

STUDIES ON SOIL EXCHANGEABLE SODIUM PERCENTAGE AND SALINITY ON BANANA

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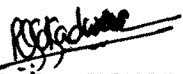
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I hereby declare that the thesis or part
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CERTIFICATE-I

Shri. R.D.Kokadwar has satisfactorily prosecuted his course of research for a period of not less than five semesters and that the dissertation entitled "Studies on soil exchangeable sodium percentage and salinity on banana" submitted by him to the Marathwada Agricultural University, Parbhani, for the award of the degree of 'Doctor of Philosophy (Agriculture) in Horticulture, is a record of original and bonafied research work done under my guidance and supervision. It is sufficiently of high standard to warrant its presentation to the examination. The results embodied in the thesis have not been submitted to any University or Institution for the award of a degree or diploma or distinction. The assistance and help received during the course of this investigation and source of literature have been duly acknowledged.

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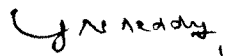
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This is to certify that the dissertation 'Studies on soil exchangeable sodium percentage and salinity on banana' submitted by Shri R.D. Kokadwar to Marathwada Agricultural University, Parbhani in partial fulfilment of the requirements for the degree 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.

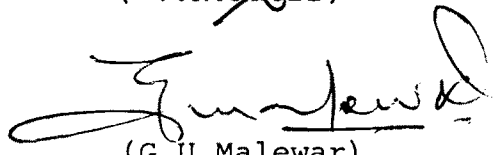

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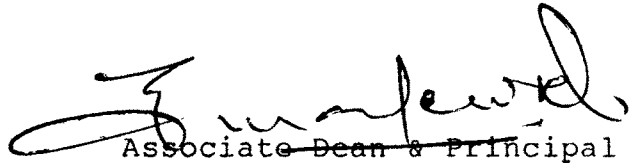

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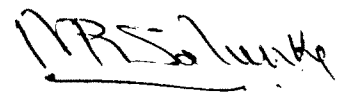
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CONTENTS

Chapter		Page
1	INTRODUCTION	1
2	REVIEW OF LITERATURE	6
3	MATERIALS AND METHODS	63
4	RESULTS	76
5	DISCUSSION	191
6	SUMMARY AND CONCLUSION	240
	LITERATURE CITED	i - xxxv
	APPENDIX	i - iii

LIST OF TABLES

No.	Title	Page
1.	Physico-chemical properties of the experimental soil	64
2.	Charactoristics of the soil after sodium bicarbonate treatment	65
3.	Relative proportion of various ions (me/l) under different salinity treatments	68
4.	Relative proportion of salts (me/l) under different salinity treatments	68
5.	Effect of ESP on pseudostem height, number of leaves and pseudostem dimeter of Ardhapuri banana	77
6.	Effect of ESP on plant spread, total leaf area/plant, root length and mortality of Ardhapuri banana	79
7.	Effect of ESP on fresh weight of whole plant, fresh, dry weight of top and root with rhizome of Ardhapuri banana	81
8.	Effect of ESP on pseudostem height, number of leaves and pseudostem diameter of Basrai banana	83
9.	Effect of ESP on plant spread, total leaf area/plant, root lenght and mortality of Basrai banana	85
10.	Effect of ESP on fresh weight of whole plant, fresh and dry weight of top and root with rhizome of Basrai banana.	86
11.	Effect of salinity on pseudostem height, number of leaves and pseudostem diameter of Ardhapuri banana	88
12.	Effect of salinity on plant spread, total leaf area/plant, root length and mortality of Ardhapuri banana	90

1	2	3
13.	Effect of salinity on fresh weight of whole plant, fresh and dry weight of whole plant, fresh and dry weight of top and root with rhizome of Ardhapuri banana	92
14.	Effect of salinity on pseudostem height, number of leaves and pseudostem diameter of Basrai banana	94
15.	Effect of salinity on plant spread, total leaf area/plant, root length and mortality of Basrai banana	96
16.	Effect of salinity on fresh weight of whole plant, fresh and dry weight of top and root with rhizome of Basrai banana	97
17.	Effect of chlorides on pseudostem height, number of leaves and pseudostem diameter of Ardhapuri banana	100
18.	Effect of chlorides on plant spread, leaf area/plant, root length and mortality of Ardhapuri banana.	102
19.	Effect of chlorides on fresh weight of whole plant, fresh and dry weight of top and roots with rhizome of Ardhapuri banana	103
20.	Effect of chlorides on pseudostem height, number of leaves and pseudostem diameter of Basrai banana	106
21.	Effect of chlorides on plant spread, total leaf area/plant, root length and mortality of Basrai banana	108
22.	Effect of chlorides on fresh weight of whole plant, fresh and dry weight of top and root with rhizome of Basrai banana	110
23.	Effect of bicarbonates on pseudostem height, number of leaves and pseudostem diameter of Ardhapuri banana	113

1	2	3
24.	Effect of bicarbonates on plant spread, total leaf area/plant, root length and mortality of Ardhapuri banana	114
25.	Effect of bicarbonates on fresh weight of whole plant, fresh and dry weight of top and root with rhizome of Ardhapuri banana	116
26.	Effect of bicarbonates on pseudostem height, number of leaves and pseudostem diameter of Basrai banana	118
27.	Effect of bicarbonates on plant spread, leaf area/plant, root length and mortality of Basrai banana	120
28.	Effect of bicarbonates on fresh weight of whole plant, fresh, dry weight of top and root with rhizome of Basrai banana	121
29.	Effect of sulphates on pseudostem height number of leaves and pseudostem diameter of Ardhapuri banana	124
30.	Effect of sulphates on plant spread, leaf area/plant, root length and mortality of Ardhapuri banana.	126
31.	Effect of sulphates on fresh weight of whole plant, fresh and dry weight of top and root with rhizome of Ardhapuri banana	128
32.	Effect of sulphates on pseudostem height, number of leaves, pseudostem diameter of Basrai banana	130
33.	Effect of sulphates on plant spread total leaf area/plant, root length and mortality of Basrai banana	132
34.	Effect of sulphates on fresh weight of whole plant, fresh and dry weight of top and root with rhizome of Basrai banana	133

1	2	3
35.	Effect of ESP on the chlorophyll content (mg/g) of leaves and macronutrient content (per cent) of leaves and roots of Ardhapuri banana.	136
36.	Effect of ESP on Ca: Na and Ca + Mg + K:Na and Micronutrient content of leaves and roots of Ardhapuri banana	139
37.	Effect of ESP on the chlorophyll content (mg/g) of leaves and macronutrient content (per cent) of leaves and roots of Basrai banana.	142
38.	Effect of ESP on Ca:Na and Ca + Mg + K:Na and micro nutrient content (ppm) of leaves and roots of Basrai banana	145
39.	Effect of salinity on chlorophyll content (Mg/g) of leaves and macronutrient content (Per cent) of leaves and roots of Ardhapuri banana.	148
40.	Effect of salinity on micronutrient content (ppm) of leaves and roots of Ardhapuri banana	150
41.	Effect of salinity on chlorophyll content (mg/g) of leaves and macronutrient content (per cent) of leaves and roots of Basrai banana	153
42.	Effect of salinity on micronutrient content (ppm) of leaves and roots of Basrai banana.	156
43.	Effect of chloride leaves on chlorophyll content (Mg/g) of leaves and macronutrient content (per cent) of leaves and roots of Ardhapuri banana	159
44.	Effect of chlorides levels on micronutrient content of leaves and roots of Ardhapuri banana.	162

1	2	3
45.	Effect of chloride levels on chlorophyll content (mg/g) of leaves and macronutrient content of leaves and roots of Basrai banana	165
46.	Effect of chloride levels on micronutrient content of leaves and roots of Basrai banana	167
47.	Effect of bicarbonate levels on chlorophyll content (mg/g) of leaves and macronutrient content (per cent) of Ardhapuri banana	170
48.	Effect of bicarbonate levels on micronutrient (ppm) content of leaves and roots of Ardhapuri banana	173
49.	Effect of bicarbonate levels on chlorophyll content (mg/g) and macro nutrient content (per cent) of Basrai banana	175
50.	Effect of bicarbonate levels on micronutrient content (ppm) of leaves and roots of Basrai plant	178
51.	Effect of sulphate level on chlorophyll content (mg/g) of leaves and macronutrient content (per cent) of leaves and roots of Ardhapuri banana plant	181
52.	Effect of sulphate levels on micronutrient content (ppm) of leaves and roots of Ardhapuri banana.	184
53.	Effect of sulphates on chlorophyll content (mg/g) of leaves and macronutrient content (per cent) of leaves and roots of Basrai banana	186
54.	Effect of sulphate levels on micronutrient content (ppm) of leaves and roots of Basrai banana	188
55.	sodium tolerance indices of banana cultivars.	194

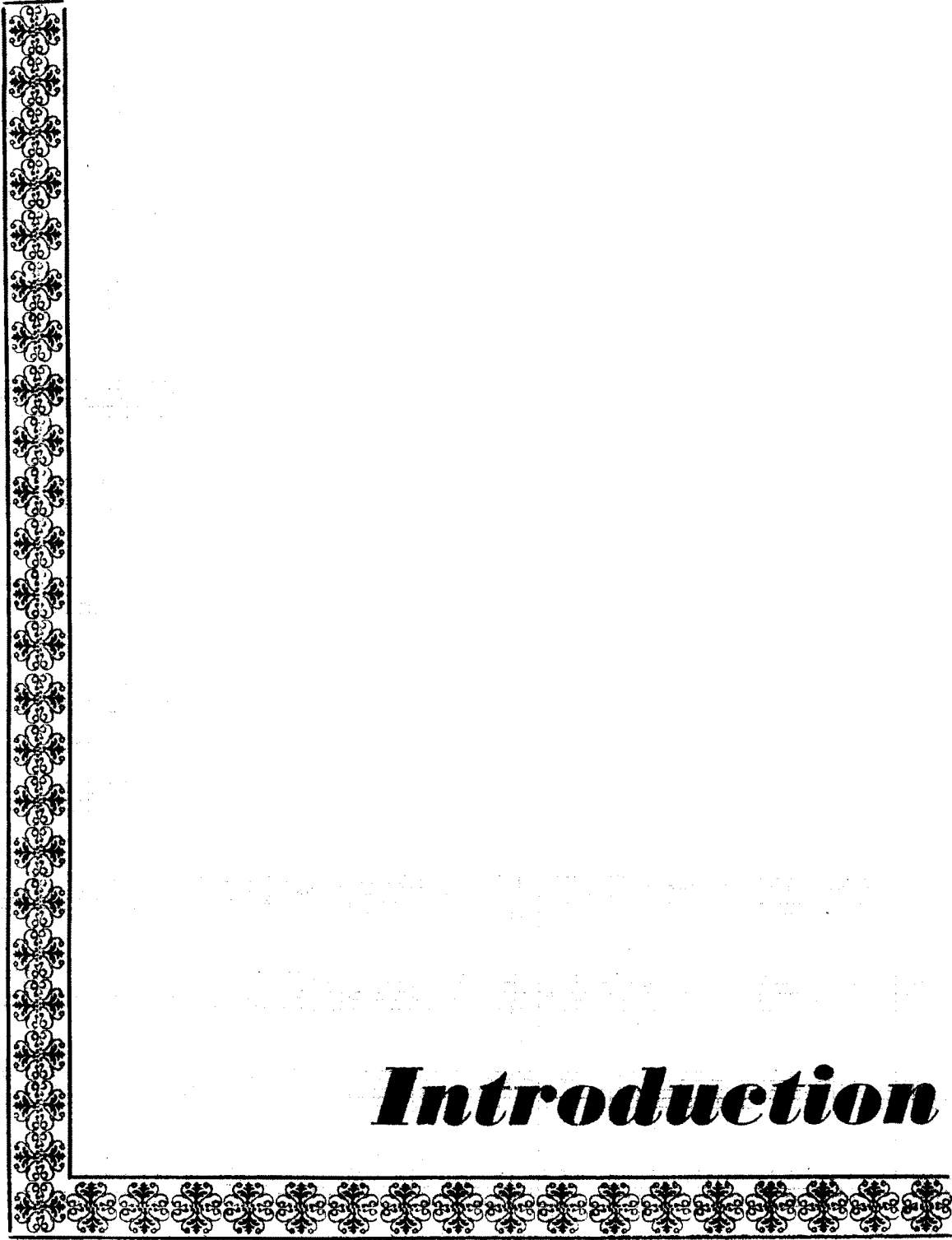
1	2	3
56.	Correlation coefficients among different characters in presence of ESP.	195
57.	Salinity tolerance indices of banana cultivars	198
58.	Correlation coefficients among different characters in presence of salinity (ECe).	199
59.	Chloride tolerance of banana cultivars.	202
60.	Correlation coefficients among different characters in presence of soil chloride levels.	203
61.	Bicarbonate tolerance of banana Cultivars	206
62.	Correlation coefficients among different characters in presence of soil bicarbonate levels.	207
63.	Sulphate tolerance of banana cultivars	209
64.	Correlation coefficients among different characters in presence of soil sulphate levels.	210

LIST OF PLATES

No.	Title	Between Pages
1	2	3
1.	Effect of ESP on top growth of banana plant cv. Ardhapuri (after 180 days of planting).	78-79
2.	Leaf injury caused by soil ESP cv. Ardhapuri banana.	78-79
3.	Effect of ESP on root growth of banana plant cv. Ardhapuri (after 360 days of planting).	81-82
4.	Effect of ESP on root growth of banana plant cv. Basrai (after 360 days of planting).	81-82
5.	Effect of ESP on top growth of banana plant cv. Basrai (after 140 days of planting).	84-85
6.	Leaf injury caused by soil ESP cv. Basrai banana.	84-85
7.	Effect of soil salinity on top growth of banana plant cv. Ardhapuri (after 120 dyas of planting.)	89-90
8.	Leaf injury caused by soil salinity cv. Ardhapuri banana.	89-90
9.	Effect of soil salinity on root growth of banana plant cv. Ardhapuri (after 360 days of planting).	92-93
10.	Effect of soil salinity on root growth of banana plant cv. Basrai (after 240 days of planting).	92-93
11.	Effect of soil salinity on top growth of banana plant cv. Basrai (after 210 days of planting).	95-96
12.	Leaf injury caused by soil salinity cv. Basrai	95-96
13.	Effect of chlorides on top growth of banana plant cv. Ardhapuri (after 210 days of planting).	101-102

1.	2.	3.
14.	Leaf injury caused by soil chlorides cv. Ardhapuri banana.	101-102
15.	Effect of soil chlorides on root growth of banana cv. Ardhapuri (after 240 days of planting).	104-105
16.	Effect of chlorides on root growth of banana cv. Basrai (after 360 days of planting).	104-105
17.	Effect of soil chlorides on top growth of banana plant cv. Basrai(after 210 days of planting).	107-108
18.	Leaf injury caused by soil chlorides cv. Basrai banana.	107-108
19.	Effect of bicarbonates on top growth of banana plant cv. Ardhapuri (after 240 days of planting).	113-114
20.	Leaf injury caused by soil bicarbonates cv. Ardhapuri banana.	113-114
21.	Effect of soil bicarbonats on root growth of banana cv. Ardhapuri (after 300 days of planting).	116-117
22.	Effect of bicarbonates on root growth of banana cv. Basrai (after 240 days of planting).	116-117
23.	Effect of soil bicarbonates on top growth of banana plant cv. Basrai (after 240 days of planting).	119-120 ,
24.	Leaf injury caused by soil bicarbonates cv. Basrai banana.	119-120
25.	Effect of soil sulphates on top growth of banana plant cv. Ardhapuri (after 210 days of planting).	125-126
26.	Leaf injury caused by sulphates cv. Ardhapuri banana.	125-126

1.	2.	3.
27.	Effect of soil sulphates on root growth of banana cv. Ardhapuri (after 240 days of planting).	128-129
28.	Effect of soil sulphates on root growth of banana cv. Basrai (after 360 days of planting).	128-129
29.	Effect of soil sulphates on top growth of banana plants cv. Basrai (after 240 days of planting).	131-132
30.	Leaf injury caused by soil sulphates cv. Basrai banana.	131-132



Introduction

Chapter 1

INTRODUCTION

Banana (Musa paradisiaca Linn) is one of the oldest tropical fruit of India, ranking at the second important position next to mango at National level. It is the most popular fruit of different ecological regions and considered as 'Poor man's apple' although it is consumed by rich and poor alike. It comes up well in regions of 10° to 40° C (Madhavrao, 1984) and cultivated over a wide range from 20°N to 20°S of the equator (Shanmungvelu et al., 1992). It stands above any other crop in terms of both harvest weight and calories (6.9 - 13.8 million calories/ha.). It occupies 3.1 lakh hectares area with annual production of 59.7 million tonnes (India, 1992). World produces 45 million tonnes of banana each year, 22 per cent of this constitutes the International trade and the remainder is consumed locally (FAO, 1987).

