	-0.812**	0.854**	0.847**
Fresh weight of whole plant	ESP								1.000	0.945**	-0.882**	-0.813**	0.978**
	ECe								1.000	0.907**	-0.865**	0.918**	0.968**
Total chloro-phyll (mg/g)	ESP									1.000	-0.836**	-0.848**	0.955**
	ECe									1.000	-0.813**	0.944**	0.916**
Stomata/unit (40 x)	ESP										1.000	0.726**	-0.836**
											1.000	-0.884**	-0.838**
Transpiration $gH_2O/cm^2/hr$	ESP											1.000	-0.794**
	ECe											1.000	-0.933**

*, ** significant at 5 and 1 per cent level, respectively.

the other characters in presence of ESP and salinity levels. In presence of ESP, the rate of trnaspiration showed negative significant association with all the characters except plant mortality and number of stomata. But the association in presence of salinity was reverse. Rest of the associations among different characters were highly significant and positive (Table 128).

4.3.7 Passion fruit

The dry matter production was highly and significantly positively correlated with plant height, number of leaves, leaf area, number of roots and fresh weight of whole plant in presence of ESP and salinity levels. Hbwever, plant mortality, total chlorophyll content and rate of trnaspiration showed negative significant correlation with dry matter production in presence of salinity levels. The magnitude of character association between rate of trnaspiration with all the characters except number of leaves, root length, chlorophyll content and number of stomata was reverse in presence of ESP and salinity levels. The total number of stomata did not found to be related with all the characters in presence of both ESP and salinity levels (Table 129).

4.3.8 Drumstick

All the characters were positively and highly significantly correlated with dry matter production both

Table 123: Correlation coefficient among different morphological characters in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in passion fruit

Characters		Plant height (cm)	Number of leaves	Leaf area (sq.cm.)	Mortality (per cent)	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chlorophyll (mg/g)	Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$	Dry matter of whole plant
Plant height (cm)	ESP	1.000	0.960**	0.963**	-0.936**	0.851**	0.926**	0.901**	0.929**	-0.848**	0.257**	0.603**
	ECe	1.000	0.437*	0.873**	-0.816**	-0.677**	0.745**	0.960**	-0.735**	-0.044	-0.749**	0.905**
Number of leaves	ESP		1.000	0.893**	-0.974**	0.882**	0.952**	0.903**	0.952**	-0.869**	0.144	0.552**
	ECe		1.000	0.760**	0.112	0.335	0.725**	0.501*	0.258	-0.841**	0.211	0.109
Leaf area (sq.cm.)	ESP			1.000	-0.976**	0.837**	0.922**	0.864**	0.940**	-0.874**	0.164	0.504*
	ECe			1.000	-0.517*	-0.305	0.862**	0.859**	-0.383	-0.405*	-0.406	0.637
Mortality (per cent)	ESP				1.000	-0.798**	-0.907**	-0.813**	-0.905**	0.821**	-0.176	-0.428
	ECe				1.000	0.957**	-0.356	-0.770**	0.981**	-0.461*	0.932**	-0.932**
Root length (cm)	ESP					1.000	0.924**	0.5 8**	0.910**	-0.731**	0.230	0.646**
	ECe					1.000	-0.150	-0.620**	0.994**	-0.641**	0.974**	-0.873**
Total number of whole plant	ESP						1.000	0.879**	0.967**	-0.797**	0.143	0.547*
	ECe						1.000	0.711**	-0.225	-0.340	-0.251	0.465*
Fresh weight of whole plant	ESP							1.000	0.876**	-0.812**	0.246	0.837**
	ECe							1.000	-0.884**	-0.130	-0.693	0.901
Total chlorophyll (mg/g)	ESP								1.000	-0.378**	0.078	0.541*
	ECe								1.000	-0.580**	0.973**	-0.906**
Stomata/unit (40 x)	ESP									1.000	-0.222	-0.505*
	ECe									1.000	-0.553**	0.235
Trnaspiration $gH_2O/cm^2/hr$	ESP										1.000	0.317
	ECe										1.000	-0.904**

*, ** significant at 5 and 1 per cent level, respectively.

Table 130: Correlation coefficient among different morphological characters in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Drumstick

Characters		Plant height (cm)	Number of leaves	Total leaf area (sq.cm.)	Mortality (per cent)	Root length (cm)	Total number of roots	Root diameter (mm)	Fresh weight of whole plant	Total chlorophyll (mg/g)	Number of stomata (40 x)	Rate of transpiration $gH_2O/cm^2/hr$	Dry matter of whole plant
Plant height (cm)	ESP	1.000	0.954**	0.975**	-0.908**	0.927**	0.929**	0.915**	0.953**	0.949**	0.935**	0.921**	0.955**
	ECe	1.000	0.937**	0.938**	-0.879**	0.833**	0.874**	0.921**	0.966**	0.935**	0.964**	-0.052	0.928**
Number of leaves	ESP		1.000	0.929**	-0.917**	0.865**	0.907**	0.908**	0.934**	0.952**	0.940**	0.883**	0.958**
	ECe		1.000	0.966**	-0.953**	0.791**	0.808**	0.907**	0.910**	0.919**	0.924**	0.074	0.878**
Leaf area (sq.cm.)	ESP			1.000	-0.892**	0.943**	0.953**	0.944**	0.973**	0.930**	0.957**	0.859**	0.948**
	ECe			1.000	-0.906	0.846**	0.856**	0.914**	0.960**	0.978**	0.951**	-0.029	0.920**
Mortality (per cent)	ESP				1.000	-0.828**	-0.888**	-0.929**	-0.920**	-0.945**	-0.880**	-0.820**	-0.885**
	ECe				1.000	-0.808**	-0.712**	-0.881**	-0.840**	-0.850**	-0.849**	-0.086	-0.826**
Root length (cm)	ESP					1.000	0.966**	0.908**	0.945**	0.883**	0.930**	0.814**	0.911**
	ECe					1.000	0.758**	0.801**	0.841**	0.833**	0.867**	-0.049	0.905
Total number of roots	ESP						1.000	0.964**	0.958**	0.895**	0.963**	0.792**	0.929**
	ECe						1.000	0.801**	0.882**	0.850**	0.873**	-0.203	0.794**
Root diameter (mm)	ESP							1.000	0.966**	0.900**	0.958**	0.788**	0.919**
	ECe							1.000	0.926**	0.904**	0.865**	0.119	0.895**
Fresh weight of whole plant	ESP								1.000	0.918**	0.964**	0.837**	0.966**
	ECe								1.000	0.982**	0.950**	-0.101	0.951**
Total chlorophyll (mg/g)	ESP									1.000	0.913**	0.535**	0.928**
	ECe									1.000	0.933	-0.123	0.927
Stomata/unit (40 x)	ESP										1.000	0.826**	0.955**
	ECe										1.000	-0.085	0.934
Transpiration $gH_2O/cm^2/hr$	ESP											1.000	0.868**
	ECe											1.000	0.076

*, ** significant at 5 and 1 per cent level, respectively.

in presence of ESP and salinity condition except rate of trnaspiration in salinity condition (Table 125). Plant mortality did not show any association with all the characters. The rate of transpiration was found to be significantly and positively correlated with all the characters in presence of ESP level. However, in presence of salinity, it showed negative non significant correlation with all characters except number of leaves and root diameter. The other character combinations showed significant positive correlation in presence of both ESP and salinity levels (Table 130).

4.4 Path coefficient analysis in different fruit crops of dry matter production under incluence of various levels of ESP and salinity

4.4.1 Cashew

The path coefficient analysis results in Table 131 and graphically shown in Fig. 11 indicated that the characters viz. total chlorophyll content followed by fresh weight of whole plant, plant mortality and plant height, showed direct positive influence on dry matter production both in presence of ESP and ECe conditions. Similarly the results revealed that all characters except plant mortality contributed indirectly for dry matter

Table 132: Path coefficient effect direct (diagonal) and indirect (off diagonal) on dry matter in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Cashew

Characters		Plant height (cm)	Number of leaves	Total leaf area (sq.cm.)	Mortality per cent	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chlorophyll (mg/g)	Total number of stomata per unit area (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
Plant height (cm)	ESP	1.248	0.006	1.564	0.645	-0.897	2.425	-0.300	-0.783	-1.831	-2.070
	ECe	0.086	0.059	-0.700	0.308	-0.396	-0.827	2.098	0.334	-0.063	-0.083
Number of leaves	ESP	0.911	0.008	1.058	0.519	-0.629	1.811	-0.210	-0.560	-1.296	-1.550
	ECe	0.060	0.084	0.538	0.258	-0.295	-0.629	1.506	0.266	-0.049	-0.063
Total leaf area (sq.cm.)	ESP	1.190	0.005	1.640	0.610	-0.838	2.333	-0.296	-0.806	-1.784	-2.085
	ECe	0.084	0.063	-0.517	0.293	-0.383	-0.826	2.088	0.353	-0.061	-0.081
Mortality per cent	ESP	-0.0983	-0.005	-1.121	-0.819	0.710	-1.867	0.271	0.582	1.478	1.698
	ECe	-0.073	-0.060	0.580	-0.362	0.389	0.690	-1.794	-0.247	0.070	0.075
Root length (cm)	ESP	1.235	0.006	1.560	0.641	-0.960	2.393	-0.299	-0.755	-1.830	-2.063
	ECe	0.080	0.059	-0.645	0.332	-0.425	-0.784	2.029	0.306	-0.067	-0.077
Total no. of roots	ESP	1.238	0.006	1.565	0.625	-0.888	2.445	-0.297	-0.756	-1.847	-2.088
	ECe	0.085	0.063	-0.706	0.298	0.397	-0.838	2.109	0.345	-0.062	-0.082
Fresh wt.of whole plant	ESP	1.185	0.006	1.538	0.703	-0.858	2.302	-0.316	-0.704	-1.795	-2.020
	ECe	0.082	0.058	-0.685	0.298	-0.393	-0.810	2.184	0.337	-0.061	-0.078
Total chlorophyll (mg/g)	ESP	1.053	0.005	1.424	0.513	-0.738	1.991	-0.230	-0.928	-1.362	-1.741
	ECe	0.078	0.061	-0.690	0.244	-0.355	-0.789	2.009	0.367	0.051	-0.072
Total no.of stomata per unit area (40 x)	ESP	-1.185	-0.006	-1.518	-0.628	0.861	-2.341	0.295	0.656	1.928	1.996
	ECe	-0.074	-0.057	0.593	-0.346	0.392	0.710	-1.822	-0.257	0.073	0.076
Transpiration $gH_2O/cm^2/hr$	ESP	-1.195	-0.006	-1.582	-0.643	0.866	-2.361	0.295	0.747	1.781	2.162
	ECe	-0.084	-0.063	0.683	-0.320	0.387	0.807	-2.007	-0.312	0.065	0.085

Residual effect ESP 0.8175 and ECe 0.2408

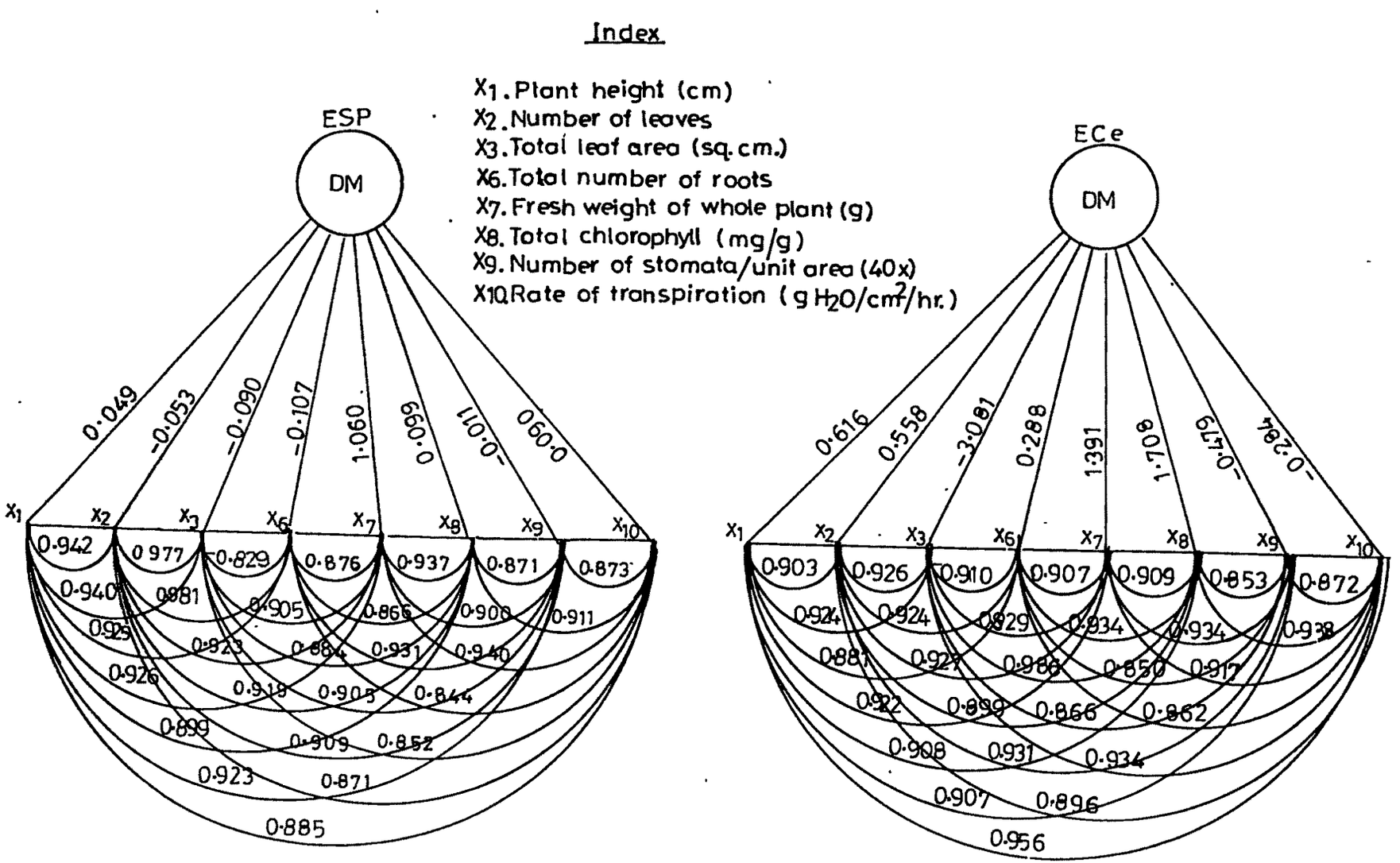


Fig 11. A path diagram and coefficients of characters influencing dry matter in Cashewnut

production through fresh weight of whole plant and total chlorophyll content in presence of both ESP and ECe levels. In presence of ESP levels all indirect effects on dry matter production were either weak positive or negative however, in presence of salinity conditions the indirect effects of dry matter production were positive and high.

4.4.2 Coconut

The path coefficient results are presented in Table 132 and diagramatically shown in Fig. 12. In presence of ESP the characters viz. total number of roots, rate of trnaspiration, total leaf area and plant height contributed maximum direct effect for dry matter production. But the direct contributor to dry matter production in presence of salinity were the characters like fresh weight of whole plant and total chlorophyll content. Similarly the characters like root length, total leaf area and fresh weight of whole plant affected dry matter production indirectly through total number of roots in presence of ESP levels. In presence of salinity condition, the characters viz. total number of roots, plant height, total leaf area, number of leaves, root length and chlorophyll content indirectly affected dry matter production through fresh weight of whole plant.

Table 132 : Path coefficient effect direct (diagonal) and indirect (off diagonal)on dry matter in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Coconut

Characters		Plant height (cm)	Number of leaves	Total leaf area (sq.cm.)	Mortality per cent	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chlorophyll (mg/g)	Total number of stomata per unit area(40x)	Rate of transpiration $gH_2O/cm^2/hr$
Plant height (cm)	ESP	1.248	0.006	1.564	0.645	-0.897	2.425	-0.300	0.783	-1.831	-2.070
	ECe	0.086	0.059	-0.700	0.308	-0.396	-0.827	2.098	0.334	-0.063	-0.083
Number of leaves	ESP	0.911	0.008	1.058	0.519	-0.629	1.811	-0.210	-0.560	-1.296	-1.550
	ECe	0.060	0.084	0.538	0.258	-0.296	-0.629	1.506	0.266	-0.049	-0.063
Total leaf area(sq.cm.)	ESP	1.190	0.005	1.640	0.610	-0.863	2.333	-0.296	-0.806	-1.784	-2.085
	ECe	0.084	0.063	-0.717	0.293	-0.383	-0.826	2.088	0.353	-0.061	-0.081
Mortality per cent	ESP	-0.983	-0.005	-1.121	-0.819	0.710	-1.867	0.271	0.582	1.478	1.698
	ECe	-0.073	-0.060	0.580	-0.362	0.389	0.690	-1.794	-0.247	0.070	0.075
Root length (cm)	ESP	1.235	0.006	1.560	0.641	-0.907	2.393	-0.299	-0.755	-1.830	-2.063
	ECe	0.080	0.059	-0.645	0.332	-0.425	-0.784	2.029	0.306	-0.067	-0.077
Total number of roots	ESP	1.238	0.006	1.565	0.625	-0.888	2.445	-0.297	-0.756	-1.847	-2.088
	ECe	0.085	0.063	-0.706	0.298	0.397	-0.838	2.109	0.345	-0.062	-0.082
Fresh weight of whole plant	ESP	1.185	0.006	1.538	0.703	-0.858	2.302	-0.316	-0.704	-1.797	-2.020
	ECe	0.082	0.058	-0.685	0.298	-0.393	-0.810	2.184	0.337	-0.061	-0.078
Total chlorophyll (mg/g)	ESP	1.053	0.005	1.424	0.513	-0.738	1.991	-0.330	-0.928	-1.362	-1.741
	ECe	0.078	0.061	-0.690	0.244	-0.355	-0.789	2.009	0.367	0.051	-0.072
Stomata / unit (40 x)	ESP	-1.185	-0.006	-1.518	-0.628	0.861	-2.341	0.294	0.656	1.928	1.996
	ECe	-0.074	-0.057	0.593	-0.346	0.392	0.710	-1.822	-0.257	0.073	0.076
Trnaspiration $gH_2O/cm^2/hr$	ESP	-1.195	-0.006	-1.582	-0.643	0.866	-2.361	0.295	0.747	1.781	2.162
	ECe	-0.084	-0.063	0.683	-0.320	0.387	0.807	-2.007	-0.312	0.065	0.085

Residual effect ESP 0.8178 and ECe 0.2408

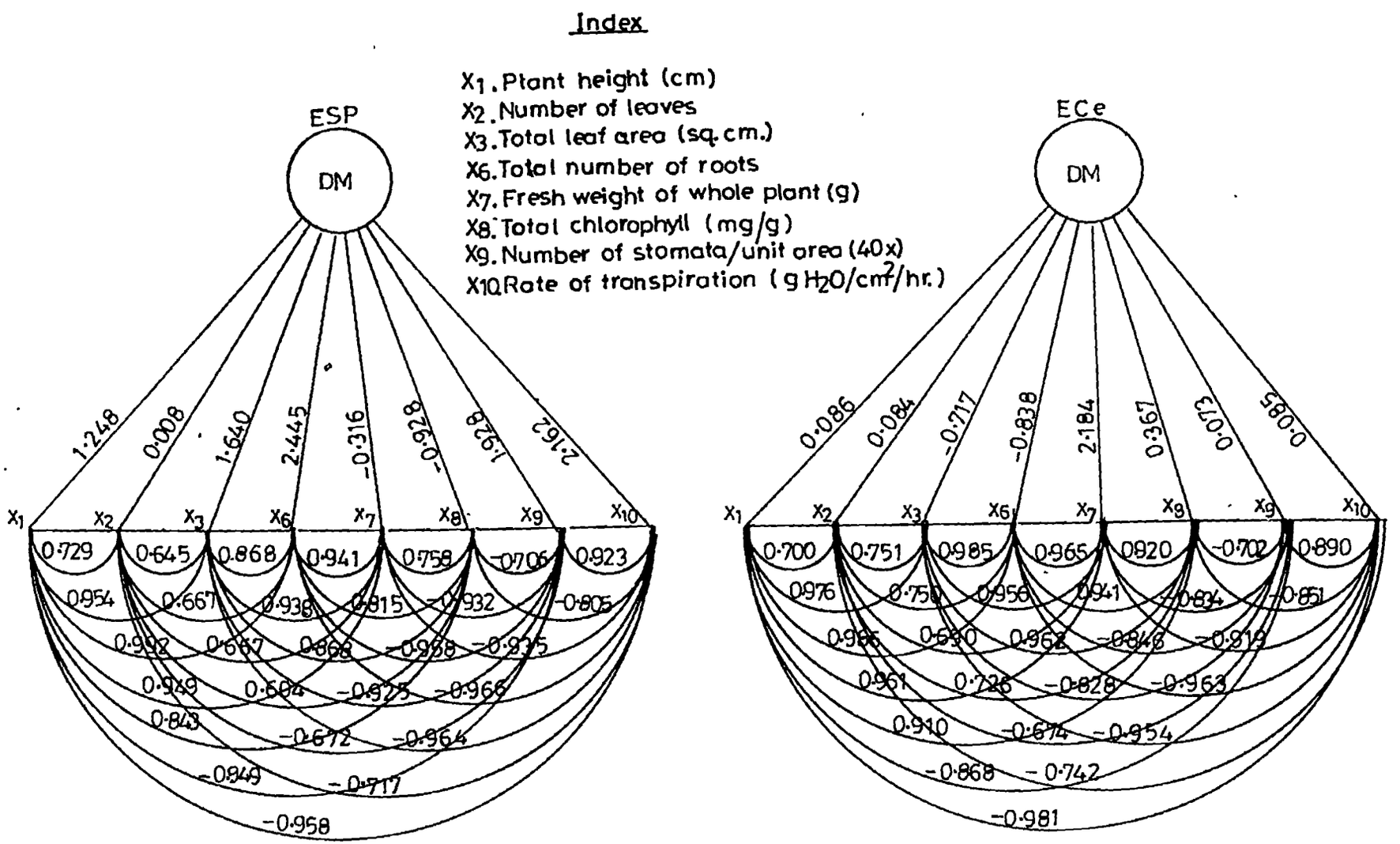


Fig 12. A path diagram and coefficients of characters influencing dry matter in Coconut

4.4.3 Markingnut

The path coefficient results (Table 133 and in Fig. 13) showed that the characters like fresh weight of whole plant and plant mortality had maximum direct effect on dry matter production in presence of both ESP and salinity condition. All the characters except plant mortality and number of stomata affected dry matter production indirectly through fresh weight of whole plant under ESP and salinity condition. All other indirect effects on dry matter production were either weak positive or negative.

4.4.4 Soapnut

The path coefficient results showed in Table 134 and in Fig. 14 indicated that the characters like total number of roots followed by number of leaves and plant height recorded maximum direct effect on dry matter production both in presence of ESP and salinity conditions. Whereas in presence of ESP the next direct contributor for dry matter production was the character like fresh weight of whole plant. In presence of ESP levels all characters except plant mortality were found responsible indirectly effective in dry matter production through fresh weight of whole plant. In presence of salinity

Table 133: Path coefficient effect direct (diagonal) and indirect (off diagonal on dry matter in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Markingnut

Characters		Plant height (cm)	Number of leaves	Total leaf area (sq.cm.)	Mortality per cent	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chlorophyll (mg/g)	Total number of stomata per unit area (40 x)	Rate of trnaspiration $gH_2O/cm^2/hr$
Plant height (cm)	ESP	0.072	0.098	-0.259	-0.041	0.182	-0.005	0.868	0.475	-0.077	-0.132
	ECe	0.123	0.012	-0.014	-0.105	-0.214	0.024	1.201	-0.041	0.020	-0.122
Number of leaves	ESP	0.062	0.110	-0.285	-0.048	0.179	-0.007	0.582	0.515	-0.079	-0.136
	ECe	0.111	0.013	-0.014	-0.100	-0.211	0.023	1.256	-0.044	0.032	-0.125
Total leaf area (sq.cm.)	ESP	0.064	0.107	-0.294	-0.049	0.186	-0.006	0.593	0.524	-0.077	-0.141
	ECe	0.115	0.012	-0.015	-0.100	-0.219	0.023	1.253	-0.042	0.031	-0.131
Mortality per cent	ESP	-0.054	-0.097	0.263	0.035	-0.163	0.005	-0.471	-0.469	0.059	0.104
	ECe	-0.114	-0.011	0.013	0.114	0.185	-0.025	-0.101	0.037	-0.023	0.117
Root length (cm)	ESP	0.063	0.094	-0.261	-0.043	0.210	-0.005	0.567	0.481	-0.072	-0.130
	ECe	0.110	0.011	-0.014	-0.088	-0.240	0.021	1.227	-0.042	0.032	-0.128
Total number of roots	ESP	0.065	0.103	-0.279	-0.042	0.187	-0.006	0.629	0.520	-0.081	-0.147
	ECe	0.115	0.012	-0.013	-0.107	-0.196	0.026	1.125	0.038	0.026	-0.119
Fresh weight of whole plant	ESP	0.064	0.100	-0.270	-0.40	0.184	-0.006	0.645	0.512	-0.081	-0.143
	ECe	0.112	0.012	-0.014	-0.095	-0.223	0.022	1.320	-0.045	0.034	-0.132
Total chlorophyll (mg/g)	ESP	0.064	0.105	-0.286	-0.048	0.187	-0.006	0.614	0.538	-0.079	-0.141
	ECe	0.109	0.012	-0.014	-0.090	-0.215	0.021	1.277	-0.047	0.035	-0.122
Stomata/unit (40 x)	ESP	0.063	-0.099	0.256	0.036	-0.171	0.005	-0.588	-0.482	0.088	0.140
	ECe	-0.084	-0.010	0.014	0.061	0.172	-0.016	-1.056	0.049	-0.042	0.104
Transpiration $gH_2O/cm^2/hr$	ESP	0.060	0.094	-0.260	-0.036	0.171	-0.005	0.578	0.475	-0.078	-0.159
	ECe	0.109	0.012	-0.014	-0.096	-0.222	0.022	1.256	-0.041	0.032	-0.139

Residual effect ESP 0.1581 and ECe 0.1352

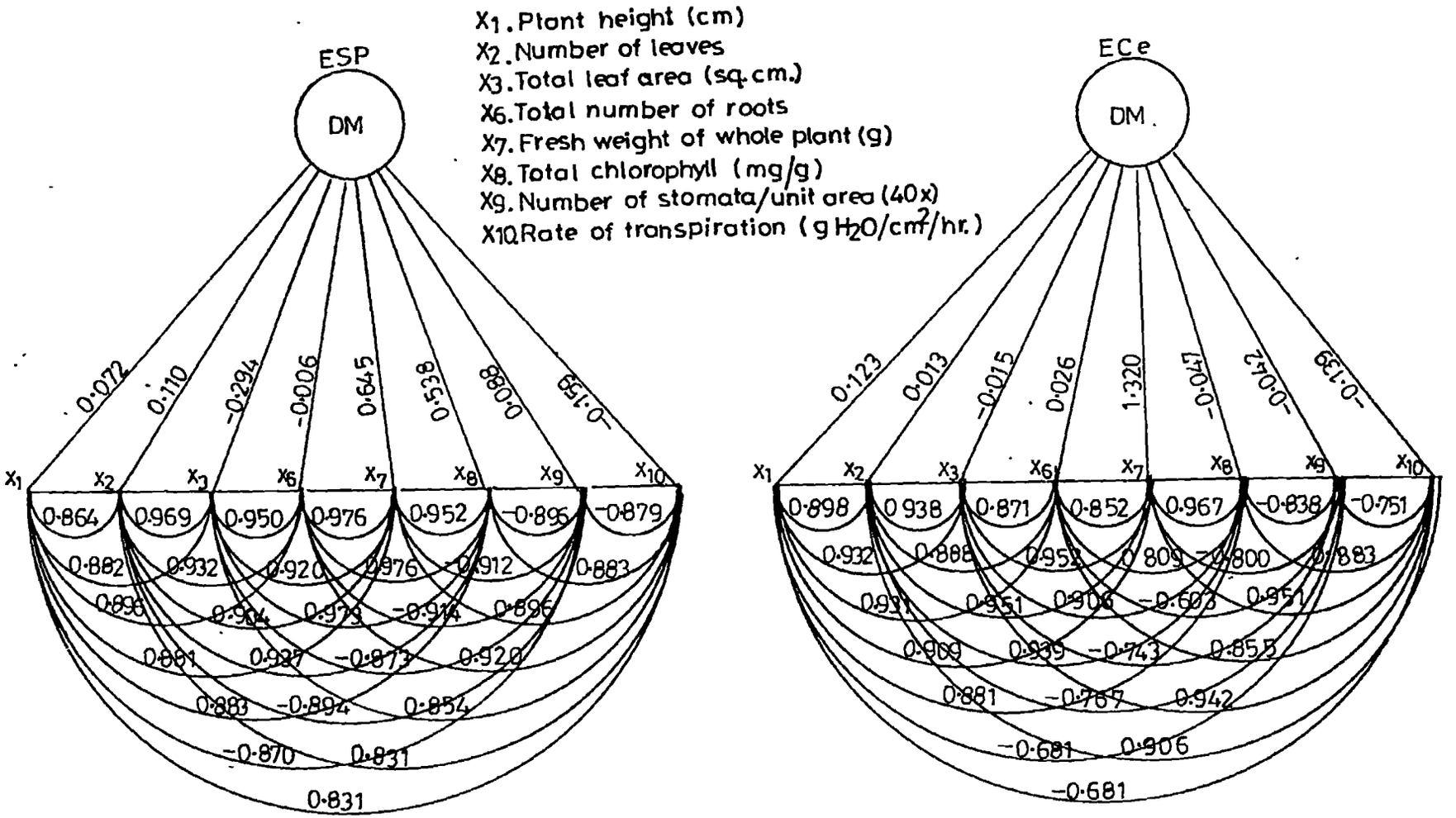


Fig 13. A path diagram and coefficients of characters influencing dry matter in Markingnut

Table 134 : Path coefficient effect direct (diagonal) and indirect (off diagonal on dry matter in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Soapnut.

Characters		Plant height (cm)	Number of leaves	Total leaf area (sq.cm.)	Mortality per cent	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chlorophyll (mg/g)	Total number of stomata per unit area (40x)	Rate of transpiration $gH_2O/cm^2/hr$
Plant height (cm)	ESP	0.010	0.095	-0.077	0.122	-0.191	0.360	0.829	-0.108	-0.030	-0.089
	ECe	0.814	0.634	-0.912	0.010	0.043	0.030	-0.010	0.264	0.110	-0.038
Number of leaves	ESP	0.010	0.099	-0.077	0.116	-0.186	0.356	0.827	-0.108	-0.031	-0.088
	ECe	0.757	0.682	-0.912	0.011	0.050	0.031	-0.010	0.273	0.111	-0.041
Total leaf area (sq.cm.)	ESP	0.010	0.094	-0.081	0.108	-0.195	0.383	0.884	-0.109	-0.031	-0.089
	ECe	0.790	0.661	-0.940	0.010	0.048	0.032	-0.010	0.0271	0.112	-0.040
Mortality per cent	ESP	-0.009	0.080	0.060	-0.144	0.162	-0.270	-0.633	0.092	0.026	0.089
	ECe	-0.739	-0.626	0.853	-0.012	-0.040	-0.026	0.010	-0.276	-0.113	0.038
Root length (cm)	ESP	0.009	0.085	-0.073	0.108	-0.216	0.370	0.850	-0.094	-0.029	-0.082
	ECe	0.618	0.593	-0.796	0.008	0.057	0.030	-0.009	0.236	0.090	-0.039
Total number of roots	ESP	0.009	0.089	-0.078	0.098	-0.202	0.396	0.898	-0.105	-0.030	-0.085
	ECe	0.685	0.593	-0.849	0.009	0.048	0.036	-0.009	0.241	0.092	-0.036
Fresh weight of whole plant	ESP	0.009	0.090	-0.079	0.101	-0.203	0.392	0.905	-0.105	-0.030	-0.086
	ECe	0.757	0.654	-0.898	0.011	0.048	0.031	-0.011	0.291	0.114	-0.039
Total chlorophyll (mg/g)	ESP	0.010	0.093	-0.076	0.115	-0.177	0.363	0.824	-0.115	-0.030	-0.089
	ECe	0.722	0.627	-0.856	0.011	0.045	0.029	-0.010	0.298	0.113	-0.037
Stomata/unit (40 x)	ESP	-0.009	0.090	0.070	-0.110	0.181	-0.347	-0.787	0.102	0.034	0.082
	ECe	-0.717	-0.603	0.841	-0.010	-0.041	-0.026	0.010	-0.270	-0.125	0.038
Transpiration $gH_2O/cm^2/hr$	ESP	0.009	0.087	-0.072	0.129	-0.178	0.338	0.781	-0.103	-0.028	-0.100
	ECe	0.713	0.632	-0.831	0.010	0.051	0.029	-0.009	0.252	0.107	-0.044

Residual effect ESP 0.2059 and ECe 0.2291

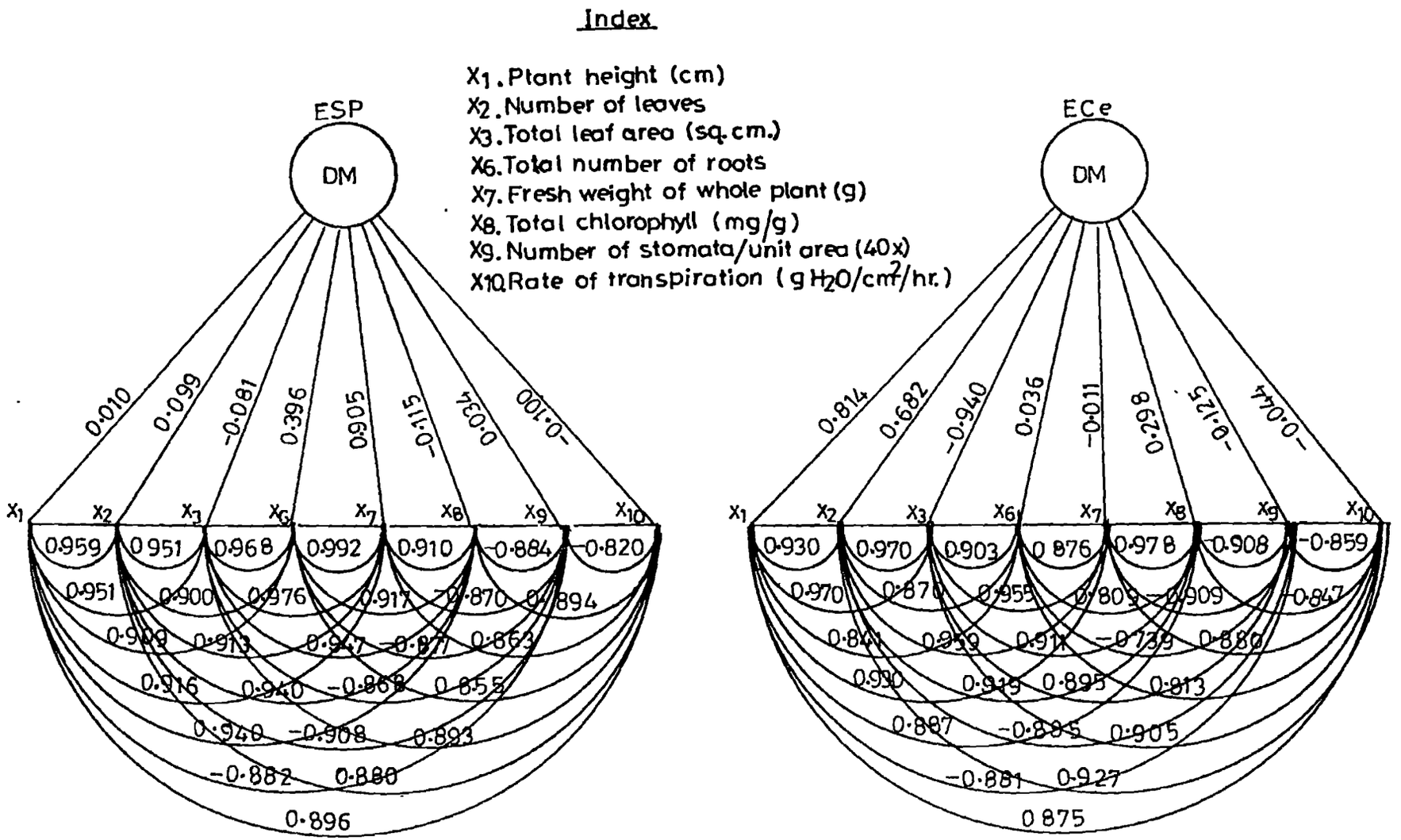


Fig 14. A path diagram and coefficients of characters influencing dry matter in Soapnut

condition most of the characters were found to be responsible in affecting dry matter production via plant height and number of leaves.