In India, it is cultivated in almost all states. Maharashtra occupies an area of 53,200 ha. standing first in acreage with annual production of 14.5 million tonnes of banana fruit. In Maharashtra State, Maximum acreage as well as production is concentrated in Jalgaon district (37,500 ha. area with 10,80,100 tonnes production). In Marathwada region (6,800 ha. area with 1,65,700 tonnes production) banana cultivation is concentrated in Parbhani district with an area of 3,200 hectare and annual production 91,100 tonnes of banana fruits (India, 1992).

More irrigation facilities due to Jayakwadi, Purna, Vishnupuri, Upper Penganga and Manjra project will be made available in future in Marathwada region. It is however, well known that the story of irrigated agriculture is not entirely one of prosperity. A sizable area of irrigated land, once producing abundantly has gone out of cultivation in several parts of the world. Bernstein (1965) reported that almost 25 per cent of the total irrigated land in United states is adversely affected by salts and the proportion would be much higher for the salt sensitive crops. In India, approximately 12 million hectares of land is affected by salinity/sodicity and the area is increasing every year at a rapid rate (Sharma and Gupta, 1987). About 0.54 million hectare area has been estimated as salt affected in Maharashtra (Abhange et al., 1986), While in Marathwada 7,700 hectares.

Saline and alkalin/sodic soils occur in most part of arid and semi-arid regions of India. Restricted drainage is the major factor that usually contribute to the salinization of soil. It is the general belief that, soil supports for the normal growth of the plant but the fact is ignored that most of the plantation and fruit crops are more sensitive to both salinity and alkalinity than cereal crops. Decrease in chlorophyll content, respiratory rate, photosynthesis and stomatal closure are the physiological changes caused due to salinity/sodicity while

biochemical changes occurring are increased production of strong organic acids, pectin content and decreased protein synthesis (Ahmad et al., 1985).

Use of canal irrigation and brackish water also results in the development of salinity and sodicity in the soil. In the process of salinization, soluble salts present in the sub-surface move towards the soil surface by the capillary rise alongwith water and accumulate on the surface after evaporation of water. The fact that the irrigated agriculture is more prone to the salt accumulation on one hand and relatively higher salt sensitivity to banana, warrants to tackle this problem with the help of well planned research so that the banana growers would not get set back due to salt accumulation in banana cultivation. Large variations exist between the salt tolerance of different banana species. Therefore, the only alternative left is to find out the extent of salt tolerance which can be used as guidelines by those who are planning to establish the banana orchards.

On careful examination of the various types of works highlighting the effect of salts as mentioned in different reviews (Bernstein, 1965 a and b; Patil ^{and Patil} 1983 a and b and Dahiya et al., 1983), it is felt necessary to differentiate between various types of salt stresses. The

injurious effects of plants may be mainly due to the individual or combined effect of higher total salinity (salinity stress) or higher exchangeable sodium percentage (sodic stress) or may be due to toxic concentration of specific ion (ionic stress) in soil. If the salt concentration is high enough to lower the water potential appreciably (0.5 to 1.0 bar) the soil condition may be called as saline. In alkaline soils, because of higher exchangeable sodium, the soil structure is poor leading to the problems of aeration, moisture movement and to the nutritional disorders.

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 horizons of the soil, while most of the tree species have deeper root system. Hence the present system of reclamation may not be quite effective for the cultivation of tree species. Various species and varieties differ markedly among themselves to the reaction of salt stresses. The published reports of various workers (Lunt, 1966; Chapman, 1968; Patil 1979 a and b; Patil, 1980; Kadam, 1984; More and Malewar, 1988; Sadaria, 1989; Valia, 1989 and Rajput, 1990) highlighted comprehensive work on citrus, grape, other major fruit crops, multipurpose tree species and general field crops.

But the literature on banana is scanty.

Therefore the present investigation is attempted by undertaking comprehensive studies on soil alkalinity, salinity and ionic salinity in relation to the banana varieties. The major objectives of the studies are-

- i) to assess the effect of various levels of soil alkalinity and salinity on the growth of two banana cultivars,
- ii) to study the effect of various levels of alkalinity, salinity and ionic salinity on chemical composition of two banana cultivars,
- iii) to estimate the relative tolerance indices of banana to alkalinity, salinity and ionic salinity,
- iv) to find out toxic levels of ionic salinity due to chlorides, bicarbonates and sulphates on growth of banana cultivars,



Review of Literature



Chapter 2

REVIEW OF LITERATURE

Salinity and sodicity are very important constraint in crop productivity in India. These type of soils occur in most part of arid and semi-arid climate in India. 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. Introduction of canal irrigation and irrigation with brackish water also result in the development of salinity in the soil. In the process of salinization soluble salts from sub-surface move towards soil surface by the capillary action along with water and accumulate on the surface after evaporation of water.

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.

Recently it has been recognized world over that more emphasis should be given to grow salt tolerant crops instead of reclaiming salt-affected soils. In evaluating the resistance of different crops on salt stress, no clear cut distinction is generally made between total salinity, ionic salinity and alkalinity of the media. In a review,

Patil (1979a) signified the importance of such a criterion and degree of total salinity, ionic salinity and sodicity for screening the salt tolerance in fruit crops.

Plants generally absorb water more slowly from root zone in which salts are accumulated (Bernstein, 1965a). The amount of soluble salts present in the saline soil control the osmotic pressure of the soil solution. In saline soil, salt concentration is high enough to lower the water potential appreciably. The stress arising from salts not capable of lowering the water potential appreciably may be due to ionic salinity or alkalinity.

In ionic salinity, the concentration of specific ions becomes critical and specific toxicity symptoms of these ions become apparent. In case of alkalinity, on account of greater exchangeable Na in soil, it becomes dispersed, leading to the problems of aeration, moisture movement and availability of nutrients.

Development of salinity / secondary salinity and sodicity.

A combination of factors which are mainly geological, climatic and hydrological in nature, is usually involved in the formation of saline and alkali soils. Primary source of salinization is rock weathering. The rivers draining into the soil along with the dry climate and high water table may be additional factors

for the accumulation of salts. Rainfall appears to have greater effect than annual temperature in determining the salinity of soil. Soluble salts will obviously accumulate whenever evaporation exceeds total precipitation. At such places surface run-off is negligible and drainage water evaporates leaving the salts on the surface. This process of evaporation also brings salts from the lower horizons if the moisture regime is connected with ground water. A thick cover of herbaceous plants reduces evaporation of ground water and thus lessens the chances of salt solutions to rise to the surface (More and Malewar, 1988).

Secondary salinization is related to the anthropogenic cycles of salt accumulation. Resalinization of soil profile starting at the end of monsoon brought the salts upwards and high salinity was developed at the start of next monsoon.

Therefore, the literature pertaining to the effect of soil exchangeable sodium percentage, salinity and ionic salinity viz., chloride, bicarbonates and sulphates on the growth and chemical composition of tree species is reviewed in this chapter under the following sub heads.

2.1 Effect of exchangeable sodium percentage

2.1.1 ESP tolerance of fruit species

A limited information is available regarding tolerance of various fruit crop species to varying levels of ESP. Martin and Bingham (1954) reported that avocado seedlings were injured by 4 per cent exchangeable sodium, 7 per cent caused moderate injury while 14 per cent caused severe injury. Bernstein and Hyaward (1958) noticed that the toxic levels of sodium would accumulate in citrus if the soil contains more than 5 per cent exchangeable sodium.

Pearson (1960) emphasized that deciduous fruits, nuts, citrus and avocado were extremely sensitive (ESP = 2 to 10) to exchangeable sodium. However, it was stated by Bhella (1966) from Hissar, Singh (1966) from Bhatinda and Chada (1966) from Sangrur that well grown citrus trees can thrive fairly well under the soil having ESP upto 15.

Bernstein (1974) emphasized that the most of the Na sensitive plants like citrus get affected by Na toxicity when the ESP of the soil was well below those levels associated with the soil structure deterioration. Patil (1979 a) reported that Poncirus trifoliata and citranges although were very sensitive to salinity showed better performance under higher ESP. The ESP tolerance indices (ESP levels representing 50 per cent growth depression)

were calculated to 16.7, 9.5, 10.2, 11.7, 13.4 and 17.0 in Jatti-Khatti, Cleopatra, Kharna Khatta, Rangpur lime, Carrizo and Jullandari Khatti, respectively (Patil and Bhambota, 1978 c). Nilangekar and Patil (1979 and 1981) related the decline of sweet orange orchards of Jalna and Parbhani district with ESP higher than 18. Exchangeable sodium upto 30 per cent in grape vines (Khanduja et al., 1980), 25.5 per cent in pomogranate (Patil and Patil, 1982), 40 per cent in bael (Tewari, 1985) and 30 per cent in aonla (Sharma et al., 1987) were estimated as the upper limits upto which these can be grown successfully.

Patil (1980) reported that chiku and fig were more ESPtolerant plants, the tolerance limit for ESP (ESP level representing 50 per cent growth depression) was calculated to be 39.2, 38.2, 45.5, 44.5, 47.5 and 53.5 in guava, pomogranate, custard apple, ber, jamun, chiku and fig, respectively. Adinarayana et al. (1986) indicated that the soil supporting good growth of banana contained 12.5 per cent exchangeable sodium.

Sadaria (1989) investigated the effect of soil ESP on eight plant species grown in pots containing varying levels of ESP, the tolerance limits of ESP (ESP representing 50 per cent growth depressions) were 48.5, 43.5, 38.5, 36.0, 51.0, 46.5, 64.0 and 52.2 in tamarind,

woodapple, mulberry, bael, khirni, eucalyptus, neem and persian lilac, respectively. Valia (1989) reported the tolerance limits of ESP (ESP representing 60 per cent growth depression) were calculated as 65.2, 77.7, 61.4, 97.4, 91.0, 80.0, 70.0 and 74.1 in cashew, coconut, marking-nut, soapnut, phalsa, karonda, passion fruit and drumstick 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 (Itallie, 1938; Bower and Turk, 1946; EL-Gabaly, 1955 and Peterson, 1961).

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

Martin et al., (1959 a) observed reduce in growth of Trifoliate orange seedlings as the ESP was increased (1 to 15 per cent). The growth reduction was much more in clay loam soil than sandy loan. 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 decrease in fresh weight of root, top and leaf area of citrus rootstocks studied with the increasing ESP levels. The growth of guava, pomogranate, custard apple, ber and jamun was adversely affected at the ESP 30, while in chiku and fig it was at ESP 40 (Patil, 1980). Turner (1983) attributed marginal chlorosis and necrosis in banana due to the presence of sodium. Kadam (1984) noticed reduction in height, stem girth, number of branches, spread, total number of leaves, leaf area, fresh and dry weight of whole plant, fresh and dry weight of whole plant, fresh and dry weight of roots and top under higher ESP in 10 different citrus rootstocks studied. Patil and Waghmare (1984) concluded that plant height, number of leaves and stem diameter were significantly declined after 360 days with rising ESP levels in sapota. According to Tewari (1983) growth parameters viz., plant height, girth and spread in bael seedlings showed decreasing trend with increasing ESP levels.

Sharma et al., (1987) observed that the increasing trend of soil sodicity (15, 30, 45 and 60 per cent) decreased the plant height, diameter and spread of the aonla plant. Sadaria (1989) recorded progressive decrease in growth parameters with increase in soil ESP. The growth parameters viz., plant height, number of leaves and stem

diameter of tamarind, woodapple, khirni, eucalyptus, neem and persian lilac were affected at ESP 40. All growth parameters of bael and mulberry were adversely affected right from ESP 30 onwards. Further, 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. Valia (1989) concluded maximum depression in plant height of phalsa, drumstick and cashew, number of leaves in passion fruit, plant spread in karonda, markingnut and phalsa, total leaf area and root length in markingnut and soapnut and total number of roots of soapnut and cashew at higher levels of ESP (60).

Singh et al. (1982) suggested that tinda (Diospyras tomentosa), dhak (Butea monosperma), mahuva (Madhuca indica) and jamun (Syzygium cuminii) were able to grow on Cl-HCO₃ type soils having a maximum pH value 8.0 and ESP 10 in one metre deep soil but in the subsoil, tolerance of plants may go still higher i.e. pH 9.3 ESP 40. Chhabra et al. (1987) studied three sesbania species viz., S.aegyptica, S. formosa and S. sesban grown in sodic soils having ESP ranging from 13 to 98. Though none of the species survived at the highest ESP level of 98, S.aegyptica was found to be more tolerant to sodic soil condition.

2.1.3 Effect of ESP on physiological parameter

2.1.3.1 Chlorophyll

Leaf chlorophyll content decreased with the increase in soil exchangeable sodium in citrus rootstocks (Patil, 1976; Patil and Bhambota, 1978 c; Kadam, 1984; Rajput, 1990). 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 and Patil, 1984), in bael (Pandey et al., 1985; Tewari, 1985) with increasing sodium in soil.

The total chlorophyll content in leaves of all species decreased with the increase in soil sodium. In general, plant species tolerant to sodium showed greater chlorophyll content in leaves (Sadaria, 1989). Valia (1989) noted the reduction in chlorophyll in soapnut and drumstick even at lowest level of ESP. The highest reduction in chlorophyll was noted in phalsa and passion fruit under the highest ESP level (ESP = 60).

2.1.4 Effect of ESP on the chemical composition

The nature and extent of Na present in the soil affect the chemical composition of plants to a great

extent. The plants take 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 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 Na. 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. Peterson (1961) also stated that high Na in the growth medium would depress the growth due 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 and (d) imbalance among nutrients. In the plants having Na resistance, a large part of Na absorbed by their roots is retained and accumulated in the vacuoles of root-cell.

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 revealed similar results in young lemon plants budded on different rootstocks. Under the influence of higher amounts of exchangeable Na, they observe total concentration of cations decreased in leaves than in tap roots. Martin et al. (1959) found that increase in Na decreased absorption of K and Mn in trifoliate orange seedlings. 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:Mg, K:(Ca + Mg) ratios in soil and leaves.

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 Joolke (1976)

observed decrease in K content of mango and citrus, respectively with increasing sodium content in the leaves. Under increased ESP conditions (Patil, 1976) observed that Kharna Khatta and Cleopatra were adversely affected in respect of N, P, Ca, Mg, Zn, Mn and Cu while Jatti Khatti, Jullandari 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, custard apple, 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. Kadam (1984) observed reduction in the P, K, Ca and Mg in leaves and roots of citrus rootstock in higher ESP level. The leaf-N increased under the higher ESP. Stem-P decreased while K and Ca in stem increased at the higher level. There was no significant difference in stem-Mg. The Na and Cl content in leaves, roots and stem increased at the higher ESP level. Rajput (1990) noticed that as the Na concentration increased from 0 to 40 me/l, there was decrease in leaf and root-K, Na and root-Cl. Chlorophyll, leaf-Ca, Na and root-Mg were decreased with each increment of Na from 10 me/l onwards. Nitrogen content in the leaves tended to increase with increasing sodium levels upto 20 me/l in case of citrus rootstocks. However, leaf-Zn, Cu, Mn

and Fe contents generally decreased with increasing soil exchangeable Na content (from 5 to 45.3 per cent) in ber (Nirlep Kumar et al., 1990).

Tewari (1983) and Pandey et al. (1985) observed decrease in N, P, K, Ca and Mg content in the foliage of aonla and bael, respectively. Whereas Na increased with the increasing sodicity. Singh et al. (1983) also reported that rise in soil sodium increased plant Na and Fe and decreased Ca and Mg in both jujube and guava and decreased K and P in guava only. While Zn and Cu contents were unaffected in both species. Awada and Suchisa (1985) inferred that increasing Na in solution increased Na petiole concentration but decreased N content in papaya.