4.4.5 Phalsa

Fresh weight of the whole plant had maximum direct positive effect on dry matter production in presence of both ESP and salinity conditions. Whereas total leaf area contributed directly to dry matter production in presence of salinity condition. In presence of ESP level, the characters viz. plant height, number of leaves, total leaf area, root length, total number of roots and total chlorophyll were found to be responsible in affecting dry matter production indirectly through fresh weight of whole plant. While in presence of salinity through total leaf area most of the characters affected indirectly the dry matter production (Table 135 and Fig. 15).

4.4.6 Karonda

The path coefficient result in Table 136 and Fig. 16 showed that the characters viz. fresh weight of whole plant, number of leaves and total chlorophyll recorded maximum direct influence on dry matter production in ESP as well as in salinity condition. The results further

Table 135: path coefficient effect direct (diagonal) and indirect (off diagonal) on dry matter in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Phalsa

Characters		Plant height (cm)	Number of leaves	Total leaf area (sq.cm.)	Mortality per cent	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chlorophyll (mg/g)	Total number of stomata per unit (40 x)	Rate of transpiration $gH_2O/cm^2/hr$
Plant height (cm)	ESP	-0.262	0.385	-0.489	0.155	0.175	-0.254	1.488	-0.245	-0.069	0.023
	ECe	0.488	-0.443	0.927	0.087	-0.336	0.159	0.154	-0.108	0.173	-0.109
Number of leaves	ESP	-0.248	0.406	-0.497	0.151	0.181	-0.255	1.544	-0.259	-0.072	0.020
	ECe	0.474	-0.455	0.956	0.060	-0.351	0.162	0.157	-0.107	0.178	-0.108
Total leaf area (sq/cm.)	ESP	-0.250	0.395	-0.511	0.135	0.174	-0.257	1.587	-0.269	-0.069	-0.017
	ECe	0.461	-0.444	0.980	0.056	-0.348	0.154	0.158	-0.115	0.178	-0.101
Mortality per cent	ESP	0.217	-0.328	0.369	-0.187	-0.153	0.202	-1.073	0.177	0.061	-0.024
	ECe	-0.453	0.432	-0.859	-0.064	0.321	-0.153	-0.145	0.090	-0.163	0.106
Root length (cm)	ESP	-0.237	0.380	-0.459	0.148	0.193	-0.245	1.413	-0.233	-0.068	0.021
	ECe	0.443	0.432	0.923	0.053	-0.370	0.150	0.150	-0.105	0.173	-0.093
Total number or roots	ESP	-0.248	0.385	-0.488	0.140	0.176	-0.269	1.536	-0.255	-0.069	0.021
	ECe	0.443	-0.421	0.863	0.055	-0.317	0.175	0.143	-0.096	0.167	-0.110
Fresh weight of whole plant	ESP	-0.242	0.389	-0.504	0.124	0.170	-0.257	1.610	-0.272	-0.069	0.016
	ECe	0.470	-0.447	0.974	0.058	-0.348	0.157	0.159	-0.113	0.179	0.104
Total chlorophyll (mg/g)	ESP	-0.230	0.377	-0.494	0.119	0.161	-0.246	1.573	-0.279	-0.068	0.013
	ECe	0.435	-0.403	0.934	0.047	-0.321	0.140	0.149	-0.121	0.166	-0.088
Stomata/unit (40 x)	ESP	0.238	-0.386	0.474	-0.150	-0.172	0.245	-1.461	0.247	0.076	-0.020
	ECe	-0.445	0.430	-0.925	-0.055	0.338	-0.155	-0.151	0.106	-0.189	0.100
Trnaspiration $gH_2/O/cm^2/hr$	ESP	-0.181	0.241	-0.265	0.134	0.123	-0.167	0.800	-0.109	0.046	0.033
	ECe	0.441	-0.410	0.819	0.056	-0.286	0.160	0.137	-0.088	0.157	-0.121

Residual effect ESP 0.1341 and ECe -0.4685

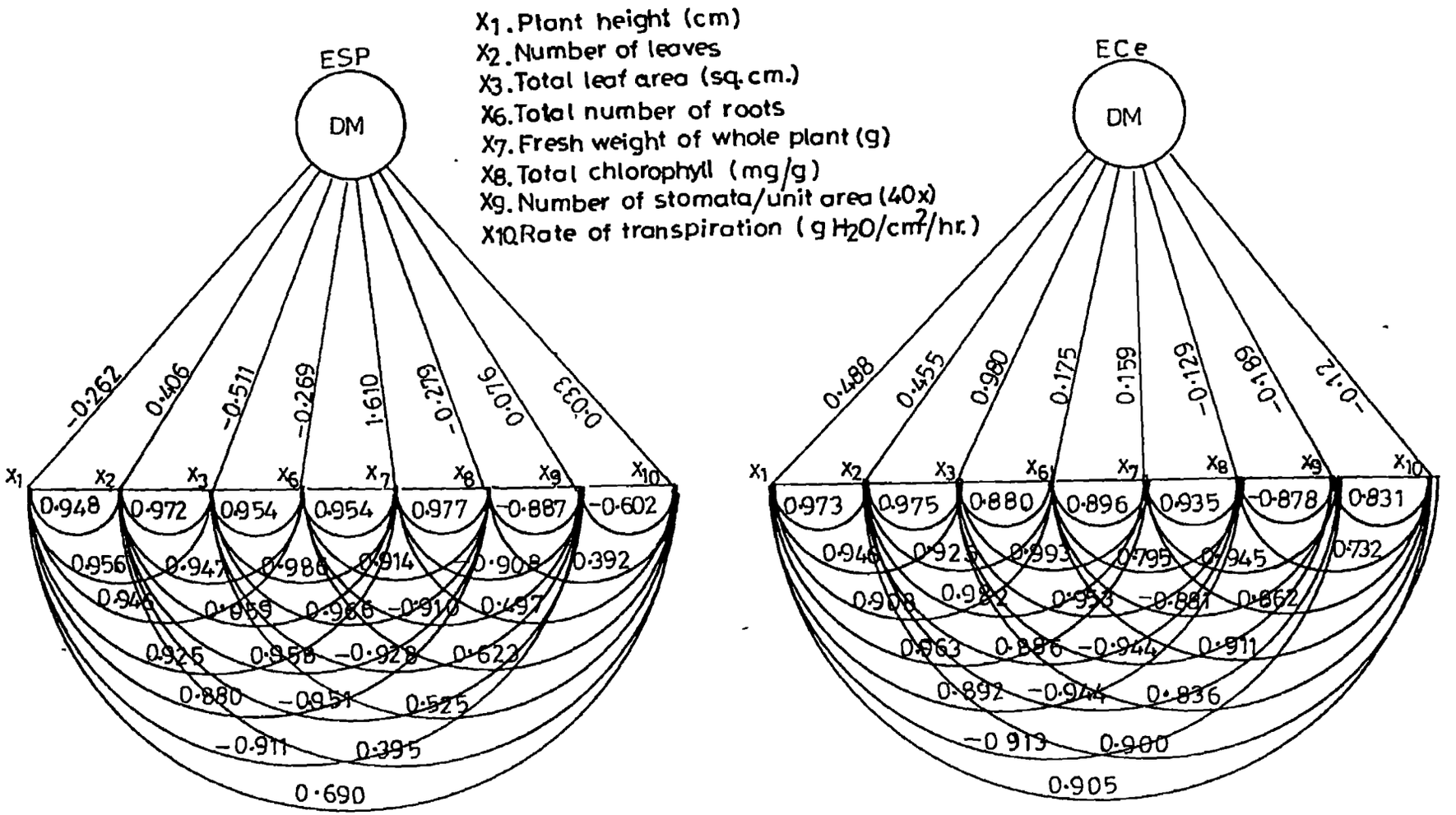


Fig 15. A path diagram and coefficients of characters influencing dry matter in Phalsa

Table 136 : Path coefficient effect direct (diagonal) and indirect (off diagonal) on dry matter in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Karonda.

Characters		Plant height (cm)	No.of leaves	Total leaf area (sq.cm.)	Mortality per cent	Root length (cm)	Total no.of roots	Total no.of branches	Fresh weight of whole plant	Total chlorophyll (mg/g)	Total number of stomata per unit area(40x)	Rate of transpiration $gH_2O/cm^2/hr$
Plant height (cm)	ESP	-0.322	0.187	-0.268	0.164	-0.270	0.121	0.113	1.004	0.127	0.093	-0.039
	ECe	0.213	0.324	-0.617	-0.060	0.204	-0.257	0.049	0.722	0.114	-0.158	0.399
Number of leaves	ESP	-0.307	0.196	-0.261	0.166	-0.255	0.113	0.108	0.981	0.125	0.087	-0.037
	ECe	0.205	0.336	-0.647	-0.050	0.196	-0.250	0.049	0.748	0.124	-0.159	0.410
Total leaf area(sq.cm.)	ESP	-0.309	0.183	-0.279	0.157	-0.284	0.123	0.113	1.032	0.127	0.100	-0.037
	ECe	0.200	0.332	-0.655	-0.045	0.183	-0.235	0.048	0.738	0.127	-0.152	0.412
Mortality per cent)	ESP	0.304	-0.188	0.253	-0.174	0.258	-0.114	-0.108	-0.983	-0.129	-0.085	0.037
	ECe	-0.162	-0.214	0.373	0.079	-0.183	0.218	-0.037	-0.463	-0.064	0.133	-0.259
Root length (cm)	ESP	-0.269	0.154	-0.245	0.139	-0.323	0.112	0.110	1.010	0.112	0.101	-0.033
	ECe	0.201	0.304	-0.554	-0.067	0.216	-0.271	0.046	0.679	0.101	-0.160	0.362
Total no.of roots	ESP	-0.303	0.173	-0.268	0.155	-0.282	0.128	0.112	1.020	0.126	0.099	-0.038
	ECe	0.199	0.305	-0.559	-0.062	0.212	-0.276	0.046	0.680	0.102	-0.155	0.364
Total no.of branches	ESP	-0.291	0.169	-0.253	0.149	-0.284	0.115	0.125	0.973	0.117	0.093	-0.035
	ECe	0.189	0.296	-0.577	-0.054	0.180	-0.230	0.055	0.663	0.106	-0.142	0.360
Fresh weight of whole plant	ESP	-0.297	0.177	-0.265	0.157	-0.300	0.120	0.112	1.088	0.126	0.096	-0.036
	ECe	0.201	0.329	-0.633	0.048	0.192	-0.246	0.048	0.764	0.120	0.151	0.391
Total chlorophyll (mg/g)	ESP	-0.307	0.185	-0.266	0.169	-0.272	0.122	0.110	1.028	0.133	0.091	-0.038
	ECe	0.184	0.316	-0.128	-0.038	0.166	-0.214	0.044	0.692	0.132	-0.142	0.402
Stomata/unit (40 x)	ESP	0.275	-0.157	0.254	-0.134	0.299	-0.116	-0.109	-0.959	-0.111	-0.109	0.032
	ECe	-0.193	-0.306	0.569	0.060	-0.199	0.246	-0.045	-0.660	-0.107	0.174	-0.377
Transpiration $gH_2O/cm^2/hr$	ESP	0.281	-0.161	0.230	-0.145	0.241	0.111	-0.098	-0.885	0.113	-0.079	0.045
	ECe	0.199	0.323	-0.633	-0.048	0.184	-0.235	0.046	0.701	0.125	-0.154	0.426

Residual effect ESP 0.1258 and ECe 0.2022

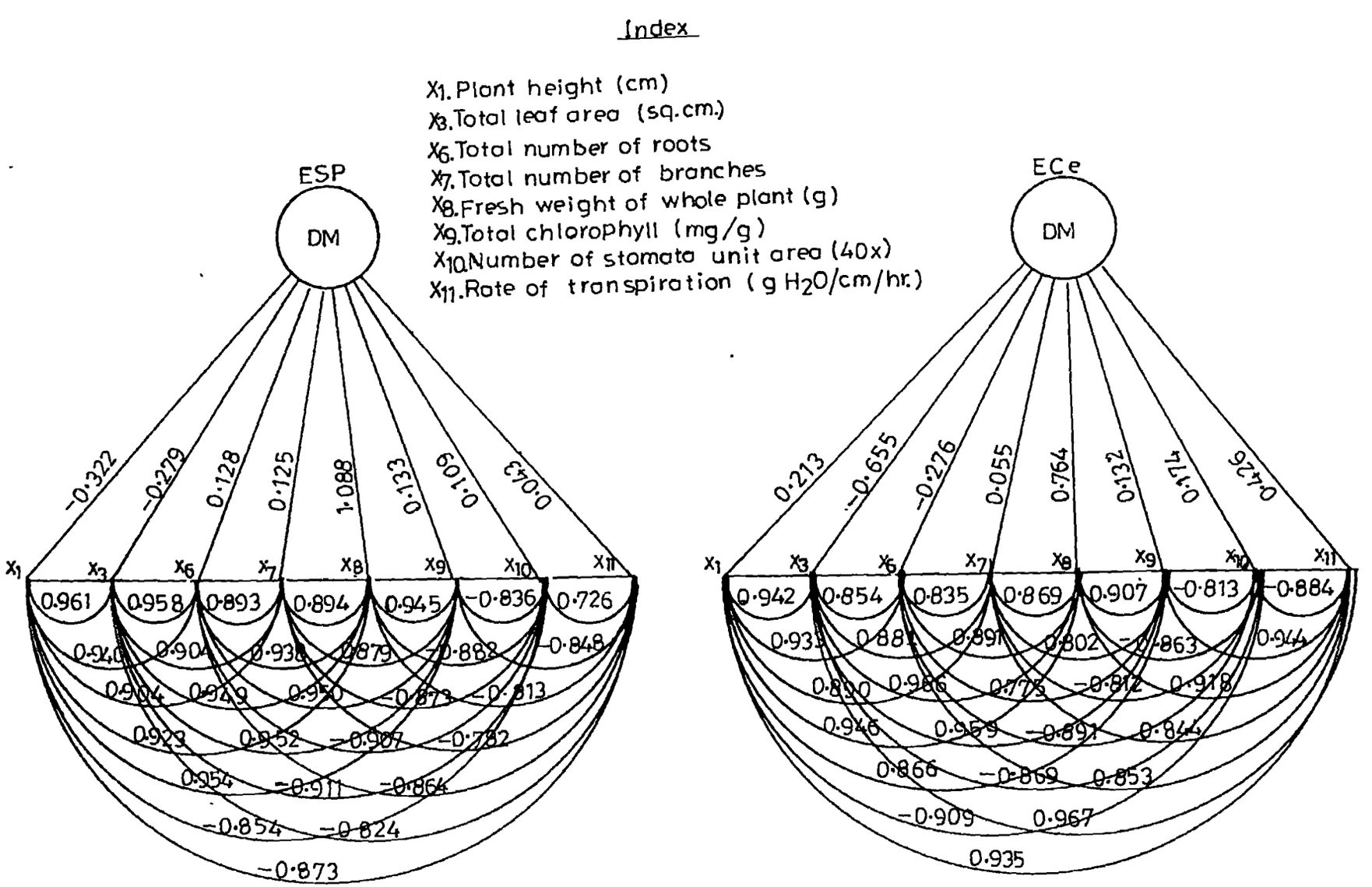


Fig 16. A path diagram and coefficients of characters influencing dry matter in Karonda

revealed that all the characters except plant mortality, number of stomata and rate of trnaspiration contributed indirectly through fresh weight of whole plant in presence of ESP and salinity levels. Similarly, the character rate of trnaspiration in presence of salinity remained as mediator for all the characters except plant mortality and number of stomata for influencing dry matter production indirectly.

4.4.7 Passion fruit

The two characters viz. fresh weight of whole plant and plant mortality exhibited maximum direct influence on dry matter production both in presence of ESP and salinity. In presence of ESP levels all characters except plant mortality and number of stomata influenced indirectly the dry matter production through fresh weight of whole plant. While plant height, total leaf area, total number of roots. fresh weight of whole plant and number of stomata were found responsible in affecting dry matter production indirectly via chlorophyll content in presence of salinity levels(Table 137 and Fig. 17).

4.4.8 Drumstick

In presence of ESP and salinity levels the characters like fresh weight of whole plant and plant mortality contributed maximum direct influence on dry

Table 137: Path coefficient effect direct (diagonal) and indirect (off diagonal) on dry matter in presence of exchangeable sodium percentage (ESP) and salinity (ECe) in Passion fruit

Characters		Plant height (cm)	Number of leaves	Total leaf area (sq.cm.)	Mortality per cent	Root length (cm)	Total number of roots	Fresh weight of whole plant	Total chlorophyll (mg/g)	Total number of stomata per unit (40 x)	Rate of transpiration gH_2O/cm^2 hr
Plant height (cm)	ESP	-0.045	-0.469	-0.023	-0.237	-0.467	0.025	1.825	0.189	-0.226	0.030
	ECe	0.368	-0.010	0.072	-1.753	0.292	-0.001	0.576	2.187	0.002	-0.828
Number of leaves	ESP	-0.043	-0.488	-0.024	-0.247	-0.484	0.026	1.829	0.194	-0.228	0.017
	ECe	0.161	-0.023	0.063	0.241	-0.144	-0.001	0.301	-0.768	0.234	0.019
Total leaf area(sq.cm.)	ESP	-0.044	-0.480	0.024	-0.247	-0.760	0.025	1.762	0.191	-0.230	0.019
	ECe	0.322	-0.018	0.082	-1.110	0.130	-0.002	0.515	1.140	0.023	-0.448
Mortality per cent	ESP	0.042	0.475	0.024	0.253	0.438	-0.025	-1.647	-0.184	0.216	-0.020
	ECe	-0.301	-0.003	-0.043	2.148	-0.412	0.001	-0.462	-2.918	0.026	1.030
Root length (cm)	ESP	-0.038	-0.430	-0.020	-0.202	-0.549	0.025	1.841	0.185	-0.192	0.026
	ECe	-0.249	0.008	-0.025	2.055	-0.431	0.008	-0.372	-2.955	0.036	1.077
Total number of roots	ESP	-0.042	-0.465	-0.022	-0.230	-0.502	0.027	1.782	0.197	-0.016	0.547
	ECe	0.274	-0.017	0.071	-0.765	0.065	-0.002	0.427	0.670	0.019	-0.278
Fresh weight of whole plant	ESP	-0.041	-0.440	-0.021	-0.206	-0.497	0.024	2.026	0.178	-0.214	0.028
	ECe	0.354	-0.012	0.071	-1.653	0.267	-0.001	0.600	2.033	0.007	-0.765
Total chlorophyll (mg/g)	ESP	-0.042	-0.465	-0.023	-0.239	-0.499	0.027	1.775	0.204	-0.215	0.009
	ECe	-0.271	-0.006	-0.032	2.106	-0.428	0.000	-0.410	-2.974	0.033	1.075
Stomata/unit (40 x)	ESP	0.039	0.424	0.021	0.208	0.401	0.022	-1.646	-0.167	0.263	-0.026
	ECe	-0.016	0.020	-0.033	-0.990	0.276	0.001	-0.078	1.724	-0.056	-0.611
Transpiration $gH_2O/cm^2/hr$	ESP	-0.012	-0.070	-0.004	-0.045	-0.126	0.004	0.498	0.016	-0.058	0.115
	ECe	-0.276	-0.005	-0.033	2.002	-0.420	0.000	-0.416	-2.893	0.031	1.105

Residual effect ESP 0.5175 and ECe 0.1445

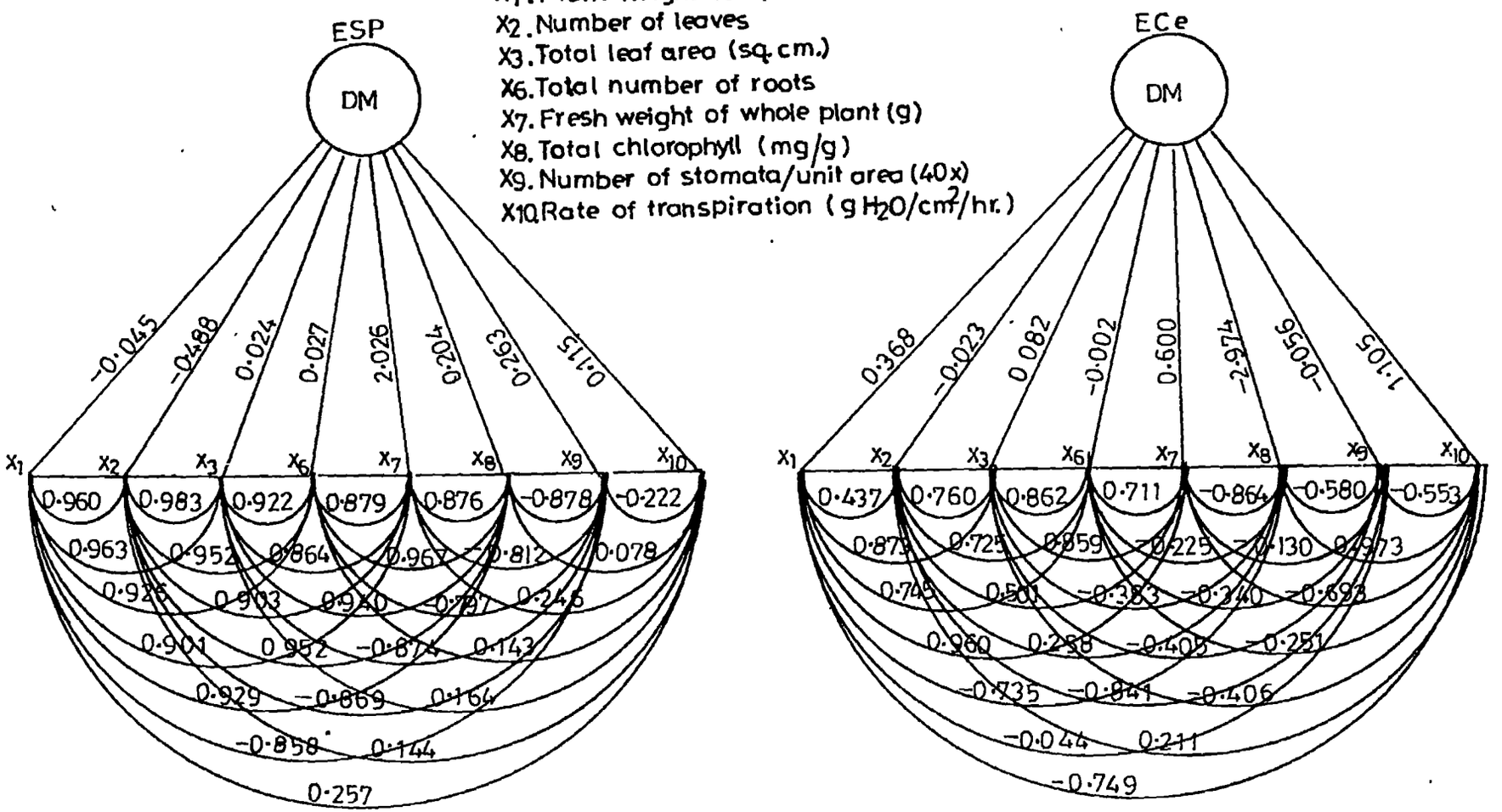


Fig 17. A path diagram and coefficients of characters influencing dry matter in Passion fruit

Table 138: Path coefficient effect direct (diagonal) and indirect(off diagonal) on dry matter in presence of exchangeable sodium percentage (ESP) and salinity(ECe) in Drumstick

Characters		Plant height (cm)	No.of leaves	Total leaf area (sq.cm.)	Mortality per cent	Root length (cm)	Total no.of roots	Root diameter (mm)	Fresh weight of whole plant	Total chlorophyll (mg/g)	Total number of stomata per unit area(40x)	Rate of transpiration $gH_2/cm^2/hr$
Plant height (cm)	ESP	0.234	0.224	-0.391	-0.301	-0.210	0.248	-0.207	0.964	0.196	0.125	0.073
	ECe	-0.294	1.030	0.267	-0.623	0.494	-0.451	0.184	1.735	-1.285	-0.138	0.011
No. of leaves	ESP	0.223	0.235	-0.373	-0.304	-0.196	0.242	-0.206	0.944	0.197	0.125	0.070
	ECe	-0.276	1.098	0.275	-0.675	0.469	-0.417	0.181	1.634	-1.264	-0.133	-0.015
Total leaf area(sq.cm.)	ESP	0.228	0.218	-0.401	-0.296	-0.213	0.255	-0.214	0.983	0.192	0.128	0.068
	ECe	-0.276	1.061	0.285	-0.642	0.501	-0.442	0.182	1.725	-1.344	-0.137	0.006
Mortality per cent	ESP	-0.212	-0.215	0.358	0.331	0.187	-0.237	0.210	-0.930	-0.195	-0.117	-0.065
	ECe	0.259	-1.046	-0.258	0.708	-0.479	0.367	-0.176	-0.509	1.168	0.122	0.017
Root length (cm)	ESP	0.217	0.203	-0.378	-0.274	-0.226	0.258	-0.206	0.955	0.174	0.124	0.064
	ECe	-0.245	0.869	0.241	-0.572	0.593	-0.391	0.160	1.511	-1.146	-0.124	0.010
Total no.of roots	ESP	0.218	0.213	-0.382	0.294	-0.218	0.267	-0.218	0.968	0.185	0.129	0.062
	ECe	-0.257	0.887	0.244	-0.504	0.449	-0.516	0.160	1.585	-1.169	-0.125	0.041
Root diameter (mm)	ESP	0.214	0.213	-0.379	-0.308	-0.205	0.257	-0.227	0.977	0.186	0.128	0.062
	ECe	-0.271	0.996	0.260	-0.624	0.475	-0.413	0.199	1.664	-1.243	-0.124	-0.024
Fresh weight of whole plant	ESP	0.223	0.219	-0.390	-0.305	-0.215	0.256	-0.219	1.011	0.190	0.129	0.066
	ECE	-0.284	0.999	0.273	-0.595	0.498	-0.455	0.185	1.797	-1.351	-0.136	0.020
Total chlorophyll (mg/g)	ESP	0.222	0.224	-0.373	-0.313	-0.191	0.239	-0.204	0.928	0.207	0.122	0.068
	ECe	-0.275	1.010	0.278	-0.602	0.494	-0.439	0.180	1.765	-1.375	-0.134	0.025
Stomata/unit (40 x)	ESP	0.219	0.221	-0.384	-0.291	-0.210	0.257	-0.217	0.974	0.189	0.133	0.065
	ECe	-0.284	1.015	0.271	-0.601	0.514	-0.450	0.173	1.706	-1.283	-0.144	0.017
Transpiration $gH_2O/cm^2/hr$	ESP	0.216	0.207	-0.345	-0.272	-0.184	0.212	-0.178	0.846	0.177	0.110	0.079
	ECe	0.015	0.081	-0.008	-0.061	-0.029	0.105	0.024	-0.181	0.169	0.012	-0.203

Residual effect ESP 0.1574 and ECe 0.2126

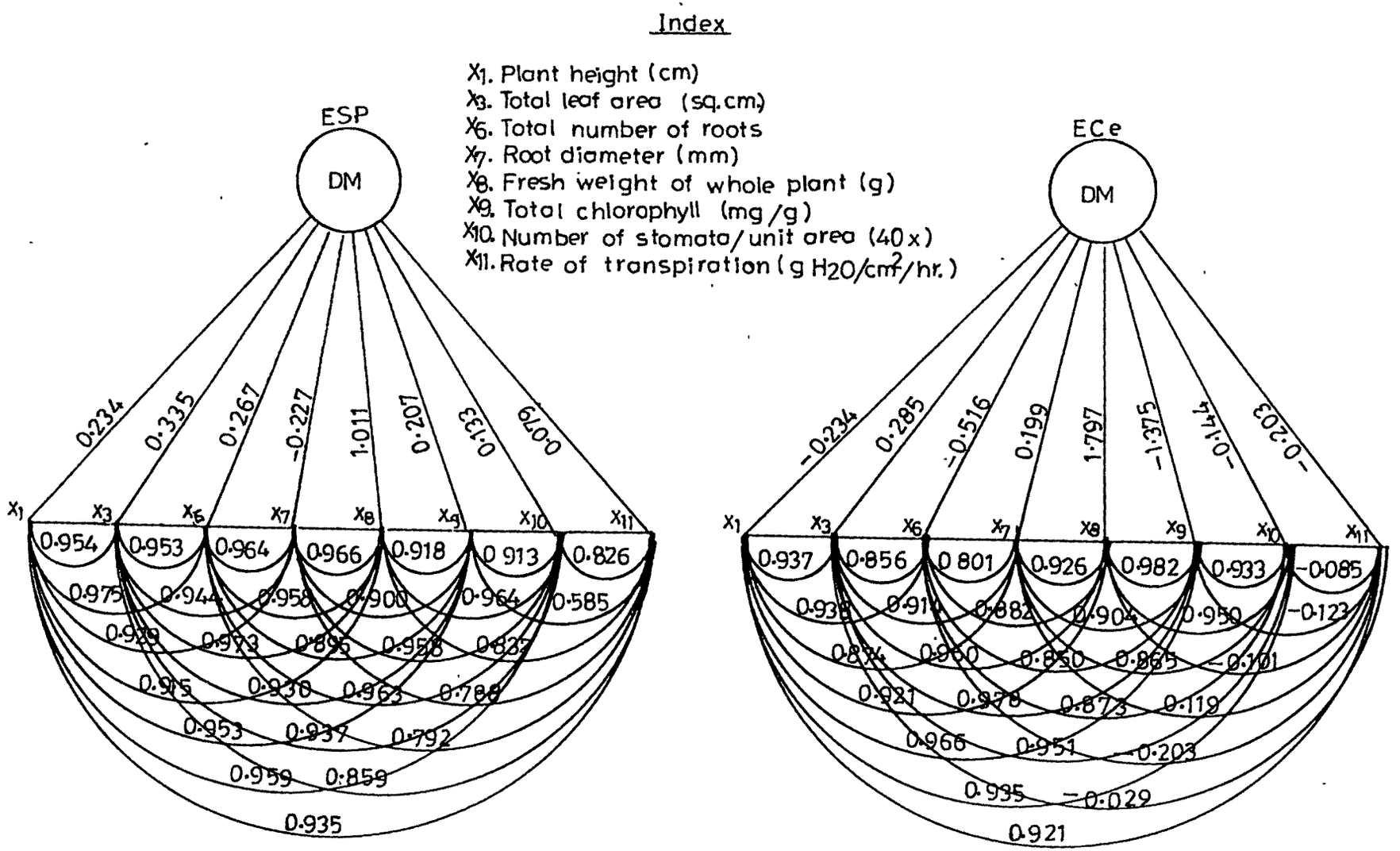


Fig 18. A path diagram and coefficients of characters influencing dry matter in Drumstick

matter production (Table 138 and diagramatically shown in Fig. 18). Whereas in salinity condition the next highest contributor in influencing dry matter production was the number of leaves followed by root diameter. The results further indicated that all the characters except plant mortality and rate of tnraspiration affected dry matter production indirectly through fresh weight of whole plant in presence of ESP and salinity levels. While in presence of salinity except plant mortality all the characters were found to be affecting indirectly the dry matter production through number of leaves. Whereas in presence of ESP all characters except plant mortality were found to be effecting dry matter production indirectly via total number of roots.

Chapter 5

DISCUSSION

The investigation was conducted to study the effect of various levels of exchangeable sodium percentage and salinity in soil on the growth, physiological parameters and chemical composition of eight fruit species. The results obtained are discussed in the following way.

5.1 Study of soil exchangeable sodium percentage

5.1.1 Effect of ESP on growth

Plant height : When ESP was 41 (problematic soil) and 60 the adverse effect was noticed right from 60 days after planting. The maximum height depression was recorded in phalsa, drumstick and cashew at 4, 8 and 12 months of planting, respectively under the highest level of ESP.

Number of leaves : The maximum reduction in number of leaves was in passion fruit, cashew and markingnut at 120 days, in markingnut, passion fruit and drumstick at 240 days and in cashew, markingnut and passion fruit at 360 days after planting under ESP 60.

Stem diameter : Pronounced adverse effect was noticed when ESP was increased to 60 ESP in passion fruit at and above 240 days after planting

Plant spread : The maximum plant spread reduction was observed in karonda, markingnut and phalsa, whereas it was medium intermediate low reduction in drumstick, coconut and cashew and was minimum in passion fruit and soapnut at ESP 60.

Total leaf area : The leaf area was severely reduced under ESP 12 in markingnut and soapnut as compared to the rest of the fruit species.

Root length : Soapnut and phalsa showed lowest depression in root length at initial ESP level. Karonda and passion fruit showed least depression in root length, whereas markingnut and soapnut showed higher depression under highest ESP level.

Root volume : Soapnut and karonda were least affected at lowest level of ESP. In markingnut the root volume was severely decreased even at lowest ESP level. The root volume was not so much affected with the higher levels of ESP in coconut and cashew.

Number of primary roots : Number of primary roots were least affected in coconut at lower level of ESP, while in

passion fruit the primary roots were severely affected at the same level. But cashew, markingnut and drumstick showed highest depression at the highest level of ESP.

Number of secondary roots : Karonda and coconut showed lowest number of secondary roots under lowest level of ESP. Passion fruit showed highest depression under the lowest level. Markingnut, soapnut and cashew were severely affected under highest level of ESP.

Total number of roots : Karonda showed least depression under lowest level of ESP. Passion fruit showed highest depression under lowest level. Markingnut, soapnut and cashew were badly affected under the higher levels of ESP.

Mortality : The mortality was noticed under ESP 12 onwards in markingnut and passion fruit, while in cashew the mortality appeared at ESP 24 and above. Cent per cent mortality was recorded in markingnut and cashew under ESP 36 and in passion fruit under ESP 41. The results indicated that markingnut, cashew and passion fruit are most susceptible to ESP levels, whereas the intermediate tolerant crops were soapnut and drumstick. The mortality symptoms in coconut karonda and phalsa were observed in ESP 36 onwards and 100 per cent mortality was recorded under ESP 60. This indicated that these crops were more tolerant to higher ESP levels.

Fresh weight of whole plant, roots and top : In different fruit crops degree of depression was different at the same ESP level. Cashew and karonda showed lowest depression in the fresh weight of whole plant under the lowest level of ESP. Coconut and passion fruit were least affected under the highest level of ESP. Fresh weight of root was least affected under the lowest level of ESP in coconut and cashew. The tops of karonda and soapnut were severely depressed under the higher level of ESP. At the start of ESP level, the fruit crop species like cashew, markingnut and karonda showed least depression percentage of dry weight of whole plant as compared to control. But passion fruit showed maximum depression percentage of dry weight of whole plant even under the same level of ESP. Relationship between relative growth (fresh weight of whole plant) per cent of each species and levels of ESP was therefore, worked out and presented in a tabulated form and Fig. 19. The theoritical growth values were obtained from regression equation given in below which are derived from the observed values.