Adinarayana et al. (1986) recorded that an average healthy leaves of banana contained 3.1 per cent potassium as against 1.73 per cent in an affected plantation, whereas their respective Na content were 0.40 and 0.91 per cent respectively. The soil supporting plants with Na excess had a mean ESP of 12.5. Palms receiving high amount of Na retained high amount of these elements (Prema ^{et al.} 1987).

Sadaria (1989) found that increase in ESP, resulted in increased Na content and mortality of different species. The highest mortality was recorded in bael followed by mulberry and eucalyptus at ESP 50. Further the

N content in leaves of bael, khirni and neem increased with the increase in ESP upto certain level, but was not constant. 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 increase in ESP

The P content in the leaves and roots of all species decreased with the increase in Na except root-P in woodapple. In general, decrease in K, Ca and Mg content in leaves and roots due to high Na was recorded in all plant species. Under increasing sodium concentration in soil the Ca:Na and Ca + Mg + K : Na ratio of the leaves and roots decreased in all species. It was lowest in the leaves of bael followed by mulberry at ESP 50. Increasing levels of Na significantly decreased Zn, Fe and Mn contents in leaves and roots of all species studied.

Valia (1989) recorded increase in N content of leaves of cashew, coconut, markingnut, soapnut, karonda and drumstick with the increasing ESP upto 41 but it was not constant. He also recorded highest deposition of Na in leaves and stem in cashew, markingnut and passion fruit.

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. These incorporate 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 EC_e, for complete ceasation of growth of various crops like dateplam-32, fig, olive, pomegranate-14, grape-12, grapefruit, orange, lemon, apple, pear, walnut, as 8 and almond, plum as 7 mmhos/cm at 25°C. Patil (1979b) also updated the information on tolerance of fruit crops to salt in his review.

Ayers and Westcost (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 was 17.9 in datepalm, 8.4 in fig, olive, pomegranate, 4.8 in grapefruit, orange, lemon, apple, walnut and 6.84 mmhos/cm in grape.

Crops with low salinity tolerance

According to USDA salinity lab staff (1954) the crops which come in the range of poor tolerance (2 to 3 mmhos/cm) are muskmelon, pear, apple, citrus, plum, peach, 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; Oganessian, 1954; Ehlig and Bernstein, 1958).

Bernstain (1968 and 1965b) reported that E_{Ce} at which yields decrease by about 10 per cent was found to be 3 to 2.5 for orange, grapefruit and lemon. Raheja (1962) found that in citrus order of tolerance was 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). Bhella (1966) correlated citrus decline with higher E_{Ce} levels. The sweet orange plants budded on rough lemon were reported to

be highly sensitive to salinity i.e. 6 mmhos/cm (Bhambota, 1965). . Amongst rootstocks evaluated, Rangpur lime and Cleopatra mandarin were reported to be tolerant upto 4.8 mmhos/cm (Joolka and Singh, 1979).

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.

Crops with medium salinity tolerance

According to the USDA salinity lab staff (1954) the crops which have been categorised in 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.

Raheja (1962) recorded that seeded varieties were more tolerant to soil salinity compared to seedless one. According to Allison (1964) the relative salt tolerant

limit for grapes was 3 to 6 mmhos/cm. Gupta (1965) registered that Perlette and Khalili grape varieties were most susceptible to salt injury, Himrod medium salt tolerant while Alamwick, Thompson seedless and Beauty seedless comparatively resistant. Nauriyal and Gupta (1967) reported that Anab-e-Shahi grape more susceptible to salt injury than Bangalore purple and Selection-7. Pal (1971) observed that salt concentrations of 3500 ppm and 4500 ppm resulted into the death of all grapevines while Bhokri was tolerant to salts 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. Hooda et al. (1990) summarised that beauty seedless cultivar was more tolerant to salinity compared to Delight and Perlette.

According to Raheja (1962), grafted varieties of mango and guava were most sensitive to salinity than ungrafted once. Gupta (1963) reported that Dasherri Mango was more hardy to soil salinity than langra, in case of guava, Allahabad safeda seedlings were superior to seedless grafted in regard to soil salinity tolerance. Patil and Patil (1980) reported that the guava plants can be grown successfully upto 8 mmhos/cm ECe. Transplanted guava seedlings could not survive beyond Ece 9 mmhos/cm (Kaul, 1981).

In the greenhouse study made by Patil (1980), the adverse effects of salinity were seen right from ECe at 8 mmhos/cm of saturation extract in guava, pomegranate and custard apple. The salinity index (Salinity level representing 50 per cent growth depression) was calculated to be 9.7, 9.0 and 9.5 for guava, pomegranate and custard apple, respectively. Patil and Patil (1983c) reported Umran variety of ber can be grown upto ECe 7.3 mmhos/cm while Jain and Dass (1988) found ber cultivars viz., Sev, Gola and Mundia survived well at 6.5, 4.5 and 4.5 ECe mmhos/cm respectively. The pomegranate variety Khog survived well under 6.5 mmhos ECe while Jalore seedless tolerated salinity only upto 4.5 mmhos.

Sadarja (1989) reported adverse effects of salinity (mortality symptoms) right from conductivity level of 8 mmhos/cm of saturation extract in mulberry, bael and eucalyptus. Valia (1989) found that phalsa, cashew, soapnut and drumstick were medium salinity tolerant (8 mmhos/cm).

Crops with high salinity tolerance

According to 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. In jamun, chiku and fig grown in pots, the adverse growth effects were noticed at 12 mmhos/cm and above. Thus they were found to have good salinity tolerance. The salinity level (ECe) representing 50 per cent growth depression was 18.8, 17.8 and 15.6 in chiku, fig and jamun, 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 ber, guava, aonla and phalsa (Yamdagri, 1983). Singh and Ganesh Murthy (1987) reported that Katchal tall variety of coconut showed good response even at salinity level of 40 dsm⁻¹.

Sadaria (1989) found salinity tolerance indices (salinity level mmhos/cm representing 20 per cent growth depression) were calculated as 13.2, 12.5, 12.7, 15.0 and 16.5 for tamarind, woodapple, khirni, neem and persian lilac, respectively. Valia (1989) in his pot culture study observed that the salinity tolerance

indices (salinity level mmhos/cm representing 20 per cent growth depression) were calculated as 86.75 and 92.25 per cent for coconut and karonda respectively at and above salinity level of 14 mmhos/cm.

2.2.2 Effect of salinity on growth

The injurious effects of the plants may be either due to the total soil salinity (salt stress) or due to toxic concentration of individual ions (ion stress) like chloride, sodium, sulphate etc. Even if the chloride and sodium concentration are not excessive, high concentration of other salts may impair the 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 (Strongonov, 1962), which results in inhibition of plant growth may probably due to the osmoatic 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 treatment decreased growth in both young and old citrus trees. Allison (1964) found that ECe Values from 1.5 to 3.0 mmhos/cm were safe for the

growth of citrus. The adverse effects on plant height, stem diameter, number of leaves and plant spread of various citrus species started right from the conductivity of 2 mmhos/cm of saturation extract, as the conductivity increased the adverse effects on different growth parameters were also accentuated. Pearson et al. (1985) observed that 10 per cent reduction was associated with electrical conductivity of the soil saturation extract of 2.3 dsm^{-1} and 50 per cent reduction of growth for citrus was associated with an ECe of 4.8 dsm^{-1} . Citrus rootstocks namely Rangpur lime L-19, Rough lemon Africa, Rangpur lime Australia and Limao Crazo Brazil were tolerant to higher salinity level ($\text{EC}=3 \text{ mmhos/cm}$) while Troyer citrange, Kichilli, Trifoliate orange and Nasnaran were susceptible at same level.

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

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 bud sprouting and also reduced the per cent of sprouting in grapevines,

most of the vines could not survive at 12 and 16 mmhos/cm E_{ce} level, various growth parameters viz., number of buds sprouted, shoot length, number of leaves, leaf area and dry weight of vines decreased due to high salt concentration in the soil. Makhija and Jindal (1984) reported that berry set remained unaffected upto 6 mmhos/cm while at E_{ce} 8 mmhos/cm there was reduction in berry set in grape cv. Perlette. Kishore et al. (1985) concluded that the reduced photosynthesis could be the cause of reduced vegetative growth because of increasing salinity of growth medium. In case of Beauty seedless, Delight and perlette varieties of grape, number of leaves per vine and plant height were decreased with increasing salinity (E_{ce} = 4 to 10 ds/m) while number of shoots per vine remained unaffected (Hooda et al., 1990).

Patil and Patil (1980) reported that upto 8 mmhos/cm of E_{ce}, there was no appreciable reduction in whole plant fresh and dry weight. Desai and Singh (1980) found that salinity tolerance indices for 20, 50 and 80 per cent growth reduction in guava was observed at 7.3, 9.3 and 11.3 mmhos/cm E_{ce} respectively. Tree canopy area was reduced significantly at E_{ce} more than 5 ds/m while trunk diameter and other growth parameters were affected at a soil E_{ce} more than 10 ds/m in case of guava.

Once established ber plants can be successfully grown upto 21 mmhos/cm ECe (Dhankar et al., 1978). Dahiya and Dhankar (1982) reported that soil salinity at and above 14.2 mmhos/cm ECe decreased the plant height, stem diameter leaf area, shoot and root dry matter yield of ber seedlings. Hooda et al. (1990) found that Umran cultivar of ber survived at ECe level of 20 ds/m while trunk diameter was affected at a soil salinity level more than 10 ds/m.

Irrigation water containing excessive dissolved salt 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). Shishva and Kapshuk (1987) reported that EC levels of 1.0, 1.9, 2.2 and 2.6 mmhos/cm affected growth of almond, olive and datepalm, respectively.

Pomier and Branin (1974) studied the effects of irrigation on coconut with saline water and observed that the saline irrigation increased foliage, however, the stomatal opening was reduced. Nagarajan et al. (1975) observed maximum yield response from saline water, irrigated with sea water did not exhibit any 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, 1983 b). The tree growth in mango cultivar Langra and Dashehari was adversely affected at soil salinity level of 10 mmhos/cm (Jindal et al. 1976).

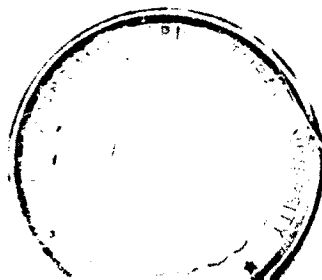
Sadaria (1989) noticed adverse effects of salinity right from the ECe level of 8 mmhos/cm in case of mulberry bael and eucalyptus, while in tamarind, wood apple, khirni, neem and persian lilac the adverse effects were noticed at and above 16 mmhos/cm. As the salinity increased the adverse effects on plant height, number of leaves, stem diameter, fresh weight of whole plant, fresh and dry weight of top and root, plant spread, root length and volume, and leaf area per plant were also accentuated. Further the 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 symptoms were observed in bael and the least in neem.

According to valia (1989), the adverse effects of salinity on plant height started right from conductivity level of 4 mmhos/cm of saturation extract in markingnut, cashew and passion fruit while soapnut showed maximum reduction in stem diameter. Mortality symptom in markingnut was observed at salinity level 4 mmhos/cm, in cashew and passion fruit it was noticed at

E_ce level of 8 mmhos/cm while soapnut, phalsa and drumstick recorded adverse effects at E_ce level of 12 mmhos/cm. Coconut and Karonda were found most tolerant amongst all crops under study (EC = 14 mmhos/cm).

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 glauca 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 (EC_{iw} 1.5 - 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.



2.2.3 Effect of salinity on physiological parameters

2.2.3.1 Chlorophyll

The specific ions of salts contribute a lot in changing the pigment concentration of plants. Bleaching of chlorophyll was 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 (Bhambota and Kanwar, 1970) in the leaves of malta Blood Red grafted on Rough lemon. Further Joolka (1976) and Patil (1976) reported decrease in level of chlorophyll in leaves of citrus rootstocks under the increasing salinity treatments. The results of Divate and Pandey (1981) revealed proportional decrease in chlorophyll content with higher salt concentration in grape cultivar however the rate of respiration was stimulated. Patil (1980) recorded lower chlorophyll content in leaves as soil salinity increased in all seven fruit crops studied.

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

Valia (1989) also found that the lowest chlorophyll reduction was estimated in drumstick under lowest levels of salinity (4 mmhos/cm). Rajput (1990) emphasized that

as salinity level increased there was reduction in chlorophyll content in citrus rootstocks.

2.2.4 Effect of salinity on the chemical composition

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 Na^+ and Cl^- 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 ^{plant} Ca , Mg and K in leaves.

P concentration in plant tissue was unaffected by the 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.

Bhambota (1965) investigated the effects of salinity levels on sweet orange budded on rough lemon and reported that the Cu and B content in the leaves were markedly depressed by higher ECe levels of 4 to 6 mmhos/cm. However, Ca, Zn and Fe content showed opposite trend. The excess of Cl^- in the orange leaves produced leaf bronzing. Injured leaves usually contained more than 1.10 per cent Cl^- on dry weight

basis and concentration in excess of 0.5 per cent was regarded as hazardous (Bernstein, 1965 b). 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 and Zn contents in the leaves decreased whereas Na, Cl and S content increased under all salinity levels. The rootstocks also differed with regard to their chemical composition.

Patil and Bhambota (1978 a and 1980) undertook greenhouse studies and reported that N and P contents in citrus rootstocks namely Kharna Khatta and Carrizo Citrage 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, uptake of Zn was particularly reduced under high salinity (Patil and Bhambota, 1980). Abdel Messih et al. (1979) added salt (NaCl + CaCl₂) upto 6000 mg/g to irrigation water and grow different citrus rootstock seedlings. The Na, Ca and to a lesser extent the K levels increased of all rootstock. Leaf Mg, N and Fe reduced and P was unaffected.

Studies were made by Hernandez et al. (1979) on 12 year old trees of Verna lemon on sour orange rootstock in saline soil. The ratio of $\text{Na} + \text{K} + \text{Ca} + \text{Mg}/\text{N} + \text{P}$ decreased in the roots and rose in the leaves in the first 24 to 90 days, respectively. The ratios $\text{Fe} + \text{Mn} / \text{N}$ and $\text{Fe} + \text{Mn}/\text{p}$ 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 complex nutrient solution with added NaCl at 2 g/l. Toxicity symptoms appeared after 3 months which were 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. Rajput (1990) found that at ECE of 3 mmhos/cm, highest leaf-N was observed in Rough lemon Africa and root-N and P in case of Nasnaran. Rangpur lime L-19, Nasnaran and Rangpur lime Australia reported maximum leaf-P and K. Root-K was highest in Trifoliate orange while leaf-Ca was maximum in Cleopatra mandarin and root-Ca in case of Troyer citrange. The lowest content of leaf-P and K was recorded in case of Kichilli, Rangpur lime Australia, Cleopatra tangerine and Troyer Citrage.

Gupta and Nauriyal (1973) reported that there was high content of chloride and sulphate in grape leaves for all treatments viz., high level of chloride,

sulphate and carbonate as compared to control. The accumulation of chloride in high chloride treatment and of sulphate in high sulphate treatments was nearly 100 and 400 times respectively that of control.

Joolka et al. (1977) found that the calcium content was high and the P content was low in chloride salinity and the Ca content was low and P content was high in So_4 salinity. Thompson seedless variety of grape contained more So_4 than rest of the varieties at the same level of salinity. Divate and Pandey (1981) observed that salinity treatment increased N, P 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, with an increase in salinity (from 4 to 10 ds/m) leaf-Mg and Na content were increased whereas those of Ca and K decreased.

According to David et al. (1958), the chloride content in cherry leaves and grape petioles was directly proportional to supply and when the chloride level was supplied with medium level, the Cl 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 that sulphur content in all plants increased with supply in the absense of chlorides, whereas high chloride levels supressed sulphate abscrption with all crops.