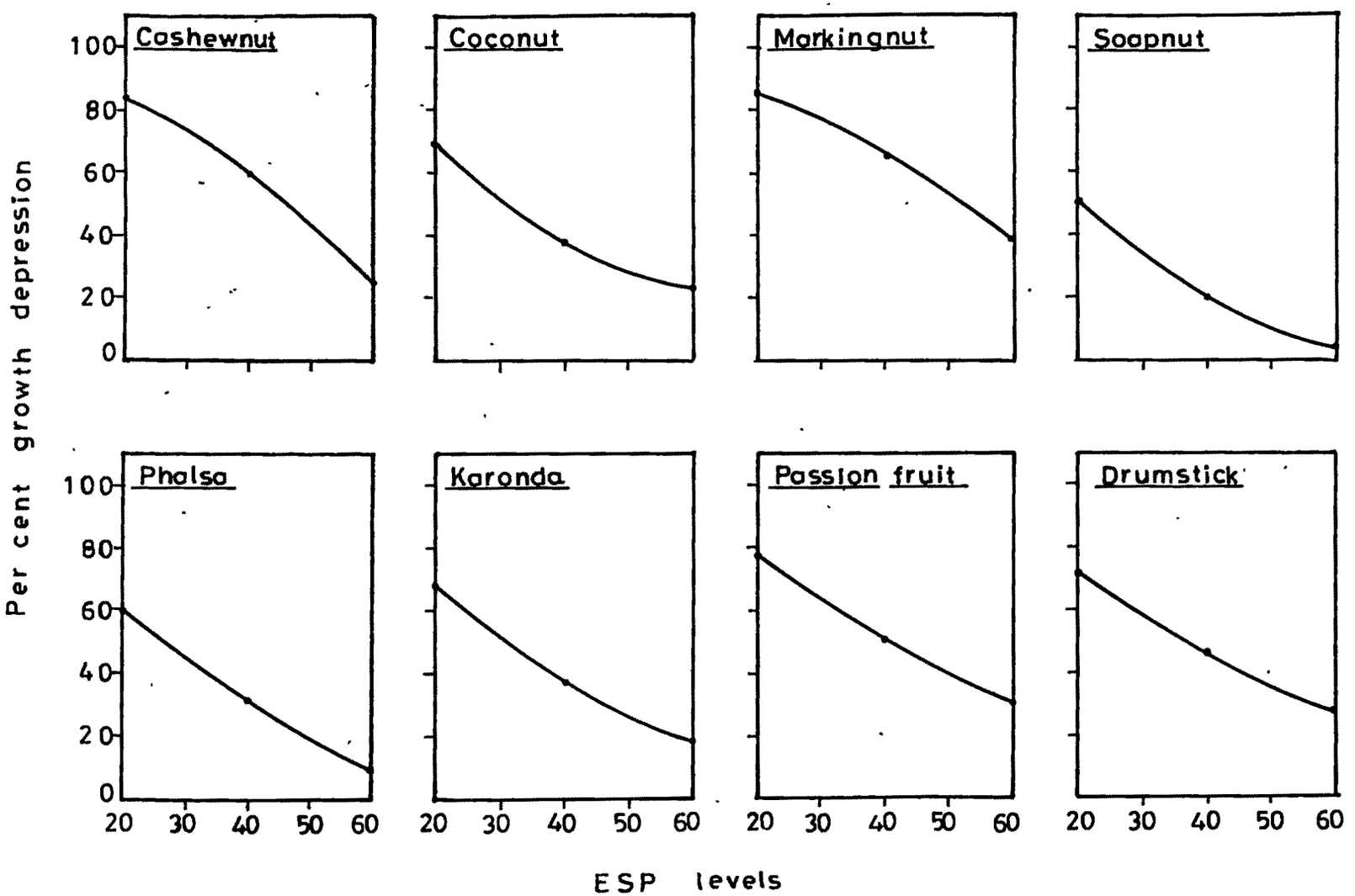


Fig 19. Relationship between relative growth (Per cent) and levels of ESP

Y =	103.72	-0.5863** X	-0.014** X^2	Cashew
	S.E. ±	0.2875	4.4531	R^2 0.9481
Y =	2.43	-0.5466** X	-0.0007 X^2	Coconut
	S.E. ±	0.1186	1.8311	R^2 0.9542
Y =	47.28	-1.6432** X	4.8697 X^2	Markingnut
	S.E. ±	0.5573	0.0086	R^2 0.8316
Y =	268.91	-7.5388** X	-0.8628** X^2	Soapnut
	S.E. ±	0.0091	0.0091	R^2 0.9725
Y =	86.28	-2.1451** X	0.0171** X^2	Phalsa
	S.E. ±	0.1175	1.8151	R^2 0.9871
Y =	357.24	-0.1211 X	-2.7525** X^2	Karonda
	S.E. ±	0.0079	0.0001	R^2 0.9368
Y =	128.60	-4.0112** X	0.0124 X^2	passion fruit
	S.E. ±	0.5199	0.0080	R^2 0.9783
Y =	225.03	-5.2928** X	-0.0135 X^2	Drumstick
	S.E.±	1.7585	0.0271	R^2 0.9131

Where, Y = growth values and X = ESP level.

The analysis indicated that the variation of fresh weight of whole plant was ranged from 83.16 (markingnut) to 98.71 (phalsa). Similar high trend of variation in fresh weight of whole plant was reported by Sadaria (1989) in eight tree species. In support of these findings Patil (1980) also reported a relationship

between relative growth (weight of whole plant) per cent of each fruit crops against ESP level.

The relative per cent growth (calculated from the regression equations) was plotted against ESP levels for each fruit crop. The estimated ESP tolerance indices fro various fruit crops are presented in Table 139.

Table 139 : ESP tolerance indices of different fruit crops

Fruit crops/ Levels of ESP	Growth depression per cent		
	20 ESP	40 ESP	60 ESP
Cashew	15.75	41.30	65.25
Coconut	31.19	60.20	77.73
Markingnut	14.83	37.93	61.37
Soapnut	50.12	80.14	97.39
Phalsa	41.83	67.75	91.03
Karonda	33.39	62.24	83.00
Passion fruit	22.11	48.46	70.01
Drumstick	29.55	49.55	74.12

The results revealed that the fruit crops viz. soapnut, phalsa, karonda and coconut were highly sodium tolerant, while the fruit crops like drumstick and passion fruit showed medium tolerance. The remaining two fruit crops namely cashew and

markingnut were highly sensitive. All the fruit speciese exhibited 20, 40 and 60 per cent growth depression range from 14.83 to 80.12, 37.93 to 80.14 and 61.37 to 97.39, respectively under ESP.

The growth suppression in sodic soils might be due to the poor soil structure leading to the problems of aeration, low water availability and nutritional disorders. These factors reduced the metabolic process within plants and also prevented the root gorwth. Different view i.e. structural deterioration of physical properties of soil, direct toxic effect, production of toxic substances within plants and nutritional imbalances etc. have been put forth to explain the detrimental effects of excess exchangeable sodium on plant growth (Bernstein and Hayward, 1958; Hayward and Wadleigh, 1949). Strogonov, 1961). Similar ill effects of sodium on growth were also reported in grapevines (Khanluja, et al., 1980), in citrus rootstocks (Patil and Bhambota, 1977), in pomegranate (Patil and Patil, 1982) and in jamun (Patil) and Patil, 1983a). Detrimental effects on growth were also observed in aonla (Tewari, 1985), ber (Pandey 1984) and bael (Pandey, et al., 1985; Tewari, 1985).

5.1.2 Effect of ESP on physiological parameters

Chlorophyll : Leaf chlorophyll content decreased with the increase in soil exchangeable sodium in various fruit crops. The total chlorophyll content was recorded lowest in soapnut followed by drumstick under ESP 41 and above. The highest reduction was noted in phalsa followed by passion fruit under highest ESP level. Such type of reduction in chlorophyll content in the leaves was also reported in citrus root stocks (Patil, 1976; Patil and Bhambota, 1978c; Kadam, 1984), in ber (Patil, et al., 1981), and in pomegranate (Patil and Patil, 1982), in ber (Pandey, 1984), in bael (Pandey et al., 1985; Tewari, 1985) and in tamarind, wood apple, mulberry, bael, khirni, eucalyptus, neem and persian lilac (Sadaria 1989) with the increase in ESP. The decrease in chlorophyll is attributed to the reduction in the uptake of essential nutrients.

Stomatal behaviour : The number of stomata was increased with increase in ESP in all fruit species except drumstick in which reverse trend was observed. The per cent increase in number of stomata over control increased due to ESP which was maximum under ESP 12, 41 and 60 in phalsa, karonda and coconut respectively. The increase of number of stomata due to the increased soil

ESP was not supported by any work in literature. The number of stomata were counted in the microscopic field (40 x). The leaves from the plants subjected to greater ESP were obviously reduced in size and hence the increased number of stomata might be as a result of the higher density of stomata in the given microscopic field. The reverse trend in drumstick in this respect may be attribu ed to the specific characterstic of this species.

Rate of transpiration : There was a trend of decreased rate of transpiration with increase of ESP levels in all fruit crops except in coconut and karonda, in which it was increased. The maximum reduction in rate of transpiration was observed in markingnut under ESP 60 followed by soapnut. The decreased and increased rate of transpiration under ESP conditions may be partly due to the changes in stomata. The effect of ESP on the transpiration rate has not been studied by any one in the past.

5.1.3 Effect on chemical composition

Nitrogen : The N content in leaves of all fruit crops except phalsa and passion fruit increased with the increase in ESP upto 41 (problematic soil) and further

it decreased. The N content increased substantially in drumstick, soapnut and cashew under ESP 41. But under high level of ESP (60) the N depletion was pronounced in passion fruit, karonda, cashew and phalsa. Patil (1980) also reported that the N content was increased in leaves with the increase in ESP upto certain limits in pomegranate, ber, chiku and fig. He further reported that N content however, decreased at high level of ESP. Similar results have also been reported by Bains and Fireman (1964); Desai and Singh (1979); Patil and Patil (1982) and Divate (1974). They argued that under high salt concentration the level of protein decreased due to its breakdown in grapes.

The reduction of N content in stem and root due to higher ESP was observed in all fruit crops except karonda and drumstick in which N content of root was increased upto 12 ESP. In the experiment conducted by Sadaria (1989) the nitrogen content of the roots of all tree species except persian lilac was decreased under high ESP.

Phosphorus : The reduction of P content in leaves, stem and roots under high ESP appears to be because of shifting of $H_2PO_4^-$ ion to HPO_4^{--} and PO_4^{---} ions

which are less available. The relation between P absorption and plant growth seems to be related with the physiological behaviour of the plant rather than the solubility of the P or the presence of different P forms in the soil. In the present investigation, P content of leaves was decreased more in markingnut, drumstick, coconut and passion fruit whereas it was decreased in stem and roots of phalsa, soapnut and drumstick, under high level of ESP. Similar results of reduced P availability under increased ESP have been recorded in citrus rootstocks (Patil, 1976; Kadam, 1984), mango (Thakur et al., 1982), pomegranate (Patil and Patil, 1982), jamun (Patil and Patil, 1983a) and in tamarind mulberry, bael khirni, eucalyptus, neem and persian lilac (Sadaria, 1989).

Phosphorus is not available in sodic soils, though it may be present in abundance. In alkaline pH range, permeability of roots is decreased. Reduction in P absorption by plant under higher ESP may be explained on the basis of the facts that the phosphorus equilibria get shifted significantly with the change in pH. The shifting is reported under higher pH and in higher ESP the pH increases (Singh, 1973 and Patil, 1976).

Potassium : The leaf K content decreased due to increased ESP in all fruit species. Under ESP 12 and 60 the maximum per cent reduction of leaf K was registered in soapnut, cashew and passion fruit. Potassium content of stem and roots was also decreased in all fruit crops, but maximum reduction under ESP 60 was observed in markingnut. Patil and Bhambota (1977) reported similar results in citrus, mango (Thakur et al., 1982), pomegranate (Patil and Patil, 1982), ber (Mehta, 1982), jamun (Patil and Patil, 1983a), tamarind, wood apple, mulberry, bael, khirni, eucalyptus, neem and persian lilac (Sadaria, 1989).

Reduction in absorption of K under high ESP levels by plants shows that Na and K were antagonistic in the absorption. According to Heiman (1966) absorption of K in presence of high Na requires more energy. This energy can be derived from metabolic process consuming oxygen. However, under high ESP due to the soil compaction, plant roots get deprived from oxygen resulting in the reduced uptake of K. The least reduction of Ca in leaves was recorded in markingnut followed by soapnut. But highest depression was seen in coconut and drumstick under ESP 60. Whereas in stem the Ca content was lowest in markingnut and soapnut under ESP 60. As far as root Ca is concerned,

the fruit crops like drumstick and karonda had highest reduction under ESP 60. The Mg content of leaves, stem and roots was severely decreased with the increase of ESP. However, under highest, ESP drumstick, cashew and drumstick recorded maximum depression of Mg content in leaves, stem and roots respectively.

Similar results of decreased accumulation of Ca and Mg have been reported by Jones et al. (1957) in young lemon plants budded on different rootstocks, Patil (1976)in citrus rootstocks, Thakur et al. (1982) in mango, Patil and Patil (1982) in pomegranate, Patil et al. (1982) and Mehta (1982) in ber, Patil and Patil (1982a) in jamun and Sadaria (1989) in tamarind, wood apple, mulberry, bael, khirni, eucalyptus, neem and persican lilac.

Sodic soils are deficient in Ca because Ca is precipitated in the soil in the presence of bicarbonate ions. Besides this obsorption of Na, K, Ca and Mg cations is mostly governed by their respective status in the exchangeable phase of the soil and in soil solution. Since, the soil with high ESP contains more sodium on the exchange complex, absorption of sodium increased and those of calcium and magnesium decreased.

This is as per the complementary ion effects as explained by Jenny and Ayers (1939). When sodium is present as complementary ion, the absorption of Ca or Mg reduces (Elgabaly, 1955). Sodium is relatively loosely held on the exchange complex than other cations and hence the replaceability of the other cation is low. This leads to the less availability of Ca and Mg in comparison to Na. Thorne (1944) also reported instances of very low availability of Ca and Mg in alkali soils. Low calcium absorption was one of the most important factors in alkali soils. In fact alkali resistance of a crop is more related to its capacity to survive and secure an adequate supply of Ca even under excessive exchangeable sodium.

Sulphur : The S content of leaves and roots was highly declined in drumstick and phalsa under ESP 41 and 60 while in stem, it was severely decreased in passion fruit followed by soapnut. Leon and George (1956) in the studies of influence of exchangeable sulphur on green beans, garden beets, clover and alfalfa plant reported that with the exception of beans total sulphur showed consistent decreased trend and large variation with the increase of ESP levels. According to Bains and Fireman (1964), only sulphur content increased in

safflower and tomato and not in corn, sorghum and ryegrass with the increase in ESP.

Sodium : Sodium accumulation increased generally in all fruit crops. The different crops accumulated different concentrations at the same ESP level. The highest accumulation of sodium content of leaves and roots was estimated in coconut over the control. In stem, it was eleven times higher in passion fruit over the control. Increased sodium was reported in citrus rootstocks (Patil, 1976; and Kadam, 1984), in mango, (Thakur, et al., 1982), in pomegranate (Patil and Patil, 1982; Doring and Ludders, 1986) and in jamun (Patil and Patil, 1983a) with increase in soil ESP levels. Similar results were also observed in aonla (Tewari, 1983), in jujube and guava (Singh et al., 1983) and in bael (Pandey et al., 1985). The accumulation of sodium in the leaves and roots could be expected because its higher status in the soil substrate.

Ca : Na and Ca + Mg + K : Na : It was observed that with the increased ESP level, there was decrease in Ca : Na and Ca + Mg + K : Na in general in almost all the fruit species. The present results are inagreement with those of Patil (1976) in citrus rootstock, Patil (1980) in guava, pomegranate, custard apple, jamun, ber

chiku and fig. Irrespective of the ESP level, coconut and drumstick registered maximum Ca : Na ratio, in leaves and roots. However, the maximum ratio in stem was noted in passion fruit. The Ca + Mg + K : Na ratio in leaves and root was highest in coconut under problematic soil and ESP 60.

The harmful effect of high ESP may among other things be due to the induced Ca, Mg and K deficiency. The tolerance of plant to sodium can not be predicted solely in terms of accumulation of sodium proposed by Bower and Wadleigh (1948). The relative absorption of Ca, Mg, K and Na ions needs to be considered. Bajwa (1975) also emphasized the need of taking into account the absorption of calcium, magnesium and potassium along with sodium by the plant species while studying the sodium tolerance of plants.

Increasing levels of ESP caused the significant decrease in the concentration of Zn in the leaves, stem and roots of all species. The first ESP level itself showed maximum depression of Zn content of leaves noted in passion fruit. Whereas in stem and roots, the maximum depression was observed in phalsa over the control. Plants. Similar results were found by Patil (1976) in citrus rootstocks, Patil (1980) in

guava, pomegranate, custard apple, jamun and fig. Patil et al., (1981) and Mehta (1982) reported the decreased Zn content in leaves of ber with increase of ESP. However, the present findings differed from that of Singh et al., (1983) who found that Zn content was unaffected under high ESP in jujube and guava. The increase in pH as a result of high ESP may affect the absorption of Zn in soil. It may also alter the uptake of Zn through the effect on microbial activity and a change in the ability of plant roots to absorb or transport it to the tops. Lindsay's (1972) stated that solubility diagram also showed a negative correlation between available Zn and pH of the soil. Since the available Zn is expected to vary under differential ESP, the Zn content of different species under different ESP levels may also vary a great deal. Agarwala et al., (1964) observed that the high ESP was associated with a decrease in water soluble zinc.

Iron : The Fe content of leaves, stem and roots was decreased with increase in ESP levels. The maximum depression of Fe content of leaves and stem was observed in soapnut under ESP 12 whereas in roots it was maximum in markingnut under the same ESP level. The present results are in fully agreement with the results of Patil (1976) in citrus rootstocks, Patil and Patil (1982) in

pomegranate and Patil et al., (1981) in ber. However, Singh et al., (1983) found increased Fe in jujube and guava. As per the solubility diagram presented by Lindsay (1972), feric ion mostly contribute to the total soluble Fe in well aerated soils. The F^{+++} activity in solution decreases 1000 fold for each unit increase in PH. Gardner et al., (1952) also stated that on alkalization of soil the Fe precipitates as iron hydroxide.

Manganese : The Mn content of leaves, stem and roots was progressively declined with the increase of ESP levels. Among all fruit species the maximum reduction of Mn content of leaves was noticed in coconut under ESP 12, 41 and 60. Under ESP 60 the Mn content of stem and roots was minimum in cashew fallowed by drumstick and passion fruit followed by coconut, respectively. In conformity to this, decreased Mn content was reported in citrus root stock (Patil, 1976), in pomegranate (Patil and Patil, 1982) in ber (Mehta, 1983), in jujube and guava (Singh et al., 1983) and in tree species (Sadaria 1989) with the increase in soil ESP levels. Zende and Khonde (1958) observed low level of active Mn in alkali soil. Lindsay (1972) concluded that solubility of Mn in soil is dependent on pH and argued that Mn deficiency would be expected in most neutral and alkaline conditions.

Martin et al.,(1955, 1959a) have also reported that high ESP adversely affected the Mn absorption by citrus seedlings.

Copper : The Cu content varied with the fruit crops and ESP levels. The maximum depression of copper content of leaves, stem and roots was observed in karonda, drumstick and phalsa in problematic soil, respectively. Similar results were also reported by Patil (1976) in citrus rootstocks, the decreased Cu content in leaves and roots of guava, pomegranate and jamun with increase in ESP in soil was also reported by Patil (1980).

5.1.3.1 Sodium concentration in leaves and stem

In general Na concentration ratio in leaves:roots increased with the increased levels of ESP except in Na tolerant crops like coconut, phalsa and karonda. Similarly Na concentration in stem and roots also showed increased trend with the increasing levels of ESP in almost all crops under studies. These observation clearly indicated the fact that Na tolerant crops have some mechanism of exlusion and inclusion and thus they can survive long under sodic conditions. Martin et al., (1953) and Martin and Bingham (1954) also indicated that increase trend of

Na ratio with increase of ESP levels in some fruit crops. But Bernstein and Pearson (1954) stated that the ratio of Na if exceeding more than one is the criterion for resistance to ESP and vice-cersa, which is highly contravertial to the present findings.

5.1.4 Quadratic response studies under exchangeable sodium percentage (ESP)

The response analysis of dry matter under varying ESP conditions to various fruit crops is discussed as given below.

From the estimates of quadratic function between different ESP levels and dry matter of different fruit crops (Table 66b), it can be concluded that R^2 values were highly significant for all fruit crops. The variations in dry matter productions due to ESP levels was ranged from 84.64 to 99.16. However, a slight low range of dry matter production as indicated by R^2 studies was reported by Sadaria (1989) for eight tree species. Further the partial regression coefficient was mostly negative and non significant to all fruit crops except cashew and coconut. This clearly indicated that the increasing levels of ESP resulted into decrease in dry matter production. Similar decline of dry matter production with increasing ESP levels was also reported by Sadaria (1989) for temarind and wood apple.

The fruit crops viz. cashew and coconut were found with estimated tolerable level of ESP to the tune of 3.74 and 11.47 respectively. Therefore, the dry matter of these two crops will decline beyond these limits. Sadaria (1989) also observed the similar trend for most of the tree species studied by him.

5.2 Study of soil salinity

5.2.1 Effect of salinity on growth of various fruit crops

Plant height : Coconut and passion fruit showed lowest depression in plant height under lowest level of salinity at 120 days after planting whereas markingnut showed pronounced reduction in plant height even under lowest salinity level (4 mmhos/cm). At 240 days after planting, phalsa and cashew showed lowest depression under the lowest salinity level. However, markingnut and cashew showed depression under the first level of salinity at 360 days.

Number of leaves : Cashew followed by phalsa recorded maximum reduction in number of leaves under the first level of salinity after four months of planting. In problematic soil, cashew, passion fruit and phalsa showed reduced number of leaves after 240 days of planting,

whereas after 360 days of planting, karonda and phalsa recorded least reduction in number of leaves under the lowest level of salinity.

Stem diameter : Cashew and coconut showed minimum reduction in stem diameter under the first level of salinity after four months of planting. Markingnut followed by drumstick were badly affected at the lower level of salinity after 120 days of planting. In problematic soil, minimum reduction in stem diameter was recorded in karonda followed by coconut at 360 days of planting.

Plant spread : The maximum plant spread reduction was recorded in markingnut under the first level of salinity. Almost the equal effect on plant spread reduction was noted in passion fruit, cashew, drumstick and phalsa under 4 mmhos/cm. At the high level of salinity, phalsa followed by markingnut had recorded maximum plant spread reduction.

Total leaf area : In problematic soil almost similar reduction in the total leaf area was noticed in all fruit crops except phalsa, soapnut and passion fruit. The maximum reduction in total leaf area was recorded in passion fruit followed by soapnut under the high level of salinity.

Root length : Cashew and coconut recorded maximum depression in root length at lowest salinity level. Karonda followed by drumstick recorded minimum reduction in root length at the first level of salinity. Maximum reduction in root length was noticed in markingnut followed by coconut under high level of salinity.

Root volume : Karonda and phalsa showed lowest depression in root volume at lowest salinity level. Cashew and markingnut showed maximum depression of root volume even at the lowest level of salinity. Cashew and phalsa were least affected in root volume at higher level of salinity.

Number of primary roots : In problematic soil number of primary roots was least affected in coconut and karonda, whereas under high level of salinity (20 mmhos/cm) great reduction in number of primary roots in cashew followed by soapnut was recorded.

Number of secondary roots : At the first level of salinity the number of secondary roots were reduced to maximum extent in passion fruit, soapnut and markingnut. Cashew and soapnut had the greater reduction in number of secondary roots than rest of the fruit species under 20 mmhos/cm.

Total number of roots : Least reduction in total number of roots was recorded in karonda followed by coconut under the first level of salinity, whereas passion fruit and soapnut had more reduction in total number of roots even under lowest level of salinity (4 mmhos/cm). The higher level of salinity recorded highest reduction in total number of roots in cashew soapnut, passion fruit and drumstick.

Mortality : Coconut and karonda were tolerant to salinity according to visuable symptoms on plants which showed no mortality symptoms upto 12 mmhos/cm. However, when salinity was reached to 20 mmhos/cm, less than 45 per cent mortality was recorded. Drumstick, soapnut and phalsa showed hundred per cent mortality under 16 mmhos/cm and showed intermediate tolerant to salinity. Most susceptible to salinity were markingnut, passion fruit and cashew which had recorded hundred per cent mortality under 8, 14 and 16 mmhos/cm, respectively.

Fresh weight of whole plant : The fresh weight of whole plant was lowest in passion fruit, drumstick, cashew and coconut under the initial level of salinity (4 mmhos/cm).

Fresh weight of roots : The reduction in fresh weight of roots was maximum in cashew under the first level of

salinity, whereas the minimum reduction was noted in drumstick followed by coconut.

Fresh weight of top : The fresh weight of top was greatly reduced in soapnut under the initial level of salinity, whereas the least reduction was noted in drumstick, passion fruit and cashew. Soapnut followed by karonda recorded low fresh weight of top as compared to other crops in problematic soil.

Dry weight of whole plant : Coconut, markingnut and phalsa showed maximum reduced dry weight of whole plant at 4 mmhos/cm while the minimum reduction was recorded in cashew under problematic soil.

Dry weight of roots : In problematic soil, soapnut and cashew had recorded minimum dry weight of roots whereas maximum reduction was noted in soapnut at 20 mmhos/cm.

Dry weight of top : Phalsa and markingnut showed more depression in dry weight of top at lower level of salinity. In case of problematic soil maximum reduction in dry weight of top was recorded in karonda.

Relationship between relative growth (fresh weight of whole plant) per cent and levels of salinity was calculated and is graphically shown in Fig.20.

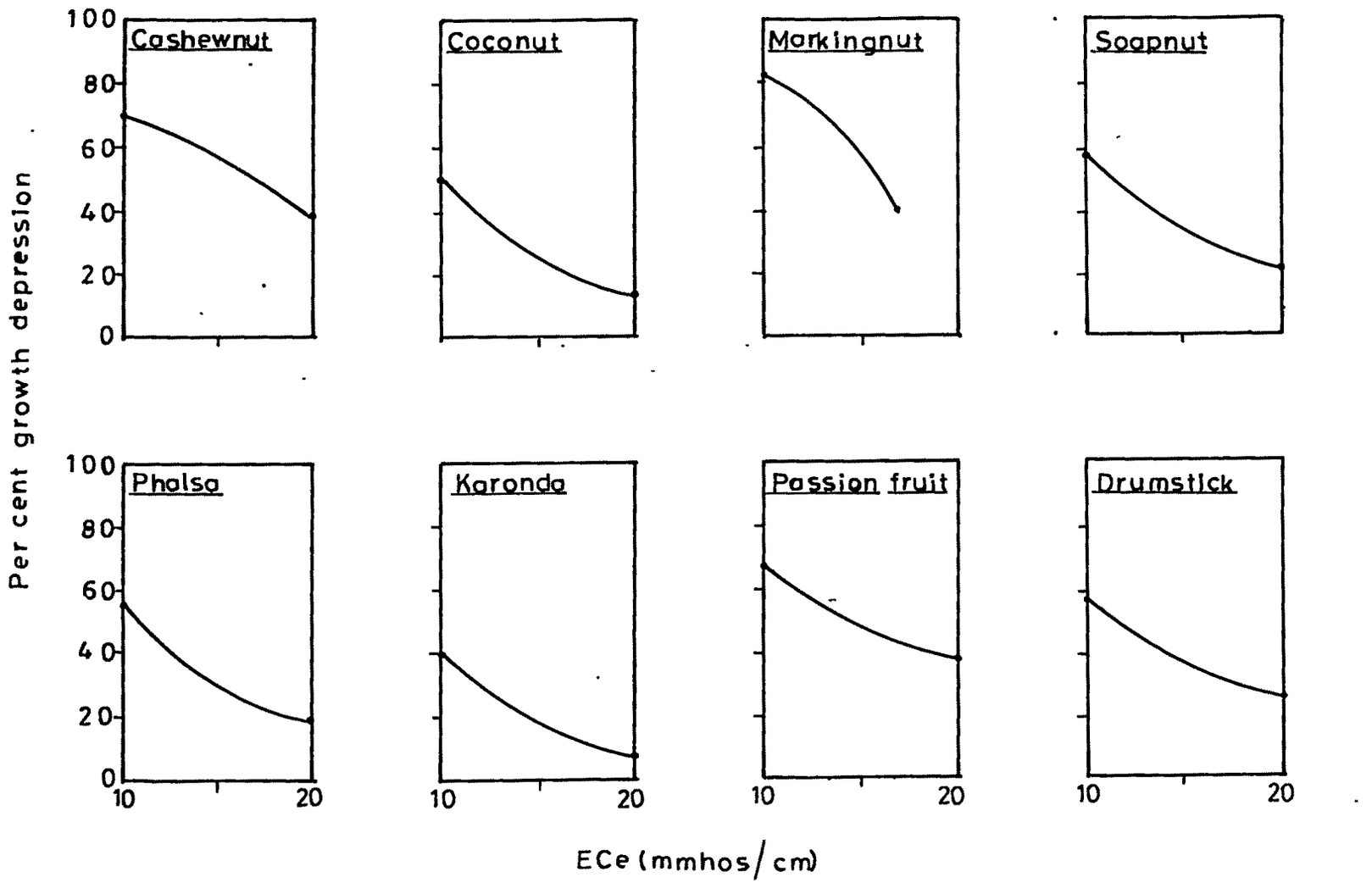


Fig 20 . Relationship between relative growth (per cent) and levels of salinity

The theorotical growth values were obtained from the regression equation given below which were derived from the observed values.

Y =	107.44	-2.5868** X	0.0683 X^2	Cashew
	S.E.±	0.8644	0.0484	R^2 0.9481
Y =	2.309	-6.9920** X	0.1863** X^2	Coconut
	S.E.±	0.5707	0.2663	R^2 0.9837
Y =	65.96	-0.5079 X	0.1679** X^2	Markingnut
	S.E.±	1.0004	0.0467	R^2 0.9338
Y =	334.65	-3.1658** X	0.0309 X^2	Soapnut
	S.E. ±	0.3536	0.0166	R^2 0.9781
Y =	116.34	-7.6897** X	0.1125** X^2	Phalsa
	S.E. ±	0.9429	0.8441	R^2 0.9652
Y =	335.54	-26.0576** X	0.5768** X^2	Karonda
	S.E. ±	1.9244	0.0050	R^2 0.9796
Y =	115.12	-0.1105** X	1.6708 X^2	Passion fruit
	S.E. ±	0.1785	0.0008	R^2 0.9428
Y =	125.71	-12.9821	0.1248	Drumstick
	S.E.±	2.1383	0.1000	R^2 0.9782

Where, Y = growth values and X = salinity levels.

The calculations indicated that the variation in fresh weight of whole plant was found in the range of 93.38 per cent (markingnut) to 98.37 per cent (coconut). Similar high estimated wide range of variation i.e. 63.9 (khirni) to 96.00 (eucalyptus) for fresh weight of whole plant in tree species was also reported by Sadaria (1989).

The relative per cent growth (calculated) from the regression equation) was plotted against salinity levels for each fruit species. The details are shown in Table 140.

Table 140: Salinity tolerance indices of different fruit crops

Fruit crops/ Levels of ECe	Growth depression per cent	
	10 ECe	20 ECe
Cashew	29.06	60.24
Coconut	51.97	86.65
Markingnut	19.01	57.20
Soapnut	43.32	77.26
Phalsa	45.86	80.65
Karonda	60.50	92.42
Passion fruit	33.64	62.70
Drumstick	42.50	72.70

It is observed from the Table that the karonda and coconut were highly tolerant to salinity levels. Phalsa, soapnut and drumstick were medium tolerant to salinity. The rest of the three fruit species viz. Passion fruit, cashew and markingnut were more susceptible to salinity levels. At the same time, the fruit species showing salinity range from 57.20 and 92.22 exhibited 20 per cent growth depression.

In saline soils, all growth attributes were decreased with increasing salinity level in all species. Different reasons could be attributed to explain the detrimental effects of salts on plant growth viz. osmatic inhibition of water absorption, nutritional imbalance, toxic effects of ions, production of toxic substance in plants and ill effects on plant metabolism. Under saline conditions, the greater osmotic pressure produces a kind of physiological drought (stress) within plants which results in depression of growth. The findings of Hayward and Wadleigh (1949), Bernstein (1962) and Allison (1964) also supported this view.

Remarkable decrease in various growth attributes like root length, root volume, leaf area/plant, plant spread, fresh weight of whole plant, fresh and dry weight of top and roots was observed with the increase in salinity level. Suppression of growth due to high salinity has also been reported in citrus species (Pearson et al., 1957; Joolka 1976; Patil and Bhambota, 1978a; Patil and Bhambota 1978b), in grapes (Joolka et al., 1977; Nauriyal and Gupta, 1967; Pandey and Divate, 1976), in guava (Makhija et al., 1980; Kaul, 1981; Patil et al., 1984) and in ber (Dhankar and Dahiya, 1980), in shisham (Singh and Yadav, 1985) in eucalyptus and acacia (Gupta et al., 1986), in neem and persian lilac (Ahmad et al., 1985).

5.2.2 Effect of salinity on physiological parameters

Chlorophyll : There was more than fifty per cent reduction in total chlorophyll content in all fruit crops when salinity level was 14 mmhos/cm and above. A decreasing trend of chlorophyll content with increasing soil salinity was also reported in the leaves of citrus species (Kanwar and Bhambota, 1968; Bhambota and Kanwar, 1970; Joolka, 1976; Patil, 1976), grapes (Davate and Pandey, 1981), guava (Kaul, 1981), neem and Persian lilac (Ahmad et al., 1985), temarind, mulberry, bael, khirni, eculyptus, neem and persian lilac (Sadaria 1989).

Stomatal behaviour : With exception of drumstick all fruit species exhibited increased number of stomata with the increase of salinity levels. In passion fruit and cashew more or less similar per cent increase in the number of stomata compared to control was recorded under 4 mmhos/cm as well as under 14 mmhos/cm. In coconut and karonda under 20 mmhos/cm, similar number of stomata was observed. A common effect of salinity was said to be the decreased in the number of stomata in groundnut (Strogonov, 1964; Waisel, 1972), Joshi (1976) observed markedly higher number of stomata in mangroves which was grown in saline habitats. Devi and Rao (1980) observed that NaCl salinity caused alterations in the stomatal characteristic and behaviour. Joshi et al.,

(1980) observed that the higher salinity did not alter stomatal structure but reduce their number in three salt marsh halophytes.

Rate of transpiration : With the exception of coconut and drumstick, all plant species decreased the rate of transpiration with the increase in salinity levels. The rate of transpiration had similar trend in karonda, soapnut and cashew at the first level of salinity, i.e. 4 mmhos/cm. The rate of transpiration was increased less as compared to control. The transpiration and other related processes under saline conditions may be partly due to the structural and physiological modifications of stomata (Strogonov, 1962; Gale, 1975). The stomatal rhythm in groundnut has been attributed with the saline environment which consequently reduced the transpiration rates (Devi and Rao, 1980). Sweet orange seedling consistently noted higher rates of transpiration with higher levels of salinity (Syvertsen and Graham, 1987). These finding supports the present result obtain in coconut and drumstick.

5.2.3 Effect of salinity on chemical composition

Nitrogen : The maximum percentage reduction of N content of leaves over the control was observed in cashew (61.27)

followed by karonda (53.23) under highest salinity level. In stem similar higher reduction of nitrogen was noticed in karonda (72.63) and phalsa (63.63) under 20 mmhos/cm of salinity. In root also the nitrogen content was severely reduced to the tune of 68.69 (coconut) and 62.45 (karonda) under the same higher salinity level. The nitrogen metabolism of plants in saline substrate seems to be different from the normal plants because of the distrubances in the protein breakdown. These distrubances resulted into formation and accumulation of nitrogenous substances, leading to increase in its level under saline conditions (Strogonov, 1962). Similar results of decreased nitrogen with increase of salinity have been reported by Patil (1976) in kharna khatta and Carrizo root stocks of citrus, Joolka and Singh (1977) in citrus rootstocks and Makhija et al., (1980) in guava.

Phosphorus : Phosphorus content in the leaves, stem and roots showed decreasing trend with increasing salinity level in all fruit species. Originally soapnut plant had highest P content in leaves and roots, whereas phalsa showed maximum P content in stem. Under the salinity level of 4 mmhos/cm. Coconut, phalsa and passion fruit showed lowest depression of P content in leaves. Numarous evidences are available corroboration to this finding. Ivanova (1972) in stone fruits,

Desai and Singh (1979) in guava, Jindal et al., (1979) in mango, Joolka and Singh (1977) and Patil and Bhambota (1980) in citrus rootstocks. Sadaria (1989) in tamarind, wood apple, mulberry, bael, eucalyptus, neem and parsian lilac recorded similar observations.

Potassium : Potasium content showed decreasing pattern with increasing salinity levels in the leaves, stem and roots of all fruit species. The highest K content of leaves, stem and roots was noticed in drumstick and higher level of salinity the highest depression of leaf K was in cashew followed by markingnut. In the same salinity levels the K content of stem and root was highly decreased in soapnut and cashew, respectively. The decrease in potassium content in various plant species was also reported by Bernstein et al., (1965a), Pearson et al., (1957), Kanwar and Bhambota (1968), Joolka and Singh (1977), Patil and Bhambota (1980) in citrus species, Desai and Singh (1979), Patil (1980), Makhija et al., (1980) in guava, Divate and Pandey (1981) in grape and Dahiya and Dhankhar (1982) in ber under higher salinity treatments. Sadaria (1989) found similar trend in wood apple, mulberry, bael, khirni, eucalyputus, neem and percian lilac.

Calcium : The leaf, stem and root Ca declined with the increase in salinity levels but the extent of reduction varied with the fruit species. The highest Ca content of leaves, stem and roots was noticed in the control plants of soapnut, passion fruit and markingnut, respectively. The reduction of Ca was pronounced in markingnut followed by cashew in leaves; phalsa followed by passion fruit in stem and drumstick followed by passion fruit in roots under problematic soils. The results in the present investigations are in agreement with those of pearson et al., (1957), Patil and Bhambota (1978a and 1980), Desai and Singh (1979), patil (1980) and Sadaria (1989). They reported decreased concentration of Ca in the leaves of various fruit species under higher salinity. Singh and Yadav (1985) also observed decreased Ca content in the leaves of Shisham under high salinity. But however, contrary to the findings of the present investigation, the increasing trend of calcium was reported by Dahiya and Dhankar (1982) in ber and Divate and Pandey (1981) in grapes with increasing salinity levels. This may be due to the fact that they used only $CaCl_2$ and $MgCl_2$ for creation of salinity.