Patil (1980) recorded lower contents of K, Ca and mg in the leaves of seven fruit crops with increase in soil salinity. Successive increase in Na due to higher salinity was observed in all crops. Under high salinity the Zn and Fe contents of leaves decreased in guava, pomegranate, custard apple, ber, jamun and fig but not in chiku. The Cu content of leaves and roots of guava and pomegranate decreased at high levels of salinity, while in other fruit crops there was no decrease.

Desai and Singh (1979) narrated the effect of salinity on the nutritional imbalance of guava leaves and they found that various salinity treatments increased N, Na and cl content in leaves and decreased K, Ca, P, 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 Dhankar et al. (1981) in guava and phalsa. Patil et al. (1984) observed that in guava leaf-N increased with increasing salinity levels but root-N decreased, whereas leaf and root P, K, Ca, Mg, Zn, Fe and Cu content decreased with higher salinity levels.

A marked increase in Na: K and Na:Ca + mg + K ratios were noted in leaves and roots. 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 (Dhankar and Dahiya, 1980; Dahiya and Dhankar, 1982; Hooda et al., 1990).

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^{2-}) in toxic amount. 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 Mg²⁺ by plant increased progressively with increase in salinity levels while the uptake of Ca^{2+} 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.

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^{2+} and increase in P content. Robinson and Smith (1970) in

citrus observed sulphate accumulation under NaCl treatment and Cl accumulation in the control.

In the experiment conducted by Sadaria (1989) the nitrogen content in leaves increased upto certain level with the increase in salinity levels in tamarind, mulberry, Khirni and persian lilac but it was not consistant. It again decreased at higher salinity level (i.e. at 20 mmhos/cm). In bael, eucalyptus and neem the N content consistantly increased with successive increase in salinity levels. Varying salinity levels had no effect on the N content in the leaves of wood apple. Root-N and P gradually decreased with the increasing salinity levels in all species. The leaf-P content of tamarind, mulberry, bael, Khirni and persian lilac decreased significantly with the increase in salinity. The K content in leaves and roots depleted with the increase in salinity level in all species except tamarind roots. In general K, Ca Root-P in all species except khirni also decreased due to high salinity level. Fe, Mn and Cu content in both leaves and roots decreased with increase in salinity levels. A decline in Mg content with successive increase in salinity level in all species except eucalyptus leaves was recorded. With the increase in salinity levels, the

Na content was increased in all species except wood apple while Zn content in the leaves and roots of all species except in leaves of Khirni decreased.

The studies carried out by Valia (1989) noticed that with the increase in salinity levels there was decrease in all macro and micronutrient contents of leaves, stem and roots of all fruit crops except sulphur and sodium which showed reverse trend. At salinity level of 20 mmhos/cm, highly significant increase in S and Na content of leaves, stem and root was estimated in markingnut followed by karonda, passion fruit, phalsa, drumstick and cashew, respectively.

2.3 Ionic salinity

The ion species contributing salinity are chloride, sodium, sulphate, carbonate and bicarbonate (Chapman, 1960). Among these ionic species except carbonate all ionic species, widely come across inflicting injurious in most of the fruits crops. The specific ion effects with special reference to chloride, biocarbonate and sulphates are explained below.

Ions which usually account for most of the salts in irrigation water and saline soils are Ca^{2+} , Mg^{2+} , Na^+ , HCO_3^- , SO_4^- and Cl^- . The proportion may vary widely but the concentration of at least several of these ions may exceed the concentration of other essential

elements, by a factor of from 10 to 100. The ratio of course much greater for the mineral elements concentration.

2.3. Effects of chloride

2.3.1. Chloride tolerance of tree species

Chloride injury is more common in various fruit crops. Citrus is very sensitive to chloride toxicity. Citrus decline has been attributed to the higher chloride concentration in soil (Singh, 1966; Chapman, 1969; Nilangekar and Patil, 1979). Bielora *et al.* (1978) undertook long term experiment with 7 to 17 me cl/l (NaCl + CaCl₂) treatments in adult grape fruit trees they noticed 1.45 per cent yield reduction for each 1 me/l increase in Cl⁻ 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. Under chloride type of salinity guava can thrive well upto 0.3 per cent salt concentration (Desai and Singh, 1980). While Kaul (1981) pointed out that in guava, chloride salinization was more injurious than sulphate salinization. Vardi *et al.*, (1988) studied response of Shamouti orange and Minneola tangelo on rootstocks to salt stress. An application of

irrigation water containing 250-300 mg cl/l or upto 3000 mg/l showed practically no mortality on Rangpur lime (C limonia). Shamouti proved more sensitive to salt than Minneola. Highest mortality was occurred in tress on sour orange followed by Citrus Valka Meniana, Troyer citrange, Poncirus trifoliata and Swingle citrumelo.

2.3.1.2. Effect of chloride on growth

Hass (1950) found in citrus that chloride injury progressed along the margins than towards the mid-rib of leaves, while reverse was true for P and K deficiency symptoms. Hewitt and Furr (1965a) grew four rootstocks in nutrient solution containing 80 me/l, Rangpur lime (salt tolerant) grew constantly throughout this treatment. Troyer citrange (salt sensitive) almost ceased to grow, while Cleopatra (salt tolerant) grew little after the termination of salt applications. Shekwasha (moderately tolerant) continued to grow at a rate similar to that of Rangpur lime, while Troyer citrange plants suffered from complete defoliation and stem die-back to the base. Alexander and Woodham (1968) reported that in certain Trifoliolate hybrid stocks leaf tip burn and defoliation were associated with high leaf chloride. The tree growth of Washington neval orange trees on citrage rootstock was significantly reduced with increase in chloride concentration (from 7 to 60

me/l) in the substrate and leaf chloride (Chapman 1968). Furr and Ream (1968) treated Valencia orange with 26,53 or 79 me/l of chloride. Higher levels of leaf chloride were associated with depressed shoot growth. Goell (1968) reported that the accumulation of chloride ions in the citrus leaves was associated with shortening in leaf longevity due to chlorides, earlier senescence and abscission. In the experiment with saline water as reported by Saglio (1969), the excess of chloride in citrus leaves produced leaf bronzing. Bhambota and Kanwar (1970) found that 500 ppm NaCl was harmful and affected growth of Blood Red on rough lemon rootstock. Chloride tip burning in citrus was reported by Salerno (1975). Kadam (1984) indicated that 20 per cent growth depression was observed at 26.5, 17.5, 7.5, 13.0, 21.5, 3.75 7.0 me/l of chloride for Nasnaran, Rangpur lime Australia, Rangpur lime L-19, Trover citrange, Trifoliate orange, Limao Cravo Brazil, Cleopatra tangerin, Kichilli and Rough lemon Africa rootstocks, respectively. Dasberg et al. (1988) noticed that main branch growth in cross section was retarded by highest salinity treatment (NaCl-530 mg/l) in Shamouti orange budded on lime* sour orange rootstock. The seedling growth of citrus rootstocks viz., sour orange, Rough lemon and Troyer citrange was progressively varied with salt type, sodium chloride (40 me/l) had most adverse effects followed by

potassium and calcium chloride. Cleopatra was most affected among the rootstock (Salem and El-khorieby, 1989) . Zekri and Pearson (1990) found that in sour orange sodium chloride salt alone reduced root and shoot dry weight by approximately 30 per cent (at the concentration of NaCl-40 mm). Addition of 7.5 mm CaCl_2 or 7 mm KCl to the NaCl solution reduced leaf-Na concentration but increased Cl^- concentration to a toxic level.

Dilley et al. (1958) reported that increasing the supply of chloride decreased the growth of apple, cherry, peach and grape. Chloride toxicity was apparent on leaves of peach. No marked effect were observed in N, P, Fe, Cu and Zn content in all crops. Increasing the level of chloride increased Mn in cherry, apple and peach, Ca in cherry and peach, Mg in peach and grape and B in cherry. Ehlig (1960) observed that high chloride treatment caused burn on leaf blades of four grape varieties. Charbaji et al. (1988) noticed that NaCl at 6 meg/l appeared to have a beneficial effect on vine growth and rates upto 40 meg/l increased root growth, while higher levels of NaCl (80 meg/l and over) killed the grape vines.

A high concentrations of chloride in substrate caused marginal burn on mature leaves of strawberry (Ehlig and Bernstein, 1958). Nasr et al. (1977 a) in

plum and peach reported that chloride content in the leaves and roots increased with salinity, whereas chloride in peach roots was not affected. Leaves of peach contained higher amounts of chloride than leaves of plum. The opposite trend was observed in roots.

Israeli et al. (1986) reported that increased salinity leads to a marked decrease in growth and productivity for the highest salinity level (38.3 meg/l of chloride) compared with control plants in banana. Kaul (1988) reported that increase in salinity level (from 6 to 12 dsm^{-1}) inhibited, delayed as well as reduced the germination of seedling. Chloride salts were found to be more injurious than sulphate in case of guava cv. L-49.

2.3.1.3. Effect of chloride on physiological parameters chlorophyll

Brusca and Haasa (1958) reported injurious effects of chloride accumulation in leaves, rootlets, pulp and peel of apricot while Ivanova (1971) found that tree stunting of apricot was not so much as to the accumulation of toxic chloride, sodium and sulphate ions as to an imbalance in leaf nutrient ratio.

Bingham et al. (1968) observed that chloride injury in avocado may result from an excessive accumulation of chloride in the leaves, which promotes dehydration and permanent injury to the leaf cells. Katz et al. (1978) reported that kinetin either partially

or completely decreased the inhibitory effects of NaCl. West (1978) reported in apple trees that whenever, a sodium chloride stress was applied to rootzone, water uptake from that rootzone was depressed to approximately 50 per cent of normal levels while water uptake from non-saline rootzone increased by 50 per cent over normal. If a low oxygen stress was superimposed upon salinity stress, water uptake decline was more at 30 per cent of normal and uptake in the non-stressed zone increased. Menary and Allen (1979) found accumulation of chloride in leaves and fruits of papaya plants. High chloride levels in tissues did not affect plant growth, protein synthesis or the level of endogenous nitrate reductase activity. Shaybany and Kashirad (1979) reported that Acacia saligna seedlings were grown in sand culture containing 0, 48, 96, 144, 192 and 240 me/l NaCl. They observed that chlorophyll content, photosynthesis and respiration were reduced after 3 months of growth in greenhouse. Parra and Cruz (1980) reported that in bean plant transpiration rates and leaf extension rates per plant or per unit of leaf area were decreased by increasing soil salinity (Cl^-) and by decreasing soil moisture. Kadam (1984) noticed a drastic fall in chlorophyll content of the leaves, with the increase in chloride level in citrus rootstock studied.

2.3.1.4. Effect of chloride on chemical composition

Investigations of USDA salinity laboratory staff (1954) showed that the leaf burn were associated with 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, peach, pecan, avocado, grape, grapefruit and Valencia orange, respectively.

Cooper and Corton (1952) in a study of 20 kinds of citrus rootstocks in salinized pots (50:50 mixture of NaCl_2 and CaCl_2) reported that small increase in chloride occurred in trees on Rangpur lime, Severinia buxifolia and Cleopatra mandarin, moderate increase in trees on rough lemon, Minneola tangelo, Sampson tangelo, sour orange and Nakron pummelo and large increase in trees on Calamondin Florida sweet orange, Cuban shaddock, Rusk citrange and Etrog citrange. There was an excess of chloride over the increased accumulation of cations for trees nine rootstocks and nearly all these showed leaf necrosis. Pearson et al. (1957) found direct relationship between conductivity of the saturation extract and the concentration of Na and chloride in the leaves of grape fruit trees. In wood, bark, branches and twigs the accumulations of chloride exceeded that of Na. Increasing levels of salinity in irrigation water decreased Ca, Mg, and K in the leaves. Cooper et al. (1958) reported that the leaves of trees on sour orange rootstock accumulated approximately twice

as much as chloride as the trees on Cleopatra rootstock. The salt treatment increased Ca content of most scion rootstock combination. The salt treatment induced an increase in K accumulation of the Shary grapefruit scion on sour orange rootstock and a decrease in this scion on Cleoptra rootstock. The accumulation of Mg was greater in the leaves of trees on Cleoptra rootstock than on sour orange. Timkar and sunki mandarin rootstock excluded chloride and citrus macrophylla excluded sodium but accumulated chloride (Cooper and Peynado, 1959). Cooper (1962) working on Ruby Red grapefruit reported that Rangpur lime, Cleopatra mandarin and Severinia buxifolia were among the most tolerant to chloride and Citrange and Trifoliate orange were the least tolerant. Increasing the chloride concentration decreased Mg and B content of grape fruit (Peynado, 1962). Smith (1963) found that there was no significant increase in leaf chloride content of Washington Neval orange as the soil salt content increased. The accumulation of chloride in citrus leaves increased linearly with increased chloride concentration (Hewitt et al., 1964; Hewitt and Furr, 1965; Saglio, 1969; Joolka, 1976 and Petolina and Leone, 1977).

Bernstein (1965 a and b) reported that injured leaves will usually contain in excess of 1.0 per cent of chloride on dry weight basis, but concentration in

excess of 0.5 per cent should be regarded as hazardous. Daito (1967) found that NaCl treatment did not affect N, P, K and Mg contents of citrus trees. Bernstein (1968) noticed that sodium or chloride concentrations in the soil will become critical at lower levels with rootstocks that transport these elements more rapidly. For example, with sweet orange or citrange roots, the chloride concentration in the saturation extract of the soil should not exceed 10 me/l or 350 ppm. Trees on sour orange, Rough lemon or Tangelo roots, however, will not be damaged if chloride is less than 15 me/l in the saturation extract. On Rangpur lime and Cleopatra mandarin roots, trees will tolerate upto 25 me/l chloride. He further mentioned that leaf wetting sprays of irrigation water containing as little as 100 ppm chloride may be injurious to citrus. Chapman (1968) observed 0.3 per cent chloride (dry matter) as threshold value in four month old spring cycle leaves from non-fruiting terminals and 0.51 per cent of leaves from fruiting terminals. Hyder (1969) reported that young leaves excluded sodium and chloride ions at the beginning of saline treatment (NaCl 80 me/l) while old leaves and stems accumulated these ions. Highest leaf chloride in Carrizo and Troyer rootstocks, while lowest on Bitter sweet sour orange, mandarins and citrumelo

were noticed by Wutscher and Shull (1972). The salinization of the substrate by NaCl (0 to 40 me/l) resulted in an increase in chloride and sodium content of leaves, which is characteristic for each rootstock variety studied. Mandarin as a group was characterised by a marked capacity to exclude chloride ions. The Allemow and Nanshodaiddai accumulated moderate, sour orange and Troyer Citrange varieties in general accumulated high amounts of chloride ions (Cerde et al., 1977). However, Zid and Boukhris (1977) reported that increase in substrate decreased the percentage of K^+ , Ca^{2+} total N and soluble N in all plant organs. Kadam (1984) reported that increase in chloride level decreased the P, K, and Ca contents in the leaves, while Na and Cl increased consistently. Further N, Cl and to some extent Na, Ca and Mg content in roots increased. The root-P decreased with increasing Cl level. N and Cl content and to some extent Ca, Mg and Na in stem increased, however, P content decreased with increase in chloride level in citrus rootstock.

Ehlig (1960) reported that the percent of Cl was 0.04 in healthy leaves of grape and reached 1.5 per cent in the leaves of deteriorated vines and 1.69 per cent in case of dead vines. Black rose and Cardinal were much more sensitive to chloride than Perlette and Thompson seedless, because they accumulated

chloride two to three times faster. The chloride type of salinity caused an increase in Ca and decrease in P content of grape (Joolka et al., 1977).

Fraugue (1968) observed decrease in K content of pecan seedlings, cherry and peach (Dilley, et al., 1958); stonefruit (Ivanov, 1971); grapes (Joolka, 1972); mango (Jindal et al., 1975); sweet cherry, pear and apricot (Ivanov and Ivanova, 1976) and citrus (Joolka, 1976) with increasing chloride concentration.

Ivanov (1971) found that increasing chloride concentration decreased the N and P content in stone fruit. Menary and Allen (1979) seen that accumulation of chloride in leaves and fruits of papaya was associated with high level of nitrate in these tissues.

2.3.2 Effect of bicarbonates

The range of bicarbonate in soil as reported by Harding and Chapman (1950) and US Salinity Lab. Staff (1954) was from 0.10 to 0.20 me/l of extract. According to these authorities satisfactory range of bicarbonate in soil was 0.10 to 2.5 me/l. Chapman (1969) opined that no precise limits of bicarbonate can be given owing to the modifying influences of soil, climate, rootstock, scion and characters of accompanying anions. The precise limits of total soluble solids can be given but not possible in the case of bicarbonates. However, leaching should be increased were bicarbonate values in

the excess range are found. Nilangekar and Patil (1979) observed relatively higher contents of bicarbonate in all the soil profile supporting chlorotic citrus orchards as against that of the healthy orchards in Marathwada region.

2.3.2.1 Bicarbonate tolerance of tree species

Gupta and Nauriyal (1973) reported that 0.09 per cent of carbonate concentration could be regarded as toxic for the grape cultivars viz., Bangalore purple, Selection-7 and Anab-e-Shahi. Anab-e-Shahi was found to be more susceptible to high salt concentration as compared to Bangalore purple and Selection-7. Good growth of grape vine was noted at 0.45 per cent carbonate level of soil.

Desai and Singh (1979) found that guava cultivar Allahabad safeda could tolerate carbonate type of salt upto 0.35 per cent. A high mortality rate was recorded at concentration exceeded 0.53 per cent and 0.70 per cent of carbonate. Kadam (1984) noticed that Rough lemon Africa, Rangpur lime Australia, Cleopatra mandarin Coorg, Limao Cravo Brazil, Troyer Citrange and Nasnaran were found tolerant to bicarbonate level of 12 me/l. Gupta et al. (1989) found that ber could tolerate EC of 3.0 dsm^{-1} at seedling stage while 7.5 dsm^{-1} bicarbonate level at germination stage.

2.3.2.2 Effect of bicarbonate on growth

Very high concentration of bicarbonate ions in high salinity water was undesirable because of their adverse effects on germination and growth of the plants.

Gupta and Nauriyal (1973) reported that a significant reduction in growth characteristics of grape vines viz., time of bud sprouting, number of buds sprouted, total extension growth, number of leaves, leaf area, dry weight of shoot and dry weight of roots resulted as carbonate level in soil exceeded 0.09 per cent.

In citrus, Kadam (1984) found that under highest bicarbonate level (12 me/l) number of branches, weight of whole plant, volume of root, fresh weight of root, fresh and dry weight of top were found maximum in Rangpur lime Australia and Rangpur lime Africa citrus rootstocks. Maximum plant spread and height was recorded in Rangpur lime Australia as compared to others. The growth data indicated 20 per cent growth depression at 19.5, 13.5, 5.0, 12.0 and 9.0 me/l of bicarbonate level for Nasnaran, Rangpur lime L-19, Troyer citrange, Trifoliate orange, Cleopatra tangerin and Kichilli, respectively. Only 10 per cent growth reduction was noted in Rangpur lime Australia, limao Cravo Brazil, Cleopatra mandarin Coorg and Rough leman Africa at 24, 15, 14 and 24 me/l of bicarbonate level, respectively.

In banana, Hernandez et al. (1986) reported that mature plants irrigated with water containing high bicarbonate had higher leaf margin. In ber, increasing bicarbonate concentration in the irrigation water tended to decrease the germination. Significant reduction in germination was recorded when HCO_3 level exceeded 7.5 ds/m in comparison with control. Thus, it was clear that ber could tolerate high bicarbonate containing water at seedling stage than at the germination stage. At the HCO_3 level of 3 ds/m significant difference on growth was noticed in ber (Gupta et al., 1989).

2.3.2.3 Effect of bicarbonate on physiological parameters

Chlorophyll

Bhambota and Kanwar (1970) observed decreasing trend of chlorophyll content with increasing salinity in the leaves of Malta Blood Red grafted on rough lemon rootstock of citrus. A loss of dark green colour of grape leaves was observed, due to excess of carbonates (0.09 per cent) (Gupta and Nauriyal, 1973).

Kadam (1984) noticed significant decrease in leaf chlorophyll content with each increase in bicarbonate level (3 to 12 me/l) of citrus rootstocks. Limao Cravo Brazil recorded highest chlorophyll content at the highest bicarbonate level (12 me/l) followed by

Cleopatra mandarin Coorg and Rangpur lime Australia as compared to other rootstocks.

2.3.2.4 Effect of bicarbonate on chemical composition

In saline soils, there is tendency for bicarbonate to cause precipitation of calcium in the soil thereby increasing exchangeable Na (Richard, 1954). Kessler (1958) reported an inverse relationship between concentration of HCO_3 and uptake of Ca in fruit trees.

Desai and Singh (1979) found that, as the salinity level increased (0.175, 0.350, 0.525 and 0.700 per cent) there was increase in leaf-N, Na, SO_4 and Cl and reduction of leaf -P, K, Ca and Mg in guava cultivar Allahabad safeda. The increase and decrease was proportional to the concentration of salts studied.

Kadam (1984) reported that with increase in bicarbonate salinity level, N, P, K and Ca content of leaf, stem and root were increased. Leaf -P was maximum at EC level 18 me/l while root-Mg was maximum at 12 me/l. Stem-P content decreased with increasing bicarbonate level. The bicarbonate level of 12 me/l showed maximum N, P and Mg content in stem while Ca content was maximum at 6 me/l.

2.3.3 Effect of sulphate

2.3.3.1 Sulphate tolerance of tree species

Zusman (1956) noticed that the toxicity of sulphate ions on sweetlime and sour orange seedlings became apparent when concentration was increased above 1000 ppm. Robinson and Smith (1970) also reported that So_4 was in toxic amount in seedlings of citrus treated even with the mixture that contain very low amount of Na_2So_4 . In Marsh seedless cultivar of grapefruit, Metochis (1989) found that irrigation with higher amount of sulphate resulted in low persistent soil salinity which could not be leached. Limao Cravo Brazil rootstock of citrus was found resistant to sulphate (60 me/l) while Rangpur lime L-19 and Cleopatra mandarin Coorg were tolerant to sulphate while Nasnaran, Kichilli and Troyer citrange were susceptible to sulphate.

Gupta and Nauriyal (1973) observed that the tolerance limit for sulphate in grape was 0.3 per cent. Leaf injury of sulphate become first apparent on the older leaves of grapes (Joolka et al., 1977). The percentage of mango leaf injury was highest with NaCl alone and least with Na_2So_4 alone and 50 per cent seedlings were died at higher levels with all treatments (Jindal et al., 1979). Desai and Singh (1980) noticed

that guava plants survived well under sulphate type of salinity upto 0.5 to 5.0 per cent salt.

2.3.3.2. Effect of sulphate on growth

Zusman (1956) reported that as the level of sulphate increased, there was decrease in growth of citrus seedlings. Bhambota and Kanwar (1970) found that salt concentration of 1100 ppm was highly detrimental to plant growth and even 500 ppm NaCl + 600 ppm Na_2SO_4 proved to be harmful. No adverse effects were observed on growth of sweet orange when the concentration of NaCl + Na_2SO_4 was 500 ppm whether alone or in combination. Growth of Citrus aurantium was inhibited even at the lowest concentration of Na_2SO_4 . Metochis (1989) noticed reduced growth in Marsh seedless grapefruit with high sulphate content. In citrus rootstock, Rajput (1990) observed that under highest treatment of sulphate (60 me/l) Limao Cravo Brazil rootstock showed more height, stem girth, number of branches and leaf area. Nasnaran showed the shortest height while largest spread and recorded in Cleopatra mandarin Coorg. More number of leaves were observed in Rangpur lime L-19 and Limao Cravo Brazil. The growth attributes namely fresh weight of whole plant, fresh and dry weight of top and root was greater in Limao Cravo Brazil, Rangpur lime L-19, Rangpur lime Australia and Cleopatra mandarin

Coorg. Furthermore, he reported that 50 per cent growth depression was noticed in Nasnaran, Rangpur lime Australia and Cleopatra mandarin Coorg, Troyer citrange, Trifoliate orange, Cleopatra tangerin, Kichilli and Rough lemon Africa at 7.5, 17.3, 45.0, 21.4, 27.0, 35.3, 21.8 and 31.5 me/l sulphate level, respectively.

Dilley et al. (1958) reported that increasing levels of sulphate did not adversely affect the growth of apple, peach and grape but depressed growth of cherry trees. Further, they emphasized that increased supply of chloride and sulphate together depressed the growth. Porups (1958) found reduction in growth of cherry tree due to the increasing levels of sulphate. In grape vines, Nauriyal and Gupta (1967) reported reduction in dry weight of roots and shoots due to sulphate concentration in soil. According to Joolka et al. (1976) increasing salt concentration delayed time of bud sprouting and percentage of sprouting in grape. As the level of sulphate increased, there was decrease in all aspect of growth, and at 12 and 16 mmhos/cm of sulphate level most of vines could not survive. The highest concentration of most salts including sulphate reduced shoot growth and leaf area in grape (Pandey and Divate, 1976). Chavan and Koradge (1980) noticed that sodium sulphate salt suppressed the growth of peanut plants.

2.3.3.3 Effect of sulphate on physiological parameters

Chlorophyll

Leaf chlorophyll content increased with increasing levels of sulphate in citrus (Bhambota and Kanwar, 1970). Divate and Pandey (1981) reported that proportional decrease in chlorophyll content in guava leaves under sulphate type of salinity as compared to chloride type of salinity.

Rajput (1990) noticed a significant consistent decrease in chlorophyll due to successive increase in sulphate level. The chlorophyll content was significantly highest in Cleopatra mandarin Coorg followed by Limao Cravo Brazil and Cleopatra tangerin. Under the highest level of sulphate (60 me/l), Rangpur lime L-19 registered highest chlorophyll content followed by Rangpur lime Australia next in order were Troyer citrange, Trifoliate orange and Limao Cravo brazil.

2.3.3.4 Effect of sulphate on chemical composition

Kretschmar et al. (1952) summarised that Whenever sulphate ion was applied to root zone of plant (So_4 above 1000 ppm), variation in So_4 content of substrate had little effect on plum. Dilley et al. (1958) studied the effect of chloride and sulphate on growth

and nutrient uptake of apple, cherry, peach and grape. They found that as the level of sulphate increased, there was apparently reduction in chloride absorption while high chloride level depressed sulphate absorption by all crops. No marked change in the P, Fe, Cu and Zn content in all crop resulted from the chloride or sulphate treatment. Increased sulphate level in the solution increased boron in cherry, apple and peach leaves. Higher level of sulphate decreased Ca in cherry and peach leaves. Porups (1958) recorded that increasing sulphate level depressed Ca, Mg and Zn but had little effect on K in the leaves of cherry. An increase in sulphate and decrease in chloride content of leaves was generally accompanied by a decrease in P content of blue berry (Walter and Ballinger, 1962).

In citrus, Zusman (1956) reported that Ca absorption was reduced with increasing soil sulphate concentration. Bhambota and Kanwar (1970) noticed that sulphate was less harmful than chloride and the harmful effects of salts were more marked in light soil than in the heavy soil. The Mg and Fe uptake were decreased with increasing salt concentration, but Na uptake was increased. Zid and Grignon (1986) recorded that the uptake of K was reduced by Na_2SO_4 ; with sodium sulphate leaf ion accumulation did not increase directly with the

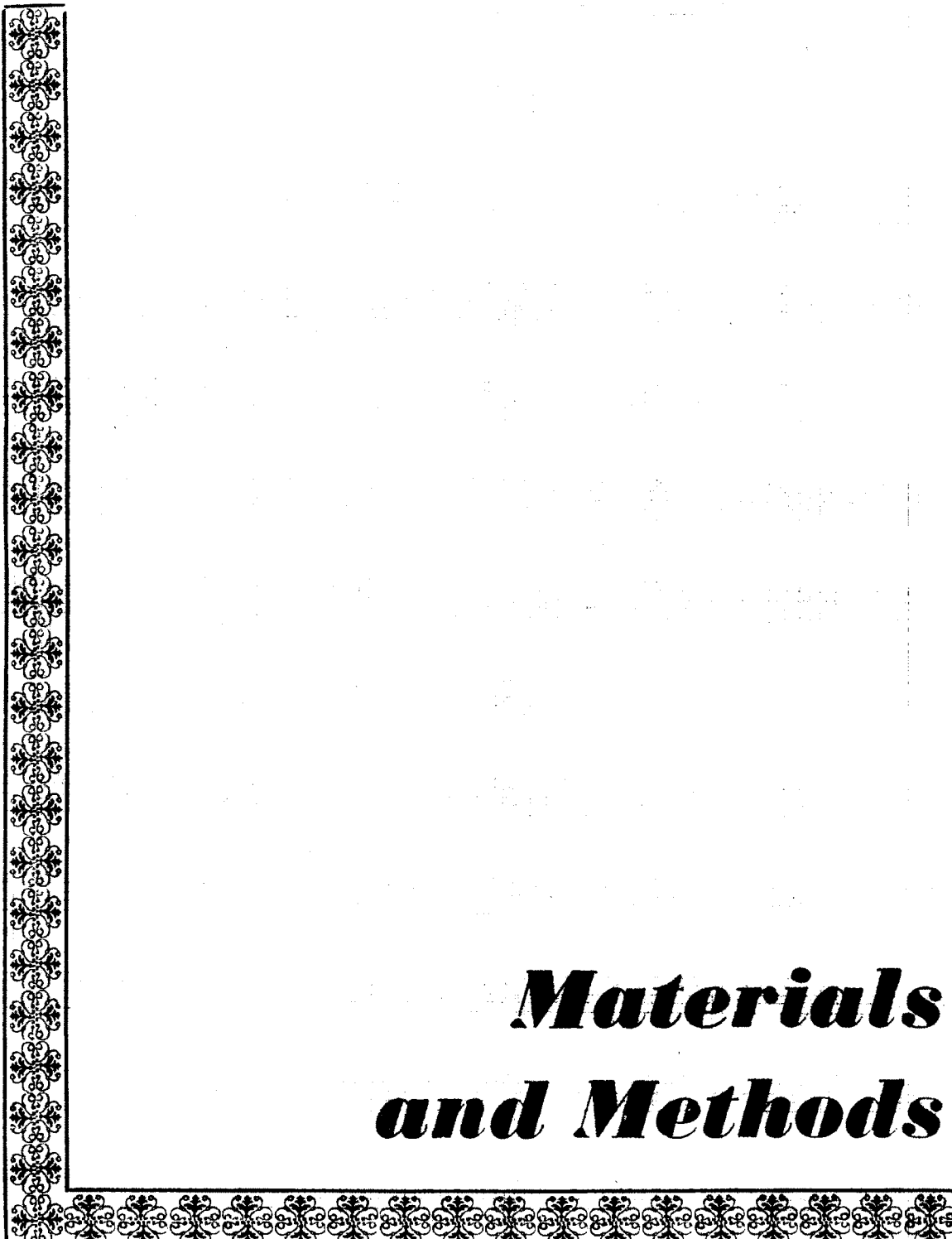
nutrient concentration in young citrus aurantium. Rajput (1990) in his study found that the root-N and leaf-P reduced with each increment of sulphate level from 30 me/l in citrus rootstock seedling. There was increase in K and S in the leaves and roots with each increment of sulphate level. Leaf and root Ca decreased with an increase in level of sulphate. While root Mg increased with increasing level of sulphate upto 30 me/l. Among the rootstocks studied Rangpur lime registered highest leaf - K and Mg, leaf and root Ca while Trifoliate orange recorded the maximum P content of leaf. The beneficial effects of CaSO_4 was mainly attributed to a reduction in accumulation of Na and Cl to below the critical toxicity levels in leaves of citrus (0.4 and 0.5 per cent respectively) when 1.5 or 7.5 mm. CaSO_4 solution was added to 40 mm NaCl solution (Zekri and Pearson, 1990).

In the study of effect of salinity on four varieties of table grape grown in sand culture, Ehlig (1960) noticed that high concentrations of sulphate caused Mg deficiency symptom on all varieties. Gupta and Nauriyal (1973) reported that the accumulation of sulphate was 400 times in high sulphate treatments as compared to control in grape leaves. Joolka et al. (1977) found that in the grape vines Ca content was high in So_4

salinity the uptake behaviour of other elements did not vary much with the type of salinity. Edelbauer (1978) indicated that in transition from chloride to sulphate treatments, the Ca, Mg, K, Fe, Mn, Cu and Zn contents of the leaves found to be decreased. In one year old stem the Fe content increased markedly and to some extent Zn content decreased in grape vines.