Magnesium : The Mg content in the leaves, stem and roots decreased with successive increase in salinity

levels in all fruit species. The Mg content as observed in the control plants of cahsew (1.98), drumstick (1.90) and markingnut (1.70) was maximum in leaves, stem and roots, respectively. But under the first level of salinity the adverse effect of Mg content of leaves was recorded in cashew (31.13 %) i and karonda (21.66 %), while in stem, it was noted maximum in passion fruit (25.49 %). Similarly in root it was depressed in coconut (19.35 %), and markingnut (12.35 %) under 4 mmhos/cm. In conformity with these results Patil (1980) recorded lower Mg content in the leaves and roots under high salinity in guava, pomegranate, fig, chiku, custard apple, jamun and ber, while under the same salinity level Mg content in leaves and roots of kharna khatta was reduced (Patil and Bhambota, 1978a and 1980). However, contrary to these results, increasing trend of magnesium was reported by Mahija et al., (1980) in guava, Divate and Singh (1981) in grapes, Dahiya and Dhankhar (1982) in ber, Singh and Yadav (1985) in shisham and Sadaria (1989) in eight tree species like tamarind, wood apple, mulberry, bael, khirni, eucalyptus, neem and persian lilac.

Sulphur : The results showed that S content increased upto certain level as the salinity increased in all fruit species except markingnut in leaves and phalsa

in stem in which the sulphur content was gradually decreased. The S content in passion fruit, cashew and drumstick was increased to a medium extent over the control in leaves under the first level of the salinity (4 mmhos/cm). The present results are in conformity with the results of David et al., (1958) in cherry, Walter and Ballinger (1967) in walnut and blueberry, Gupta and Nauyriyal (1973) and Joolka et al., (1977) in grape and Jindal et al., (1979) in mango and Desai and Singh (1979)in guava).

Sodium : Irrespective of the salinity level, leaf, stem and root Na content of different fruit species differed significantly from each other. Highly significant increase, more than 3 folds Na content of leaves, stem and roots over the control was estimated in markingnut followed by karonda, passion fruit followed by phalsa and drumstick followed by cashew, respectively under 20 mmhos/cm. Pearson et al., (1957) found a direct relationship between conductivity of saturation extract and the concentration of sodium or chloride in the leaves of citrus. Similarly, Dhankhar et al., (1978) for phalsa, Desai and Singh (1979) for guava, Jindal et al., (1979) for mango, Patil and Bhambota (1980) for citrus rootstocks, Patil (1980) for guava, pomegranate, ber, jamun, chiku and fig, Sadaria

(1989) for all the tree species except wood apple, recorded that sodium increased with the increase in salinity.

Ca : Na and Ca + Mg + K : Na : In general the ratio of Ca : Na and Ca + Mg + K : Na were decreased with corresponding increase of salinity in all the fruit species under study. The ratio of Ca : Na over the control was highest and lowest in markingnut (84.76) and phalsa (53.12) in leaves, passion fruit (90.74) and cashew (77.12) in stem, coconut (87.46) and karonda (44.66) in roots, respectively under problematic soil. The ratio of Ca + Mg + K : Na was highest and lowest in markingnut (98.21) and phalsa (45.34) in leaves, passion fruit (90.29) and cashew (75.16) in stem and cashew (85.18) and phalsa (47.93) in root, respectively under the same salinity level i.e. problematic soil. However, beyond this salinity level, both ratios had higher range under salinity level of 20 mmhos/cm. Wahid et al., (1974) observed a significant correlation between K : Na, K : (Ca + Mg) and K : Mg ratios in the soils and leaves of coconut.

Zinc : Among control plants, the lowest Zn content was observed in leaves and stem of drumstick and roots of cashew. The highest reduction of Zn over the control was noted in leaves and stem of soapnut and roots of

drumstick under the higher level of salinity. The results of the present investigations are in agreement to those of Patil (1976) who reported that the uptake of Zn was particularly reduced in citrus rootstocks under higher salinity. The zinc content as reported of leaves was decreased in guava, pomegranate; custard apple, ber, jamun and fig (Patil (1980). Sadaria (1989) also found similar results on Zn content of leaves of all tree species except khirni.

Iron : The leaf, stem and root Fe was decreased significantly in all fruit species under high salinity. This indicates clearly that absorption of Fe was also adversely affected under saline conditions. Under the first level of salinity the Fe depression was maximum in cashew in all plants parts (leaves, stem and roots). Similar results were recorded by Abdel Messih et al., (1979) in citrus rootstocks. Patil (1980) also recorded lower Fe content in the leaves and roots of guava, pomegranate, custard apple, ber, jamun and fig under higher salinity.

Manganese : More than fifty per cent reduction of Mn content over the control was noted in passion fruit and markingnut in leaves, drumstick and karonda in stem, drumstick and markingnut in roots under the salinity level of 14 mmhos/cm.

There was a significant correlation of soil pH with available Mn. Higher the Ph, less was the available Mn and vice-versa. Decrease in Mn content under saline conditions may be due to the increase in pH as demonstrated by Lindsay (1972). Similar findings were also reported by Patil (1980) in seven fruit crops and Sadaria (1989) in eight tree species.

Copper : More than sixty per cent reduction of Cu content in all plant parts was recorded in all fruit species under the level of 20 mmhos/cm. In the investigations carried out by Bhambota (1965), Cu content of leaves was depressed by the higher levels of salinity in orange leaves. Patil (1980) also reported the decreased Cu content of leaves and roots of guava and pomegranate.

5.2.3.1 Sodium concentration in leaves and stem

Each crop has its own salinity tolerance limit beyond which the plants shows sign of injury to the leaves. Many workers have reported different salinity tolerance indices for different crops. Sodium tolerance of a plant is also judged by the ratio of Na in the plant tops to Na in the roots (Bernstein and Pearson 1956). Although this type of studies were undertaken to estimate the tolerance to soil exchangeable sodium, this ratio criterion is not applied for estimating salinity tolerance.

The present results attempts the estimation of ratio of sodium in leaves and stem under different salinity levels indicated that karonda and coconut were catagorized as salinity tolerant crops because these crops had least mortality symptoms and less depression percentage under high salinity (29 mmhos/cm). Coconut exhibited less than 1 ratio of Na in leaves:root. But the ratio in leaves:root and stem:root was more than one in karonda. These crops might be having certain machinism to accomodate sodium even in high salinity condition so that the plants did not show any severe mortality symptoms and the plants were survived for a longer period. Patil (1980) has reported salinity tolerance indices of 9.70, 9.00 and 9.50 for guava, pomagranet and clustard apple, respectively. In rest of the crops like passion fruit, cashew and markingnut there was increase in sodium ratios in leaves:root and stem:root with the increase of salinity upto 20 mmhos/cm and showed sign of mortality and the plants were died either in problematic soil or in high salinity conditions indicating their poor salinity tolerance (14 mmhos/cm). These findings are in agreement with that of USDA salinity staff (1954) as they had stated that the crops viz. walnut, cocoa, appricot were poor salt tolerance (2 to 3 mmhos/cm).

Phalsa exhibited medium tolerance of salinity as indicated by the salinity indices i.e. salinity level of 20 mmhos/cm where the depression percentage was estimated to the tune of 80.65 %. However, the recent work on fruit crops in relation to salinity tolerance as reported by Yamadagni (1983) has added a few more fruit crops in the list of tolerance crops and these crops are ber, guava, aonla and phalsa.

5.2.4 Quadratic response studies under salinity

The response analysis of dry matter under varying salinity conditions to various fruit species is discussed in the following way.

As compared to ESP, the coefficient of multiple determination (R^2) was high under different salinity levels (Table 122A). The two crops viz. cashew and passion fruit showed estimated tolerable level of salinity to the extent of 0.259 and 4.38 respectively, which indicated that if salinity is increased beyond these limits, there will be reduction to the limit shown in bracket in the estimated dry matter production (40.47 to 44.83). However, Sadaria (1989) found some what different tolerance limit of ECe for five tree species with their estimated dry production (5.79 to 367.57).

5.3 Correlations and path coefficient studies

Association of growth characters and their direct and indirect influences on economic yield helps to identify the suitable plant type needed for improvement of the crop. This type of study has its immense use not only to the plant breeders but also to the horticulturist. Even though quite a bit of work has been reported in the field crops, very little work has been done in fruit crops. In the case of fruit crops understudy the character association and path coefficient studies have not been reported so far. In the present investigation attempts were made to establish interrelationship of different growth parameters with dry matter production and direct and indirect components related to dry matter production in eight fruit species. The results obtained are discussed in the following pages.

5.3.1 Correlation coefficients

In the eight fruit species under study the dry matter production which is mostly related to the final development of fruits was considered as dependent and important variable. The other 10 to 11 indenpendent variables were studied to establish their

relation to dry matter production. The studies revealed that the correlations among different characters in ESP and salinity conditions were more or less in similar trend in almost all the crops except in coconut and passion fruit. In these two crops the dry matter production was greatly affected due to artificially riched ESP and salinity levels. In coconut under ESP, most of the independent variables were either weak positively or negatively correlated but under salinity, the plant height, number of leaves, total leaf area, root length, total number of roots, fresh weight of whole plant and total chlorophyll content had strong positive correlations with dry matter production. Similarly in passion fruit the characters were strongly related in ESP but the association under salinity was somewhat weaker. Similar to these findings Kohli et al., (1988) in fenugreek, a leafy vegetable crop found that the green yield was possitively but non significantly correlated with leaf area, plant height and number of leaves per plant and stated that number of shoots per plant may be a good index to select a high yielding plant (green) combined with judicious selection for the characters like leaf area, plant height and number of leaves per plant.

The studies further indicated that except phalsa and coconut the fresh weight of whole plant had strong positive association with dry matter production

indicating its importance. But plant height and total number of leaves, leaf area were the principal factors related to dry matter production in coconut and phalsa, respectively. Therefore, these characters need special attention for deciding a ideotype which will produce maximum dry matter production. Sadaria (1989) had also reported a significant positive correlation of fresh weight of whole plant, plant height, root volume and plant spread with dry matter production in eight tree species under both ESP and salinity conditions, which corresponds to the present findings of character association in eight fruit crops species. The plant mortality had almost negative and significant correlation with most of the characters in all the crops except coconut. Similarly the number of stomata also showed negative correlation with dry matter and most of the characters. The rate of transpiration was also had significant and negative correlation with dry matter and other characters. Therefore, these characters had their ill significance in the fruit crops.

5.3.2 Path coefficient studies

Only correlation studies are not the final clue to establish a relation of independent and dependent variables. Unless the direct and indirect effects which are the breakdown of correlations through

path coefficient analysis, the criteria as an additional selection indices will not be fulfilled. Therefore, the direct and indirect influence on dry matter production in the present eight fruit species was studied. From the analysis it was cleared that, the fresh weight of whole plant had highest direct influence on dry matter production in all the crops except coconut and soapnut. In these two crops, the total number of roots had direct positive effect on dry matter production under eESP condition. But under salinity, fresh weight and plant height with number of leaves were the direct dontributors for dry matter production in coconut and soapnut, respectively. Kohli et al., (1988) also reported a maximum contribution towards green yield in fenugreek through direct effects of number of shoots per plant.

At the same time the dry matter was influenced indirectly through fresh weight and rate of transpiration in cashew; fresh weight of whole plant and total chlorophyll in coconut; number of leaves and rate of transpiration in markingnut; leaf area, plant height and fresh weight of whole plant in soapnut; leaf area and fresh weight of whole plant in phalsa; total chlorophyll content in karonda; root length and fresh

weight of whole plant in passion fruit and fresh weight of whole plant in drumstick. The path coefficient results of Sadaria (1989) in eight tree species under ESP and salinity indicated that the fresh weight of whole plant was the direct as well as indirect substantial attributes in dry matter production. The next important contributors in dry matter production were root volume and number of leaves. These results are more of less equally comparable to the present results of path coefficient analysis. Lal and Achal (1987) in the path coefficient analysis of 14 yield components in strawberry reported that number of leaves at genotypic level had positive and maximum direct effect on yield but at phenotypic level it had nagative direct effect. Therefore, these characters simulteneously need to be considered for selecting the plants which will produce high dry matter production.

The correlation and path coefficient studies clearly indicated that, fresh weight of whole plant followed by total leaf area, number of leaves, total number of roots and root length were the important independent variables and they need to be concentrated while selecting the plants of the fruit species under study for production of the high dry matter.

Chapter 6

SUMMARY

The pot culture experiments in greenhouse were conducted during 1987 and 1988 at Marathwada Agricultural University, Parbhani by subjecting plants of cashew, coconut, markingnut, soapnut, karonda, phalsa, passion fruit and drumstick to varying levels of ESP and salinity in soil, which was orginally classified as inceptisol. The trial was laidout in completely randomized design with one plant per pot constituting a single plant unit and there were three replications for each fruit species.

The results of these experiments are summarised in the following pages.

I. Exchangeable sodium percentage

The soil was treated with the solusion of sodium biocarbonate ($Na\ HCO_3$) for building up five levels of ESP namely 12, 24, 36, 48 and 60 besides control (ESP 3.82). A natural sodic soil (ESP 41) representing problem soil of purna command area formed an additional treatment. The earthen pots (40 cm height with 35 cm upper diameter) of 12 kg capacity were used for all fruit species except coconut for which big sized cement pots of 30 kg capacity

were used. The pots were filled with the treated soil weighing 25 kg and 10 kg respectively for coconut and rest of the fruit species.

1. Effect of ESP on growth parameter

The maximum depression in plant height was recorded in phalsa, drumstick and cashew at 4, 8 and 12 months of planting under highest level of ESP. The number of leaves were reduced in descending order in passion fruit, cashew and markingnut at 120 days after planting, in markingnut, passion fruit and drumstick at 240 days after planting and in cashew markingnut and passion fruit at 360 days after planting under ESP 60. A marked adverse effect on stem diameter was noted when ESP was increased to 60 in passion fruit as compared to rest of the fruit crops at 240 days and onwards. The maximum plant spread reduction was observed in karonda, markingnut and phalsa under ESP 60. In respect of ESP 12, most striking depressive effect on total leaf area was recorded in markingnut followed by soapnut. Karonda and passion fruit showed least depression in root length under highest ESP level. The markingnut and soapnut showed highest depression in root length under highest ESP level. The root volume in soapnut and karonda was least affected under lowest level of ESP. Cashew, markingnut and drumstick

showed highest depression in number of primary roots under higher ESP levels. The number of secondary roots in karonda and coconut were lowest in lower level of ESP i.e. ESP 12. The total number of roots in soapnut and cashew were badly affected under highest level of ESP (ESP 60). In markingnut and passion fruit the mortality symptoms were recorded even under the lowest level of ESP. Coconut, phalsa and karonda with stood even under higher level of ESP (ESP 48). These fruit species had showed least toxicity symptoms and the plants survived till the end of experiment. Cashew and karonda showed lowest depression in the fresh weight of whole plant under first level of ESP. The first level of ESP resulted into maximum depression in dry weight of whole plant of passion fruit and soapnut.

The tolerance limit of ESP (ESP level representing 60 per cent growth depression) were calculated to 65.25, 77.73, 61.37, 97.39, 91.03, 80.00, 70.01 and 74.12 in cashew, coconut, markingnut, soapnut, phalsa, karonda, passion fruit, and drumstick, respectively.

2. Effect of ESP on physiological parameters

Chlrophyll :

The total chlorophyll content was lowest in soapnut followed by drumstick under ESP 41 (problematic

(soil) and above. The highest reduction in chlorophyll was noted in phalsa followed by passion fruit under the highest ESP levels.

Stomatal behaviour :

There was trend of increased stomata with increase in ESP level in all fruit crops except drumstick in which reverse trend was observed. Higher number of stomata were seen in coconut and passion fruit under higher ESP.

Rate of trnaspiration :

There was a trend of decreased rate of transpiration with increased level of ESP in all fruit crops except coconut and karonda.

3. Effect of ESP on chemical composition

The N content in leaves of all fruit crops except phalsa and passion fruit was increased with the increase of ESP upto 41 (problematic soil), but it was not consistent. The same, however, decreased under higher ESP levels. The maximum reduction of N content in stem and roots due to higher ESP was observed in soapnut and markingnut respectively. The P content of leaves, stem and roots was decreased more conspicuously in markingnut, phalsa and phalsa under ESP 60, respectively.

The passion fruit had lowest K content in leaves and roots under the highest ESP, whereas in stem of markingnut recorded lowest K content under the same ESP level. Under ESP 12, markingnut, passion fruit and soapnut showed least depletion of Ca in leaves, stem and roots respectively. But under the same level of ESP, the Mg content of leaves, stem and root was reduced in markingnut, cashew and karonda, respectively. Coconut, cashew and passion fruit showed least depletion of sulphur under higher ESP level in leaves, stem and roots, respectively. Under the highest ESP Na increased to the maximum extent in stem of passion fruit followed by karonda. Similarly, highest accumulation of sodium in leaves (5 times more compare to control) and root (4 times more compare to control) was observed in coconut.

Increasing level of ESP decreased the Zn, Fe, Mn and Cu content in leaves, stem and roots of all the fruit species. The first ESP level itself showed maximum decrease of Zn, Fe, Mn and Cu in the leaves of passion fruit, soapnut, coconut and karonda, respectively. Whereas these elements were low in the stem of drumstick, soapnut, markingnut and cashew, respectively. The Zn, Fe, Mn and Cu in root were markedly low in phalsa, markingnut, passion fruit and markingnut under the first level of ESP, respectively.

The ratios of Na content of leaves:roots and stem:roots were more than one in cashew, markingnut, karonda and passion fruit indicating higher deposiation of Na in leaves and stem.

Quadratic function of dry matter production

The coefficient of multiple determination of R^2 was significant in all the fruit crops for quadratic functional relationship between dry matter production and different ESP levels. The R^2 ranged from 0.8464 to 0.9916 under ESP levels.

II. Salinity

Besides control (1:2 ECe) electrical conductivity of saturation extract viz. 4, 8, 12, 16 and 20 mmhos/cm were tried. The salinity levels were developed by addition of requisite amount of salt ($NaCl_2$, $NaHCO_3$, Na_2SO_4, $CaCl_2$ and $MgCl_2$) to soil in pots. Natural saline soil representative problem soil of Purna command area having 14 mmhos/cm level was included as an additional treatment. The design of experiment, replications, the earthen pots size and soil quantity used in salinity was same as used in ESP studies.

1. Effect of salinity on growth

The adverse effect of salinity on plant height was seen right from conductivity level of 4 mmhos/cm

of saturation extract in markingnut, cashew and passion fruit. Problematic soil showed maximum depression of plant height and number of leaves in phalsa at 360 days after planting. Whereas, soapnut showed maximum reduction in stem diameter under the same ESP level. Plant spread and total leaf area were leastly affected in karonda and passion fruit under 4 mmhos/cm. Under highest salinity, highest reduction in plant spread and total leaf area were recorded in phalsa and passion fruit, respectively. In respect of 4 mmhos/cm the maximum reduction was noted in root length and root volume of cashew and markingnut respectively. The number of primary roots was less affected in coconut under first level of salinity. Cashew and soapnut showed greater reduction in number of secondary roots than the rest of the fruit crops under 20 mmhos/cm. Least reduction in total number of roots was recorded in karonda followed by coconut under 4 mmhos/cm. Whereas, passion fruit and markingnut showed more reduction in total number of roots even under the lowest level of salinity. Under first level of salinity maximum reduction in fresh weight of whole plant was noted in markingnut. Whereas dry weight of the whole plant was markedly reduced in phalsa followed by markingnut under the same level of salinity.