Mango seedlings grown on alkaline soil showed great variation in growth. The most vigorous had the lowest foliar contents of Na, Cl and SO_4 ions and the highest N, P and Ca levels, indicating the tolerance to the typical alkaline soils (Jindal et al., 1975). Furthermore, Jindal et al. (1979) emphasized that P and Mg deficiencies were caused to a greater extent by sodium sulphate than by other salts in mango.

Ivanov and Ivanova (1976) reported that with a increase in soil Na_2SO_4 and MgSO_4 , leaf-N decreased and K and S content increased. The P, Fe and Na levels were unaffected in peach, apricot, sweet cherry and pear trees. Chavan and Koradge (1980) noticed that Na_2SO_4 ceased accumulation of Na, P, Fe and Mn in root, leaf and stem of peanut. Doring and Ludders (1987) reported that Na accumulation was more in roots while Cl and SO_4 in leaves of three months old pomogranate cuttings.



Materials and Methods

Chapter 3

MATERIALS AND METHODS

In order to assess the effects of ESP and salinity in banana sets of potted experiments were conducted during 1990 and 1991 in the Department of Horticulture, Marathwada Agricultural University, Parbhani. Further separate experiments were laid out for banana cultivars viz., Ardhapuri and Basrai to study -

- i) the effect of different levels of exchangeable sodium percentage (ESP) in the soil
- ii) the effect of different levels of salinity (ECe)
- iii) the effect of different levels of chlorides
- iv) the effect of different levels of bicarbonates and
- v) the effect of different levels of sulphates.

3.1 Experimental soil

The experimental soil was black clayey and it was classified as inceptisol (Malewar, 1976) according to USDA soil classification system. The soil was collected in bulk and passed through 2 mm. sieve. Similarly the representative soil sample was subject to physico-chemical analysis by standard methods (Table 1).

3.2. Exchangeable sodium percentage

The part of bulk soil was treated with the solution of sodium bicarbonate (Na HCO_3) for building the ESP of 8,16,24,32,40 and 48 by following the procedure described by Bains and Fireman (1964). The

characteristics of soil after NaHCO_3 treatment were given in Table 2.

Table 1: Physico-chemical properties of experimental soil.

Particulars	Results of analysis	Method used
A). Mechanical composition		
1. Coarse sand (%)	8.75	International Pipette Method (Piper, 1950)
2. Fine sand (%)	12.50	
3. Silt (%)	30.00	
4. Clay (%)	46.00	
5. Textural class	Clayey	
6. Saturation percentage	55.00	
B) Chemical composition		
1. pH (1:2.5 soil : water)	8.20	U.S. Salinity Lab. Staff (1954)
2. EC (1:2.5 soil water suspension dsm^{-1})	0.20	---
3. ECe (dsm^{-1})	0.42	---
4. Exchangeable sodium (me/100 g)	0.60	---
5. Cation exchange capacity (me/100 g)	40.00	---
6. Total Nitrogen (%)	0.07	Micro Kjeldahl's Method (A.O.A.C., 1970)

Particulars		Results of analysis	Method used
7. Total phosphorus	(%)	0.03	Jackson(1973)
8. Total potassium	(%)	0.45	Jackson (1973)
9. Available phosphorus	(%)	0.003	Olsen <u>et al.</u> (1954)
10. Available potassium	(%)	0.038	Jackson(1973)
11. Soluble sodium	(%)	0.05	Jackson (1973)
12. Organic carbon	(%)	0.76	Walkey and Black's method (1934)
13. Chloride (me/l)		3.00	Piper (1950)
14. Bicarbonate (me/l)		2.00	Piper (1950)
15. Carbonate (me/l)		0.08	Piper (1950)
16. Sulphate (me/l)		1.25	Piper (1950)

Table 2 : Characteristics of the soil after sodium bicarbonate treatment.

ESP		pH	ECe
Desired	Obtained	1:2.5 Soil:Water suspension	(dsm^{-1})
8	7.80	8.50	0.80
16	15.70	8.70	1.25
24	23.70	8.85	1.40
32	30.60	9.30	1.50

ESP		pH	Ece
Desired	Obtained	1:2.5 Soil:Water suspension	(dsm ⁻¹)
40	39.00	9.50	1.60
48	46.50	9.65	1.75

The control had 3.6 ESP.

The big sized cement pots of 30 kg soil capacity (45 cm height with 40 cm upper diameter) were used for experimentation. The inner side and bottom of each pot were covered with a polythene sheet (300 guage) in order to avoid the loss of soluble salts and also to check root growth outside the pots. Twenty five kg of sodic soil, already prepared under each treatment was filled in the 30 kg capacity pots. The soil was pressed firmly. Two litres of water was added to each pot to settle down the soil. Uniform banana sucker weighing 750 g of both the cultivars were planted, one in each pot on 27.09.1990. The sodicity treatments were replicated thrice and fit in the completely randomised block design. The details of banana genotypes are as follows.

English name	Botanical name	Cultivar
Banana	<u>Musa paradisiaca</u>	Ardhapuri (Mutant of
	Linn	Basrai) and
		Basrai (dwarf)

3.3 Salinity levels

The same bulk soil was used to develop different salinity levels. The cement pots of 50 litres capacity (height 45 cm and diameter of upper face 40 cm) were used for this experiment. The pots were prepared as described earlier. Each pot was provided with a false bottom having 5 cm layer of gravel to facilitate drainage. Thirty kg soil was filled in the pots of 50 litres capacity for both Ardhapuri and Basrai cultivars.

3.3.1 Treatments

Salt concentrations @ 30,60,90,120,150 and 180 ml/l of saturation extract were considered to raise the conductivity to 3, 6, 9, 12, 15 and 18 dsm^{-1} respectively (U.S. salinity staff, 1954).

The relative proportion of various ions and amount of salts used to achieve the desired salinity levels are given in Table 3 and 4 respectively.

Table 3: Relative proportion of various ions (me/l) under different salinity treatments

Electrical conductivity of saturation ₁ extracts dsm ⁻¹	Na ⁺ :	Ca ⁺⁺ :	Mg ⁺⁺ :	Cl ⁻ :	SO ₄ ⁻ :	HCO ₃ ⁻
3	8	: 11	: 11	: 16	: 12	: 2
6	16	: 22	: 22	: 32	: 24	: 4
9	24	: 33	: 33	: 48	: 36	: 6
12	32	: 44	: 44	: 64	: 48	: 8
15	40	: 55	: 55	: 80	: 60	: 10
18	48	: 66	: 66	: 96	: 72	: 12

Table 4 : Relative proportion of salts (me/l) under different salinity treatments.

Conductivity dsm ⁻¹	S a l t s				
	NaCl	KHCO ₃	Na ₂ SO ₄	CaCl ₂	MgCl ₂
3	5	2	1	11	11
6	10	4	2	22	22
9	15	6	3	33	33
12	20	8	4	44	44
15	25	10	5	55	55
18	30	12	6	66	66

Weighed amounts of above salts were dissolved in enough quantity of water so as to bring the soil in the pots to saturation point. Uniform weighed suckers of Ardhapuri and Basrai cultivars of banana were planted in pot on 27.09.1990. These experiments were also laid out in completely randomized block design. Plant unit was one and there were three replications.

3.4 Chloride levels

Besides control, six chloride treatments namely, 6, 12, 18, 24, 30 and 36 me/l of saturation extract were tried. While making up these treatments, original chloride concentration of soil was taken into consideration. Weighed amount of calcium chloride ($\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$) was dissolved in the enough quantity of water that brought the soil in pot to the saturation point. Uniform (weight) suckers of Ardhapuri and Basrai cultivars of banana were planted one in each pot on 27th September, 1990. This experiment was also laid out in completely reandomised block design. The plant unit was one and there were three replications.

3.5 Bicarbonate levels

Besides control, six bicarbonate treatments namely 5, 10, 15, 20, 25 and 30 me/l of saturation extract were tried. While making up these treatments, original bicarbonate content of soil was taken into

consideration. Weighed amount of potassium bicarbonate (KHCO_3) was dissolved in the enough quantity of water, that brought the soil in pot to the saturation point. Uniform (weight) suckers of Ardhapuri and Basrai cultivars of banana were planted, one in each pot on 27th September, 1990. The experiment was laid out in completely randomized block design. The plant unit was one and it was replicated three times.

3.6 Sulphate levels

Besides control, six sulphate treatments namely 7, 14, 21, 28, 35 and 42 me/l of saturation extract were tried. While making up these treatments, original sulphate content of soil was taken into consideration. Weighed amount of sodium sulphate (Na_2SO_4) was dissolved in enough quantity of water that brought the soil in pot to the saturation point. Uniform (weight) suckers of Ardhapuri and Basrai cultivars of banana were planted, one in each pot on 27th September, 1990. The completely randomized block design was adopted for this trial. Plant unit was one and there were three replications.

3.7 Cultural operations and irrigation practices

The pots were kept in green house and protected from rains. Watering was given to the pots, whenever required with well water. The pots containing sodic soil were irrigated as per requirement, while on the other hand pots containing saline soil were irrigated carefully

each time so as to avoid leaching and obtain uniform distribution of salts. Urea was applied twice, 5 g. per pot each time, during the course of experimentation. Urea was dissolved in well water and water was applied to each pot. Plants treated with chloride, bicarbonate and sulphate were irrigated as per their requirement. The well water used had the following composition:

CO_3^{--}	0.20 me/l
HCO_3^-	2.50 me/l
Cl^-	0.50 me/l
Ca^{++} plus Mg^{++}	5.40 me/l
Na^+	0.60 me/l
SO_4^-	0.60 me/l
Electrical conductivity	0.50 dsm^{-1}

During summer the pots were regularly irrigated. The quantity of water applied was enough to make-up the loss of water due to transpiration and evaporation. Thus the moisture lost was daily restored. The soil in the pot was raked as and when required. The pots were kept weed free. The plants were protected from insect pests and diseases by adopting appropriate preventive and control measures.

3.8 Growth observations

3.8.1 Plant height

The height of individual plant was measured in cm every month from the soil level to the growing point of plant.

3.8.2 Number of leaves

Leaf count was taken at an interval of month

3.8.3. Stem diameter

Stem diameter of the plant was measured in mm at the marked point every month with the help of vernier caliper.

3.8.4 Plant spread

Maximum plant spread both in North-South and East-West directions was noted. The mean was taken as the plant spread.

3.8.5 Leaf area

For calculation of leaf area ten representative leaves of each treatment from each cultivar were taken. The area of the leaves was measured on automatic leaf area meter. The average leaf area and total leaf area per plant were calculated.

3.9 Mortality

The adverse effects of exchangeable sodium, salinity and ionic salinity viz., chlorides, bicarbonates and sulphates in soil was evident from the various types

of symptoms on the plants. The following key was used to assess the extent of mortality.

Sr.No.	Symptoms	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

3.10 Fresh weight and dry weight of plant

In the first week of October, 1991, plants from each treatment were uprooted, taking due care to avoid damage to the root system. The roots were cleaned by washing them with water to clear the adhering soil particles and immediately fresh weight of the whole plant was recorded.

The fresh weight of roots (with rhizome) and top (leaves and pseudostem) were separately recorded. Dry weights of roots (with rhizome) and top (leaves and pseudostem) was also recorded after drying the samples to a constant weight in an electric oven at 60 °C temperature.

3.11 Root length

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

3.12 Collection of leaf sample for chemical analysis

The leaves for chemical analysis were collected in the first week of October, 1991 (before one week of termination of experiment). Matured leaves were randomly taken from the mid position of the plants. These leaves were washed thoroughly first with tap water then with 0.1 N HCl and finally with distilled water. Similarly, representative samples of roots were also taken. The leaf and root samples were then dried in an electric oven at 60 °C constant temperature. Dried samples were taken, ground, powdered and used for chemical analysis.

3.13 Chlorophyll estimation

Chlorophyll was estimated as per procedure suggested by Singh (1977).

3.14 Collection of leaf sample for chemical analysis

Analysis of oven dried leaves and roots for different nutrient elements was carried out separately. Known quantities of the samples were digested as per the method described by Piper (1950). Total P, K, Ca, Mg, Na, Zn, Fe, Mn and Cu were estimated in the extracts prepared by the tri-acid-wet digestion method using nitric acid, hydrochloric acid and perchloric acid. Nitrogen was estimated by micro-kjeldahl's method as described in A.O.A.C. (1970). The methods followed for various estimations were as below.

Analysis	Method used
Nitrogen	Micro-kjeldahl's method (A.O.A.C., 1970)
Phosphorus	Vanadophospho-molybde yellow colour method (Jackson, 1973)
Calcium and Magnesium	Versenate titration method (Cheng and Bray, 1951).
Sodium and Potassium	Flame photometer (Jackson, 1973)
Sulphur	Chaudhary and Cornfield (1966)
Chloride	Volumetric method (Piper, 1950)
Bicarbonates	Volumetric method (Piper, 1950)
Zinc, Iron, Manganese and Copper	Atomic absorption spectrophotometer (Bradfield and Spencer, 1965)

3.15 Statistical analysis

3.15.1 Analysis of Variance

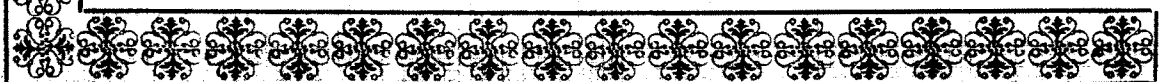
The analysis of variance was carried out according to the method given by Panse and Sukhatme (1967) for completely randomized design. Results were tested at 5% probability level of significance.

3.15.2 Correlation study

Simple correlations among the 7 independent variables and dry matter production as dependent variable were worked out as per the method suggested by Johnson et al. (1955).



Results



Chapter 4

RESULTS

The results obtained from the study of the effects of different levels of exchangeable sodium percentage, salinity and ionic salinity viz. chlorides, bicarbonates and sulphates on the growth and chemical composition of banana cultivars, Ardhapuri and Basrai are presented in this chapter.

4.1 Effect of exchangeable sodium percentage on growth

the results reported here pertain to a study on the effect of various levels of ESP on banana cultivars.

4.1.1 Cultivar Ardhapuri

4.1.1.1 Effect on plant height

The periodic observations on the height of Ardhapuri cultivar of banana plants expressed over the initial reading under different ESP are given in Table 5.

It is evident from the data (Table 5) that the adverse effects started at ESP 24. The ESP 8, 16 and control were similar and gave more height over ESP 24, 32, 40 and 48. The ESP 40 and 48 were not different from each other. The treatment started showing greater differences from 180 days after planting.

4.1.1.2 Effect on number of leaves

From Table 5 it is seen that the increase in the number of leaves started decreasing from ESP 24 as compared to other levels. ESP 8, 16, 24 and control

Table 5: Effect of ESP on pseudostem height (cm), number of leaves and pseudostem diameter (mm) of Aardhapuri banana.