The salinity tolerance indices (salinity level mmhos/cm representing 20 per cent growth depression)

were calculated to be 60.24, 86.65, 57.20, 77.26, 80.65, 92.42, 62.70 and 72.70 for cashew, coconut, markingnut, soapnut, phalsa, karonda, passion fruit and drumstick, respectively.

2. Effect of salinity on physiological parameters

Chlrophyll :

The lowest chlorophyll reduction was estimated in drumstick under the lowest level of salinity.

Stomatal behaviour :

With exception of drumstick all fruit crops exhibited increased number of stomata with increase in salinity levels. Highest number was seen in passion fruit under highest level of salinity.

Rate of transpiration :

With the exception of coconut and drumstick, all fruit crops registered decreased rate of trnaspiration with increase in salinity levels. The rate of transpiration was almost similar in karonda, soapnut, and cashew under the first level of salinity.

3. Effect of salinity on chemical composition

With the increase of salinity there was decrease in almost all macro and micronutrient contents

of leaves, stem and roots of all fruit crops, except sulphur and sodium which showed reverse trend. The N in leaves was reduced in cashew and karonda. Whereas the stem N decreased to a great extent in phalsa and karonda. The root N decreased to the greatest extent in coconut and karonda under the highest level of salinity. The soapnut had highest P content in leaves and roots, whereas phalsa showed maximum P content in leaves under the 4 mmhos/cm. Under problematic soil and higher level of salinity cashew followed by markingnut showed the highest amount of reduction of leaf K. The reduction of calcium was severe in markingnut followed by cashew in leaves, phalsa followed by passion fruit in stem and drumstick followed by passion fruit in roots under problematic soil. The adverse effect of Mg content of leaves was recorded in cashew and karonda under 4 mmhos/cm of salinity, while in stem the same was noticed in passion fruit and soapnut. Coconut and markingnut were badly affected in Mg content of roots under the same level of salinity. The result on S content showed that there was increase upto certain level with the increase in salinity level in almost all fruit species in different plant parts except in leaves of markingnut and stem of phalsa. In these two crops the S content decreased gradually in leaves and stem. Highly significant increase Na content of leaves, stem and roots was estimated

in markingnut followed by karonda, passion fruit followed by phalsa and drumstick followed by cashew, respectively under 20 mmhos/cm.

The ratio of Ca : Na was greatly decreased under higher level of salinity in leaves of markingnut, in stem of passion fruit and in root of drumstick, whereas the Ca + Mg + K : Na ratio decreased to a maximum extent in the leaves of markingnut , in the stem of soapnut and in the root of cashew under the same level of salinity.

The highest reduction of Zn was in leaves and stem of soapnut and root of drumstick under the higher level of salinity. Under the first level of salinity there was maximum reduction of Fe content in leaves, stem and roots of cashew. Under highest level of salinity, there was highest reduction in Mn content of leaves of passion fruit. Similarly under the same salinity level there was reduction in Mn content of leaves and stem of drumstick. There was great reduction of Cu content of all plants parts of all fruit species under higher level of salinity.

In markingnut, soapnut, karonda and passion fruit, the ratio of sodium in leaves and root was more than one in higher salinity indicating higher

amount of deposiation of Na in leaves however, only karonda did not show severe mortality symptoms. Whereas in phalsa and drumstick the leaves:root and stem:root, the ratio of sodium was less than one. Under higher salinity. These plants showed mortality symptoms at 150 days after planting. The coconut was tolerant to salinity even if the leaves:root ratio of Na was less than one under higher salinity level.

Quadratic function of dry matter production

The coefficient of multiple determination of R^2 was significant in all fruit species for quadratic functional relationship between dry matter production and salinity level. The R^2 estimated ranged from 0.9187 to 0.9912.

Correlation and path coefficient analysis

Considering dry matter production as dependent variable and 10 variables as independent in cashew, coconut, markingnut, soapnut phalsa and passion fruit and 11 independent variables in karonda and drumstick, the correlation of dependent and independent variables and path coefficient analysis was carriedout. The analysis indicated that fresh weight of whole plant,

followed by total leaf area, number of leaves, total number of roots and root length were the important morphological characters which showed strong positive correlation with dry matter production under both ESP and salinity conditions. Similarly these characters had direct and indirect influence on dry matter production in these fruit species.

CONCLUSION

Among the fruit species studied, soapnut, phalsa, karonda and coconut were highly tolerant to ESP, while drumstick and passion fruit showed the intermediate tolerance to ESP. Cashew and markingnut were susceptible to ESP.

Karonda and coconut were found highly tolerant to salinity levels. Phalsa, soapnut and drumstick were medium salinity tolerance. Passion fruit, cashew and markingnut were susceptible to salinity.

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* Originals not seen.

APPENDIX

APPENDIX I

Meteorological data during the course of investigation from June 1987 to September 1988.

Month	Meteo-rolo-gical week	Temperature		Humidity		Rain-fall (mm)	No.of rainy days	Sun-shine hr/ day
		Max.	Mini.	AM	PM			
1.	2.	3.	4.	5.	6.	7.	8.	9.
June	23	40.2	26.7	58	26	9.00	2	9.1
	24	36.5	24.4	78	46	96.20	3	8.5
	25	35.4	24.6	75	43	8.40	2	8.4
	26	36.6	23.6	84	43	14.20	2	10.0
July	27	31.3	23.2	85	71	87.2	4	4.3
	28	32.3	23.3	83	49	24.5	3	4.5
	29	34.2	23.6	78	49	6.0	1	6.0
	30	32.8	23.3	83	54	23.9	3	4.8
	31	35.3	24.0	78	44	1.4	1	9.2
August	32	29.2	22.4	92	75	113.8	4	2.7
	33	31.7	23.2	92	68	97.7	5	7.2
	34	30.0	29.9	88	77	93.8	5	2.9
	35	30.0	23.2	86	68	20.3	2	1.9
September	36	32.8	22.5	82	46	-	-	7.8
	37	35.2	22.6	83	40.5	1.5	1	6.9
	38	37.0	23.1	72	32	0.8	1	10.7
	39	36.8	23.4	76	37	1.2	1	7.9
October	40	32.2	22.1	90	62	83.8	5	7.0
	41	33.4	19.0	87	37	11.8	1	11.2
	42	32.5	21.2	85	50	26.8	2	6.9
	43	32.7	15.1	78	28	-	-	11.3
	44	32.8	15.7	73	34	-	-	10.1

Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.
November	45	30.9	16.5	80	40	4.0	1	8.5
	46	29.7	20.3	87	63	36.2	3	3.2
	47	29.6	15.9	91	43	9.0	1	9.0
	48	30.8	11.4	82	26	-	-	11.0
December	49	29.9	9.8	83	30	-	-	11.0
	50	28.4	14.9	93	52	3.0	2	5.0
	51	27.4	6.0	83	27	-	-	10.9
	52	29.1	9.1	82	28	-	-	10.9
January	1	29.1	9.1	81	30	-	-	10.7
	2	30.6	11.9	77	30	-	-	10.1
	3	32.3	13.2	74	28	-	-	10.8
	4	32.4	13.8	64	26	-	-	10.4
	5	33.8	12.9	63	16	-	-	11.1
February	6	33.7	12.0	56	15	-	-	11.1
	7	34.0	16.4	54	23	-	-	9.7
	8	35.0	16.6	53	20	-	-	17.1
	9	35.2	14.2	42	13	-	-	9.3
March	10	36.9	17.9	44	16	-	-	10.3
	11	38.8	20.4	38	15	-	-	11.0
	12	37.3	14.9	24	7	-	-	11.6
	13	38.0	16.9	30	11	-	-	11.9
April	14	41.8	21.8	37	16	-	-	10.5
	15	40.8	24.3	47	17	3.5	2	7.9
	16	40.8	23.6	38	14	4.5	2	9.6
	17	38.4	22.6	48	19	1.5	1	9.6

Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.
May	18	41.7	26.0	31	14	-	-	10.1
	19	45.5	25.5	29	11	-	-	11.5
	20	43.8	27.4	31	13	-	-	10.4
	21	42.1	27.9	42	21	-	-	9.0
June	22	43.2	26.3	50	19	-	-	12.1
	23	39.0	25.5	69	33	39.8	3	9.5
	24	36.0	24.1	77	50	34.5	9	7.5
	25	32.4	22.4	91	60	162.2	6	4.4
July	26	34.6	24.1	78	42	2.0	1	9.0
	27	30.9	23.4	90	75	34.0	5	1.7
	28	34.6	24.0	79	47	7.5	2	6.5
	29	30.4	22.9	90	73	167.2	6	3.9
	30	29.2	22.3	91	71	102.3	5	2.2
August	31	28.4	22.5	92	76	163.3	3	0.7
	32	32.5	23.5	87	52	4.1	3	5.3
	33	31.6	23.3	90	65	94.2	5	4.7
	34	28.9	22.5	95	76	162.0	5	3.5
	35	29.6	22.4	94	87	171.2	5	2.0
September	36	30.6	22.9	92	66	134.5	3	5.2
	37	32.0	22.7	88	63	32.7	2	7.7
	38	30.4	22.6	91	70	116.9	5	5.5
	39	31.8	22.7	91	66	104.7	4	7.3

APPENDIX II

Chemical analysis of soil used for different fruit crops at the end of experimentation under exchangeable sodium percentage (ESP)

Treatments	Orgenic carbon (Kg/ha)	Phos-phorus (kg/ha)	Pota-ssium (kg/ha)	Cal-cium (me/ 100g)	Magn-esium (me/ 100g)	Pota-ssium (me/ 100g)	Sodium (me/ 100g)
1.	2.	3.	4.	5.	6.	7.	8.
			Cashew				
Control	326.70	21.45	284.50	27.20	19.60	0.311	5.96
ESP 12	314.50	24.48	308.50	26.40	18.26	0.299	8.63
ESP 24	309.70	27.65	312.40	24.53	17.00	0.248	11.00
ESP 36	300.10	28.10	320.80	23.50	16.53	0.227	12.50
ESP 41	314.55	21.70	326.10	23.00	14.28	0.211	14.03
ESP 48	295.75	28.10	334.10	20.00	13.00	0.197	15.79
ESP 60	290.65	30.45	340.70	15.00	12.95	0.129	16.40
			Coconut				
Control	354.50	19.50	296.10	37.60	21.10	0.406	3.50
ESP 12	340.60	20.30	300.40	35.30	20.00	0.384	4.23
ESP 24	330.65	24.50	310.80	33.60	18.50	0.381	8.00
ESP 36	316.65	26.10	325.60	30.00	17.10	0.379	10.30
ESP 41	310.75	25.80	330.40	29.50	15.50	0.280	12.00
ESP 48	300.10	29.50	345.60	26.10	14.50	0.270	14.50
ESP 60	285.60	29.80	360.70	20.26	14.95	0.200	15.26

Contd.....

1.	2.	3.	4.	5.	6.	7.	8.
			Markingnut				
Control	334.10	17.45	294.10	28.80	18.40	0.278	4.29
ESP 12	316.70	20.75	309.50	25.60	16.40	0.277	7.00
ESP 24	310.50	21.50	320.50	24.00	15.00	0.251	9.06
ESP 36	300.90	22.75	329.45	21.90	14.00	0.210	9.60
ESP 41	317.80	21.50	339.50	20.10	13.53	0.177	11.00
ESP 48	295.85	24.50	345.60	18.26	11.67	0.150	11.33
ESP 60	290.65	25.60	350.75	12.80	11.07	0.126	12.00
			Soapnut				
Control	345.40	16.65	285.10	28.33	19.00	0.34	3.93
ESP 12	335.80	18.45	306.70	26.90	18.53	0.32	5.18
ESP 24	325.90	19.75	311.80	25.50	16.00	0.30	5.48
ESP 36	316.70	21.95	318.10	25.30	13.00	0.29	8.10
ESP 41	309.90	20.10	325.10	23.70	12.00	0.29	11.00
ESP 48	300.80	23.10	340.80	19.60	9.45	0.29	14.50
ESP 60	295.10	24.50	362.78	18.26	9.76	0.23	14.66
			Phalsa				
Control	356.80	24.50	284.80	38.07	21.6	0.342	3.50
ESP 12	342.75	22.68	314.80	33.00	20.0	0.341	4.00
ESP 24	339.80	23.10	320.80	31.80	17.8	0.320	6.76
ESP 36	336.70	22.45	325.10	30.00	15.2	0.299	8.00
ESP 41	330.80	23.50	334.10	25.66	13.6	0.293	11.76
ESP 48	328.70	24.50	344.50	19.60	12.9	0.264	13.50
ESP 60	306.50	19.80	358.60	17.00	10.5	0.218	14.00

Contd.....

1.	2.	3.	4.	5.	6.	7.	8.
			Karonda				
Control	374.50	16.70	295.60	36.80	22.00	0.320	3.83
ESP 12	364.45	18.40	320.80	35.10	21.5	0.299	4.00
ESP 24	350.10	19.70	329.60	31.90	18.0	0.293	6.24
ESP 36	334.10	20.50	336.60	28.80	17.0	0.277	8.10
ESP 41	345.10	18.70	339.80	28.10	15.0	0.275	11.27
ESP 48	320.45	23.50	345.10	24.80	14.5	0.207	13.50
ESP 60	265.74	24.30	356.70	17.66	13.4	0.134	10.71
			Passion fruit				
Control	367.80	20.75	276.10	33.60	20.00	0.32	4.41
ESP 12	355.10	23.45	311.10	31.20	19.00	0.31	9.69
ESP 24	347.10	26.75	316.70	30.00	16.00	0.31	10.08
ESP 36	329.80	29.50	319.80	28.60	15.90	0.26	14.19
ESP 41	325.80	24.80	322.60	27.40	14.90	0.24	16.21
ESP 48	310.10	30.50	330.70	26.30	13.60	0.20	17.65
ESP 60	306.70	32.45	345.10	22.80	12.33	0.15	18.83
			Drumstick				
Control	385.60	17.80	297.60	33.60	21.5	0.36	6.00
ESP 12	354.80	19.50	321.50	31.90	20.1	0.34	6.50
ESP 24	340.10	20.50	326.50	29.80	17.5	0.32	8.20
ESP 36	325.10	21.50	332.85	27.30	15.9	0.29	11.10
ESP 41	340.10	24.80	339.80	26.30	13.6	0.27	12.30
ESP 48	305.70	26.50	346.80	24.80	12.4	0.24	14.50
ESP 60	297.80	27.45	350.6	23.70	9.3	0.20	15.10

APPENDIX III

Chemical analysis of soil used for different fruit crops at the end of experimentation under salinity

Treatments	Orgenic carbon (%)	Phosp-horus (kg/ ha)	Potas-sium (kg/ ha)	Cal-cium (me/ 100g)	Magn-esium (me/ 100g)	Potas-sium (me/ 100g)	Sodi-um (me/ 100g)
1.	2.	3.	4.	5.	6.	7.	8.
			Cashew				
Control	0.95	25.6	309.7	40.0	24.8	0.29	2.61
4 mmhos/cm	0.91	27.7	307.4	39.0	20.0	0.29	3.47
8 mmhos/cm	0.89	18.1	206.9	38.7	16.0	0.28	4.58
12 mmhos/cm	0.79	18.0	285.8	37.3	14.5	0.26	4.91
14 mmhos/cm	0.75	17.7	279.2	35.2	13.6	0.23	6.24
16 mmhos/cm	0.68	15.0	223.6	30.3	11.6	0.21	7.62
20 mmhos/cm	0.65	13.3	199.1	26.6	11.0	0.19	7.91
			Coconut				
Control	0.93	62.33	418.33	33.53	26.0	0.40	2.94
4 mmhos/cm	0.89	49.32	397.70	31.93	24.83	0.39	3.98
8 mmhos/cm	0.84	41.10	388.60	31.53	24.53	0.38	4.60
12 mmhos/cm	0.80	32.88	382.87	31.20	19.37	0.38	5.26
14 mmhos/cm	0.77	32.84	380.77	29.07	18.0	0.31	6.03
16 mmhos/cm	0.70	25.36	376.13	27.33	16.73	0.30	6.28
20 mmhos/cm	0.71	16.44	344.17	24.0	13.47	0.29	6.30

Contd....

1.	2.	3.	4.	5.	6.	7.	8.
			Karonda				
Control	0.98	39.05	300.03	36.0	23.17	0.29	3.91
4 mmhos/cm	0.94	33.91	295.50	34.40	23.0	0.28	4.35
8 mmhos/cm	0.88	33.91	291.33	34.0	22.0	0.28	5.86
12 mmhos/cm	0.86	21.72	279.80	33.80	21.17	0.27	5.93
14 mmhos/cm	0.85	19.52	273.17	31.60	10.68	0.26	6.69
16 mmhos/cm	0.84	17.47	268.63	24.61	13.00	0.26	6.89
20 mmhos/cm	0.62	13.36	257.47	19.81	11.17	0.25	7.30
			Passion fruit				
Control	0.90	34.9	356.1	47.6	23.9	0.34	6.52
4 mmhos/cm	0.85	30.8	335.3	37.8	19.1	0.32	6.50
8 mmhos/cm	0.80	29.7	328.3	30.0	17.5	0.31	7.09
12 mmhos/cm	0.76	27.8	314.3	29.2	16.3	0.30	7.35
14 mmhos/cm	0.70	26.7	314.0	28.8	12.8	0.29	7.80
16 mmhos/cm	0.65	24.6	312.0	24.0	11.8	0.27	7.81
20 mmhos/cm	0.55	18.4	293.4	19.2	9.7	0.25	7.84
			Drumstick				
Control	1.17	41.25	382.83	35.20	20.00	0.37	4.35
4 mmhos/cm	1.09	36.48	349.30	33.60	16.78	0.33	5.42
8 mmhos/cm	1.07	29.80	336.07	32.80	13.67	0.32	5.85
12 mmhos/cm	1.01	26.72	326.97	31.80	11.33	0.31	6.62
14 mmhos/cm	0.91	24.66	322.40	31.40	9.83	0.31	6.62
16 mmhos/cm	0.90	22.61	313.73	29.80	9.33	0.30	7.16
20 mmhos/cm	0.86	15.41	290.97	26.40	10.83	0.28	7.20