Treatments	Days after planting					
	60	120	180	240	300	360
Plant height						
Control	28.33	49.63	75.00	93.67	105.00	110.67
ESP 8	29.00	51.00	78.00	96.00	106.00	112.37
ESP 16	28.33	48.50	73.00	90.67	101.37	105.00
ESP 24	28.00	44.67	68.67	84.00	92.00	94.00
ESP 32	25.50	40.00	61.67	78.00	81.67	84.00
ESP 40	24.43	37.67	54.50	62.30	64.67	65.00
ESP 48	22.17	31.40	42.33	50.00	51.00	51.00
S.E.†	1.86	2.30	8.07	11.34	11.68	10.66
C.D.	5.61	6.93	23.80	33.71	34.71	31.78
Number of leaves						
Control	6.33	10.33	14.00	16.33	18.00	18.00
ESP 8	7.00	12.00	15.33	17.00	18.33	18.67
ESP 16	6.33	10.00	14.67	16.00	18.00	18.00
ESP 24	5.33	8.00	12.00	13.67	14.67	14.67
ESP 32	4.67	7.33	9.67	11.33	12.33	13.00
ESP 40	4.00	6.33	8.33	10.00	10.00	10.00
ESP 48	4.00	5.67	7.67	8.00	8.33	8.33
S.E.†	0.73	1.01	1.75	2.11	2.62	2.68
C.D.	2.15	2.99	5.16	6.22	7.72	7.90
Stem diameter						
Control	33.00	45.33	64.00	85.00	95.67	98.33
ESP 8	34.00	48.00	66.67	86.33	97.00	101.00
ESP 16	32.33	44.00	62.33	83.33	94.33	97.67
ESP 24	30.00	41.00	58.00	76.67	83.00	83.67
ESP 32	27.67	38.63	52.67	70.00	72.33	73.00
ESP 40	25.00	35.50	49.33	60.00	61.33	61.00
ESP 48	23.00	30.67	41.00	48.00	48.33	48.33
S.E.†	1.73	2.90	4.90	6.99	7.57	9.21
C.D.	5.10	8.55	14.45	20.62	22.33	27.17

although atpar with each other were significantly superior to ESP 32 40 and 48. At 180 days, sudden decrease in number of leaves was observed at ESP 48. The marked adverse effects started discerning at ESP 40 and 48 from 180 days and onwards after planting

4.1.1.3 Effect on diameter of pseudostem

It is evident from the data (Table 5) that the plants under ESP 8, control and ESP 16 showed significantly greater increase in the pseudostem diameter than those under ESP 40 and 48. The growth as measured in terms of pseudostem diameter suffered from ESP 24 and the adverse effect was further accentuated at ESP 40 and 48.

4.1.1.4 Effect on spread of plants

The average of North-South and East-West spread of plant under different treatments has been presented in Table 6.

The spread of plants under ESP 8, control and ESP 16 did not differ significantly with each other and they had larger spread than those under higher ESP levels.

4.1.1.5 Effect on leaf area per plant

The leaf area (Table 6) decreased with the increase in ESP from 24 and onwards. The decrease was more pronounced at ESP 40 and 48.



Plate 1: Effect of ESP on top growth of banana plant cv. Ardhapuri (after 180 days of planting).

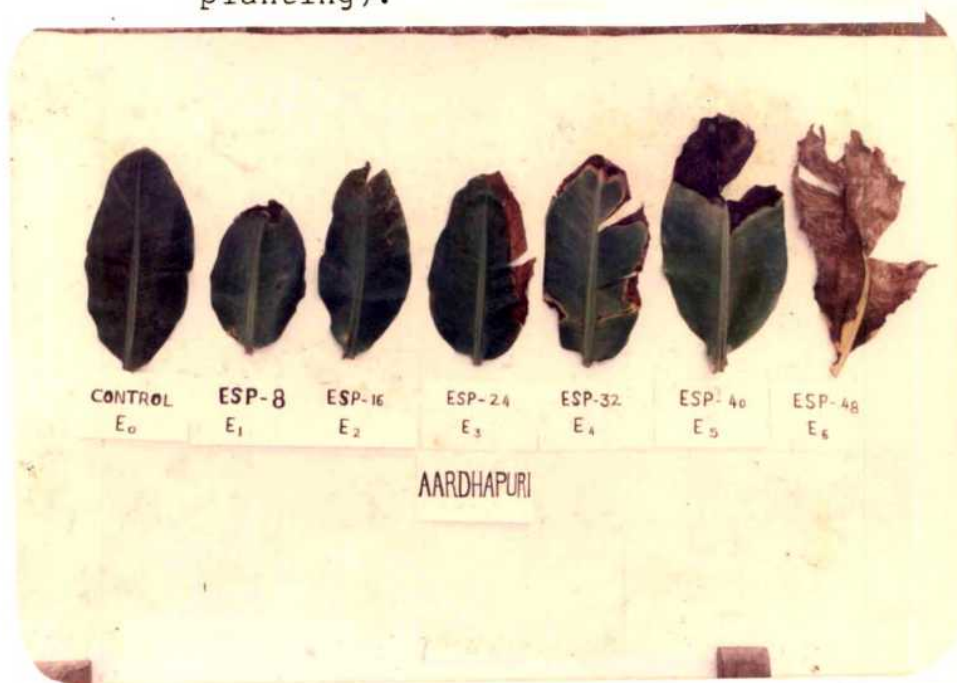


Plate 2: Leaf injury caused by soil ESP cv. Ardhapuri banana.

Table 6: Effect of ESP on the plant spread (cm), total leaf area (sq.m), length of root (cm) and per cent mortality of Ardhapuri banana.

Treatment	Plant spread (cm)	Total leaf area(sq.m)	root length (cm)	Mortality (%)
Control	85.67	9.21	90.33	00.00
ESP 8	87.12	9.54	93.66	00.00
ESP 16	85.00	9.12	89.33	00.00
ESP 24	73.33	8.87	80.67	12.50
ESP 32	69.21	7.78	81.00	37.50
ESP 40	54.50	6.63	82.17	50.00
ESP 48	48.33	5.16	84.00	75.00
S.E.+	5.18	1.08	1.62	-
C.D	15.28	3.19	4.91	-

4.1.1.6 Effect on length of root

The data pertaining to the length of root as affected by different ESP (Table 6) showed that there was corresponding decrease in root length with the increase in ESP. However, the extent of root-length reduction was very marked at ESP 24 and 32.

4.1.1.7 Effect on plant mortality.

The data pertaining to plant mortality have been shown in Table 6. As per the method described in

materials and methods, the mortality data were collected and the values of mean percentage of mortality have been presented. It is evident from the Table that plants were worst affected at ESP 48. The adverse effects of ESP started after 4 to 5 months of increase in levels.

4.1.1.8 Effect on fresh weight of whole plant

The data on fresh weight of whole plant as affected by different percentage of exchangeable sodium are presented in Table 7. There was decrease in fresh weight of whole plant with the increase in exchangeable sodium. A sudden significant drop in fresh weight of whole plant was observed at ESP 32, 40 and 48.

4.1.1.9 Effect on fresh weight of root with rhizome & top

Root with rhizome : On perusal of the data (Table 7) it is seen that there was consistent fall in fresh weight of roots with rhizome with the increase in ESP. Significant reduction in fresh weight was seen at ESP 40 and 48.

Top: From the Table 7, it is evident that there was consistent fall in fresh weight of top with the increase in ESP. A significant decrease in fresh weight of top was seen from ESP 16 and onwards. The decrease was statistically significant at ESP 32, 40 and 48.

4.1.1.10 Effect on dry weight of root with rhizome & top

Root with rhizome: It may be seen from the data (Table 7) that with the increase in ESP, there was

decrease in dry weight of roots with rhizome. The dry weights under ESP 32 and onwards were significantly affected.

Top: From the perusal of the data (Table 7), it is observed that the dry weight of top decreased with the increase in ESP. The decrease was statistically significant at ESP 40 and 48 over other ESPs.

Table 7: Effect of ESP on fresh weight of whole plant (g), fresh and dry weight of top and root with rhizome (g) of Ardhapuri banana.

Treatments	Fresh weight of whole plant(g)	Fresh weight of top (g)	Fresh weight of root + rhizome(g)	Dry weight of top(g)	Dry weight of root + rhizome (g).
Control	3220.0	1510.0	1710.0	770.0	980.6
ESP 8	3380.0	1590.0	1790.0	795.0	998.0
ESP 16	3178.3	1505.1	1673.2	753.4	973.5
ESP 24	2643.5	1316.5	1327.0	658.3	960.0
ESP 32	2233.1	1140.0	1093.1	558.6	683.5
ESP 40	1981.7	1056.7	925.0	528.3	582.2
ESP 48	1818.3	1000.0	818.3	510.0	507.4
S.E.	37.7	21.3	24.5	22.1	31.1
C.D.	114.4	62.8	72.3	65.1	91.7



Plate 3: Effect of ESP on root growth of banana plant cv. Ardhapuri (after 360 days of planting).



Plate 4: Effect of ESP on root growth of banana plant cv. Basrai (after 360 days of planting).

4.1.2 Basrai

4.1.2.1 Effect on plant height

Periodic observation on the height of Basrai plants over the initial readings under various ESP levels are depicted in Table 8. The effects at ESP 8, 16, 24, 32 and control were statistically similar and they showed lower reduction in plant height over ESP 40 and 48. The adverse effects were apparent from 120 days after planting.

4.1.2.2 Effect on number of leaves/plant

The number of leaves showed a decreasing trend with increase in ESP (Table 8). Severe effects of ESP were observed from 180 days after planting. The ESP 8, 16, 24 and control were similar and they produced more number of leaves than ESP 40 and 48. The effects of ESP 40 and 48 were similar in reducing the number of leaves for 240, 300 and 360 days.

4.1.2.3 Effect on pseudostem diameter

The decrease in diameter with the increase in ESP was evident from the data (Table 8). The pseudostem diameter of plants got adversely affected at ESP 24 and above. The levels 8, 16 and control were statistically at par and gave significantly superior over that of ESP 40 and 48.

4.1.2.4 Effect on plant spread

The data presented in Table 9 showed that the

Table 8 : Effect of ESP on pseudostem height (cm), number of leaves and stem diameter (mm) of Basrai banana.

Treatments	Days after planting					
	60	120	180	240	300	360
Pseudostem height						
Control	25.83	46.80	71.40	90.13	98.14	100.00
ESP 8	27.60	47.50	74.73	92.80	99.84	103.13
ESP 16	26.50	46.13	70.80	88.10	95.30	98.64
ESP 24	24.00	41.77	65.89	81.67	92.30	94.44
ESP 32	23.67	40.10	59.14	76.67	84.70	86.00
ESP 40	22.13	36.40	53.33	61.19	63.00	63.00
ESP 48	20.40	29.84	40.00	46.33	47.00	47.00
S.E. _t	1.59	2.21	7.84	10.68	11.32	11.03
C.D.	4.69	6.52	23.12	31.50	33.39	32.54
Number of leaves						
Control	6.00	11.00	14.00	16.33	18.00	18.33
ESP 8	6.67	12.33	14.33	17.00	18.00	18.33
ESP 16	6.33	10.33	13.67	15.67	17.00	17.00
ESP 24	5.33	7.67	11.67	13.00	14.33	15.00
ESP 32	5.00	7.00	10.00	12.00	12.67	12.67
ESP 40	4.67	6.67	7.67	9.67	10.33	10.33
ESP 48	4.00	5.33	7.00	7.67	8.33	8.33
S.E. _t	0.59	1.11	1.83	2.23	2.62	2.72
C.D.	1.74	3.27	5.40	6.58	7.73	8.02
Pseudostem diameter						
Control	31.50	43.50	62.00	82.33	94.00	97.00
ESP 8	32.33	45.00	65.00	83.00	95.67	98.67
ESP 16	31.67	43.00	63.00	80.00	93.00	95.00
ESP 24	30.60	41.33	58.00	74.00	80.00	81.00
ESP 32	28.00	38.33	54.50	66.50	70.67	72.33
ESP 40	26.24	36.00	50.00	61.33	62.33	63.00
ESP 48	24.00	31.00	39.00	46.00	47.00	47.00
S.E. _t	1.29	2.68	4.72	6.94	8.12	9.29
C.D.	3.80	7.91	13.92	20.47	23.95	27.40

plant spread under ESP 8, 16, 24 and control were statistically similar with each other and they showed greater increase in plant spread than ESP 32, 40 and 48.

4.1.2.5 Effect on leaf area

The total leaf area per plant (Table 9) decreased with the increase in ESP, pronounced effect was seen at ESP 40 and 48. These treatments recorded low leaf area per plant as compared to control and other ESPs.

4.1.2.6 Effect on root length

It is evident from Table 9 that the extent of root length reduction was significant at ESP 24 and 48 over control and other ESP levels. The effects on root length reduction at ESP 24 and 48 were similar.

4.1.2.7 Effect on plant mortality

The data regarding plant mortality are given in Table 9 and shown graphically in Fig.1. Plants did not show any kind of mortality at ESP 8, 16 and 24. The ESP 48 showed burning of leaf margins and defoliation.

4.1.2.8 Effect on fresh weight of whole plant

The observations presented in Table 10 showed that a sudden drop in fresh weight of whole plant was observed at ESP 40 and 48. The effects of ESP 8, 16, 24 and control were similar. Similarly, the effects was different statistically among 40 and 48.



Plate 5: Effect of ESP on top growth of banana plant cv. Basrai (after 140 days of planting).



Plate 6 : Leaf injury caused by soil ESP cv. Basrai banana.

Table 9: Effect of ESP on plant spread (cm), total leaf area (sq.m), length of root (cm) and per cent mortality of Basrai banana

Treatments	Plant spread (cm)	Total leaf area(sq.m)	Length of root(cm)	Mortality (%)
Control	72.67	8.39	96.16	00.00
ESP 8	77.12	8.86	95.83	00.00
ESP 16	73.22	8.48	92.33	00.00
ESP 24	64.32	8.21	91.00	00.00
ESP 32	59.66	7.21	88.00	25.00
ESP 40	48.66	5.88	87.67	41.67
ESP 48	44.58	3.95	84.33	66.67
S.E. $\pm$	6.13	1.23	1.44	-
C.D.	18.08	3.63	4.25	-

4.1.2.9 Effect on fresh weight of top and root with rhizome

Top: It is evident from the data (Table 10) that with the increase in ESP there was decrease in fresh weight of top but ESP 8, 16 and control were statistically similar and superior to ESP 24, 32, 40 and 48. The lowest fresh weight of top was recorded at ESP 48 which was similar with ESP 40.

Root with rhizome: On perusal of the data (Table 10) it is seen that the ESP 8,16 and control produced more fresh weight as compared to rest of the treatments. The fresh weight obtained with respect to ESP 40 and 48 levels was more or less similar.

Table 10: Effect of ESP on fresh weight of whole plant (g). fresh and dry weight of top and root with rhizome (g) of Basrai banana

Treatmen- ts	Fresh weight of whole plant(g)	Fresh weight of top (g)	Fresh weight of root rhizome (g)	Dry weight of top(g)	Dry weight of root + rhizome(g)
Control	3090.0	1440.00	1636.7	650.0	835.5
ESP 8	3196.7	1443.3	1653.3	700.0	849.5
ESP 16	3112.5	1465.0	1647.5	661.0	845.0
ESP 24	2580.0	1246.6	1333.3	560.0	680.0
ESP 32	2250.0	1106.6	1143.3	495.5	580.0
ESP 40	1950.0	1016.0	933.3	460.4	475.0
ESP 48	1793.3	926.6	866.7	415.3	440.0
S.E $\pm$	35.5	17.3	23.2	23.9	28.4
C.D.	104.9	51.4	68.6	70.6	83.6

4.1.2.10 Effect on dry weight of top and root with rhizome

Top: The data (Table 10) indicated that the dry weight of top at ESP 40 and 48 were low as compared to ESP 8, 16, 24, 32 and control. The effects of ESP 40 and 48, and the effects of ESP 8, 16, and 24 with control were similar with each other.

Root with rhizome: It may be seen that from the data given in Table 10, the dry weight affected severely at ESP 32, 40 and 48. These levels had significantly less dry weight as compared to control, ESP 8 and 16.

4.2 Effect of salinity on growth

The results pertain to the study on the effect of different levels of soil salinity, namely 0,3,6,9,12,15 and 18 dsm^{-1} designated as $S_0, S_1, S_2, S_3, S_4, S_5$ and S_6 , respectively are presented below.

4.2.1.1 Ardhapuri

4.2.1.1 Effect on plant height

The periodic observations on height of the Ardhapuri plants expressed over the initial observations are given in Table 11. The plants were worst affected at 15 and 18 dsm^{-1} and they showed lower plant height in comparison to other levels and control. The effect of salinity levels 3,6,9 and 12 dsm^{-1} was statistically not different from each other.

Table 11 : Effect of salinity on height of pseudostem (cm), number of leaves and pseudostem diameter(mm) of Aardhapuri banana.

Treatments	Days after planting					
	60	120	180	240	300	360
Pseudostem height						
S ₀	28.33	49.63	75.00	93.47	105.00	110.67
S ₁	27.67	49.00	74.00	92.00	104.00	109.00
S ₂	27.00	47.00	75.00	90.00	102.00	105.00
S ₃	25.52	44.15	70.65	86.36	98.72	99.00
S ₄	26.33	40.36	64.50	80.67	90.12	91.00
S ₅	24.24	39.00	60.67	72.50	74.50	74.50
S ₆	21.67	34.31	43.00	47.33	47.33	47.33
S.E.†	1.64	2.12	3.51	7.39	9.87	10.13
C.D.	4.84	6.25	10.35	21.80	29.09	29.88
Number of leaves						
S ₀	6.33	10.33	14.00	16.33	18.00	18.00
S ₁	6.00	10.00	14.00	16.00	17.67	18.00
S ₂	5.00	8.33	12.67	14.67	16.00	16.00
S ₃	5.33	7.67	11.33	12.67	14.00	14.00
S ₄	5.00	7.33	10.33	11.33	12.00	12.33
S ₅	4.33	6.67	8.33	9.00	9.33	9.33
S ₆	4.00	5.67	7.00	7.33	7.33	7.33
S.E.†	0.51	0.94	1.06	2.00	2.12	2.14
C.D.	1.52	2.77	3.13	5.90	6.25	6.31
Pseudostem diameter						
S ₀	33.00	45.33	64.00	85.00	95.67	98.33
S ₁	31.67	45.00	63.33	83.00	94.67	95.00
S ₂	30.17	43.00	60.00	79.33	89.37	91.00
S ₃	30.17	40.67	57.00	73.00	83.00	89.00
S ₄	27.67	36.33	53.67	68.00	76.00	77.00
S ₅	25.00	33.00	48.00	62.00	62.00	62.00
S ₆	22.67	29.37	39.00	49.33	49.33	49.33
S.E.†	1.02	2.14	3.54	5.89	6.83	9.02
C.D.	3.01	6.31	10.44	17.37	20.15	26.61

4.2.1.2 Effect on number of leaves

It is observed from Table 11, that there was decrease in the number of leaves with the increase in salinity level. The treatment effects were conspicuously seen from 120 days after planting. The salinity levels 3,6,9,12 dsm^{-1} and control were statistically similar and superior to 15 and 18 dsm^{-1} .

4.2.1.3 Effect on pseudostem diameter

From Table 11, it is evident that the plants under control and salinity level 3,6 and 9 dsm^{-1} were similar and superior to rest of the treatments. The effects of 12,15 and 18 dsm^{-1} were not different from each other for 300 and 360 days. In general, the decreasing trend was conspicuous from 120 days onwards.

4.2.1.4 Effect on plant spread

It is evident from Table 12 that the plant spread at salinity levels 3,6,9 dsm^{-1} and control was statistically similar. These levels had larger spread as compared to 12,15 and 18 dsm^{-1} . The effects of 15 and 18 dsm^{-1} were also different from each other.

4.2.1.5 Effect on leaf area

The data regarding the leaf area per plant are presented in Table 12. The total leaf area per plant decreased with the increase in salinity levels. The salinity levels 15 and 18 dsm^{-1} showed lower leaf area



Plate 7: Effect of soil salinity on top growth of banana plant cv. Ardhapuri (after 120 days of planting).

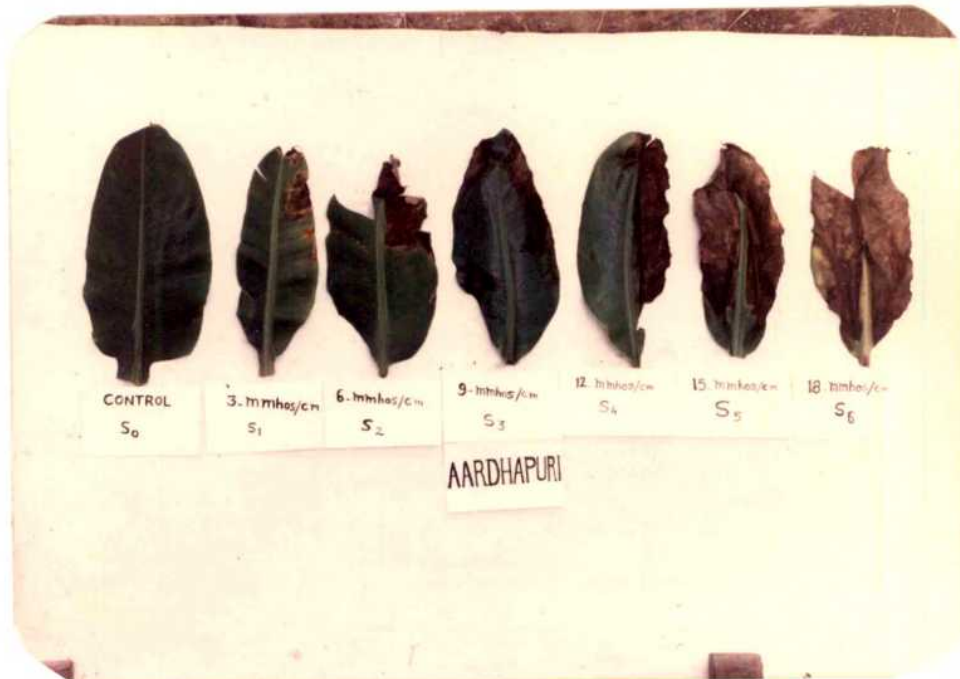


Plate 8: Leaf injury caused by soil salinity cv. Ardhapuri banana

than control and other, levels. The effects of salinity levels up to 12 dsm^{-1} were similar with control.

4.2.1.6 Effect on root length.

It is evident from the Table 12, that the root length at salinity levels 3,6,9 and 12 dsm^{-1} and control were statistically similar and superior to 15 and 18 dsm^{-1} . The lowest root length was recorded at 18 dsm^{-1} which was also different from all other levels.

Table 12: Effect of salinity on the plant spread (cm), total leaf area (sq.m), length of root (cm) and per cent mortality of Ardhapuri banana.

Treatments	Plant spread (cm)	Total leaf area(sq.m)	Length of root(cm)	Mortality (%)
So	85.67	9.21	96.33	00.00
S ₁	83.93	9.05	94-66	00.00
S ₂	79.66	8.69	92.67	00.00
S ₃	75.67	7.97	92.11	25.00
S ₄	64.33	7.38	91.00	50.00
S ₅	51.74	6.48	90.33	66.67
S ₆	44.43	5.02	86.67	100.00
S.E.	5.23	0.96	1.17	-
C.D.	15.43	2.83	3.45	-

4.2.1.7 Effect on plant mortality

The data presented in Table 12 showed that the plants did not exhibit any symptoms up to 6 dsm^{-1} . The plants were more affected at 18 followed by 15 dsm^{-1} . These treatments showed buring of leaf margin and defoliation.

4.2.1.8 Effect on fresh weight of whole plant.

The data on fresh weight of whole plant as affected by different salinity levels are presented in Table 13. The fresh weight of whole plant was lower at salinity levels 15 and 18 dsm^{-1} as compared to control and other salinity levels.

4.2.1.9 Effect on fresh weight of top and root with rhizome

Top: It is obvious from the results (Table 13) that the salinity levels 3, 6, 9 dsm^{-1} and control were statistically similar and they recorded more fresh weight of top than 12, 15 and 18 dsm^{-1} . The effects of 15 and 18 dsm^{-1} were different from each other.

Root with rhizome: The data presented in Table 13, showed that fresh weight of root with rhizome decreased with the increase in salinity level. The root weight at 15 and 18 dsm^{-1} were low as compared to control and other salinity levels. The effects of salinity levels 3, 6, 9, 12 dsm^{-1} and control were similar.

Not so!

Table 13: Effect of salinity on fresh weight of whole plant (g) , fresh and dry weight of top and root with rhizome of Ardhapuri banana.

Treatmen- ts	Fresh weight of whole plant(g)	Fresh weight of top (g)	Fresh weight of root rhizome (g)	Dry weight of top(g)	Dry weight of root + rhizome(g)
S ₀	3220.0	1510.0	1710.0	770.1	980.7
S ₁	3165.0	1465.0	1695.0	747.2	966.0
S ₂	2826.5	1385.0	1441.0	707.0	825.0
S ₃	2700.6	1365.0	1335.6	695.0	760.9
S ₄	2313.5	1135.0	1178.5	568.5	670.0
S ₅	1800.8	1020.5	779.5	521.0	450.0
S ₆	1760.5	978.0	782.5	498.0	451.0
S.E.	93.3	37.3	83.5	23.8	24.8
C.D	283.2	107.1	251.9	72.2	75.2

4.2.1.10 Effect on dry weight of top and root with rhizome

Top : From Table 13 it is evident that the treatments 3,6 9 dsm⁻¹ and control were statistically similar and they had more dry weight of top as compared to 12,15 and 18 dsm⁻¹. The effect at 18 dsm⁻¹ was maximum in reducing the dry weight of top.



Plate 9: Effect of Soil salinity on root growth of banana plant cv. Ardhapuri (after 360 days of planting).



Plate 10: Effect of soil salinity on root growth of banana plant cv. Basrai (after 240 days of planting).

Root with rhizome : Significant reduction in dry weight of root was recorded at 15 and 18 dsm^{-1} over control and other salinity levels. As salinity level get increased there was reduction in dry weight of root (Table 13).

4.2.2 Basrai banana

4.2.2.1 Effect on plant height.

Periodic height observation of banana plants expressed over the initial observation under different salinity levels are given in Table 14. The data indicated that salinity levels 3,6,9 dsm^{-1} and control were statistically similar and they showed more height as compared to 12,15 and 18 dsm^{-1} . The adverse effects were more pronounced at 12,15 and 18 dsm^{-1} and started appearing from 180 days onwards. At salinity level 18 dsm^{-1} plant were died 240 days of planting.

4.2.2.2 Effect on number of leaves

It is evident from the data (Table 14) that there was decrease in number leaves with the increase in salinity level. The decrease was more pronounced at 12, 15, 18 dsm^{-1} and the adverse effect of these levels started immediately after planting i.e. from 60 days onwards. The salinity levels 3,6,9 dsm^{-1} and control were statistically similar and they showed superior performance over rest of the treatments. The effect of 18 dsm^{-1} was higher than other levels.

Table 14: Effect of salinity on pseudostem height (cm), number of leaves and pseudostem diameter (mm) of Basra banana.

Treatments	Days after planting					
	60	120	180	240	300	360
Pseudostem height						
S ₀	25.83	46.80	71.40	90.13	98.14	100.00
S ₁	26.67	47.43	73.20	92.33	99.00	100.00
S ₂	25.67	46.26	69.50	87.40	95.00	95.00
S ₃	25.16	41.75	64.50	80.00	82.00	82.00
S ₄	22.80	38.33	59.80	71.33	72.00	72.00
S ₅	21.60	37.00	50.00	60.00	61.00	61.00
S ₆	19.35	34.00	43.00	42.00	-	-
S.E.†	1.03	1.78	4.96	7.01	9.00	9.01
C.D.	3.04	5.25	14.63	20.68	26.55	26.58
Number of leaves						
S ₀	6.00	11.00	14.00	16.33	18.00	18.33
S ₁	6.00	12.00	15.33	16.33	17.00	17.00
S ₂	6.00	11.00	14.00	15.00	15.00	15.00
S ₃	5.33	10.67	11.67	12.00	12.00	12.00
S ₄	5.00	7.00	10.00	10.33	10.33	10.33
S ₅	4.67	7.00	9.00	9.00	9.00	9.00
S ₆	4.33	6.00	6.00	6.00	-	-
S.E.†	0.33	1.02	1.73	1.78	2.01	2.01
C.D.	1.01	3.01	5.10	5.25	5.93	5.93
Pseudostem diameter						
S ₀	31.50	43.50	62.00	82.33	94.00	97.00
S ₁	32.33	44.00	63.17	84.00	94.00	96.33
S ₂	30.67	43.00	60.16	79.67	91.00	94.00
S ₃	28.83	41.33	57.44	71.00	77.00	80.00
S ₄	27.33	37.16	52.33	63.00	67.00	69.00
S ₅	25.83	35.50	47.67	57.83	57.72	58.00
S ₆	23.00	33.00	40.00	40.00	-	-
S.E.†	1.61	2.50	3.65	6.89	7.79	7.83
C.D.	4.75	7.38	10.76	20.32	32.00	23.12

4.2.2.3 Effect on stem diameter

The data in Table 14 showed that the plants under control, salinity levels 3,6,9 dsm^{-1} were statistically similar and showed superiority over rest of the treatments. The effects between 12 and 15 dsm^{-1} were also similar with each other. While at salinity 18 dsm^{-1} the pseudostem diameter was ceased at 120 days of planting.

4.2.2.4 Effect on plant spread

The data pertaining to the plant spread under different salinity levels are projected in Table 15. The plants under control, salinity levels 3,6,9 dsm^{-1} did not differ but had larger spread than those under 12,15 and 18 dsm^{-1} . The effect of 12 and 15 dsm^{-1} were similar with each other. The lower spread was observed at 18 dsm^{-1} .

4.2.2.5 Effect on total leaf area/plant

The leaf area decreased with the increase in salinity (Table 15). The decrease was more sharp at 12,15 and 18 dsm^{-1} . These levels produced lower leaf area than control, 3,6 and 9 dsm^{-1} .

4.2.2.6 Effect on root length

It is evident that (Table 15) the significant reduction in root length was recorded in case of 12,15 and 18 dsm^{-1} as compared to control and other treatments.

The effects of 12 and 15 dsm^{-1} were similar with each other.



Plate 11: Effect of soil salinity on top growth of banana plant cv. Basrai (after 210 days of planting).



Plate 12: Leaf injury caused by soil salinity cv. Basrai banana.

4.2.2.7 Effect on plant mortality

The data regarding plant mortality are given in Table 15 and shown graphically in Fig.2. The salinity level 3 and 6 did not show any kind of mortality symptoms. The mortality symptoms started from 9 dsm^{-1} onwards after 120 days of planting. The salinity levels 9 dsm^{-1} show burning of leaf margin whereas 12 and 15 dsm^{-1} show heavy defoliation while at 18 dsm^{-1} plants died 240 days of planting.

Table 15 : Effect of salinity on plant spread (cm), total leaf area (sq.m), root length (cm), percent mortality of Basrai banana

Treatments	Plant spread (cm)	Total leaf area(sq.m)	Root length (cm.)	Mortality (%)
S ₀	72.66	8.39	88.00	00.00
S ₁	71.66	8.24	87.00	00.00
S ₂	69.90	7.96	84.50	00.00
S ₃	65.50	7.83	79.60	25.00
S ₄	58.36	6.96	73.32	66.67
S ₅	51.20	5.42	67.28	75.00
S ₆	40.23	3.83	59.67	100.00
S.E.	4.21	0.66	2.69	-
C.D	12.41	1.96	7.93	-

4.2.2.8 Effect on fresh weight of whole plant.

The results of fresh weight of whole plant were affected by different salinity levels are presented in Table 16. The drop in fresh weight of whole plant was recorded from 9 dsm⁻¹ onwards over 3,6 dsm⁻¹ and control.

The highest drop in fresh weight of whole plant was observed at 18 dsm⁻¹ which was different from other level.

Table 16 : Effect of salinity of fresh weight of whole plant (g), dry weight of top and root with rhizome of Basrai banana

Treat- ments	Fresh weight of whole plant(g)	fresh weight of Top (g)	fresh weight of root +rhizome(g)	Dry weight of top (g)	Dry weight of root + rhizome(g)
S ₀	3090.0	1440.0	1636.6	650.0	835.5
S ₁	3106.7	1430.0	1676.7	600.00	780.0
S ₂	2813.3	1300.3	1513.0	550.5	681.0
S ₃	2658.5	1118.5	1539.9	521.0	636.0
S ₄	2334.8	1000.5	1334.3	498.0	598.0
S ₅	2018.5	930.5	1088.0	448.0	554.0
S ₆	1680.5	720.0	960.5	399.5	408.5
S.E.	90.3	38.8	51.9	28.2	29.2
C.D.	266.5	114.3	153.1	83.1	86.2

4.2.2.9 Effect on fresh weight of top and root.

Top: It is evident from the data (Table 16) that the plants under control and $3,6 \text{ dsm}^{-1}$ were statistically similar and they showed more fresh weight of top than rest of the treatments. The effects of 12 and 15 dsm^{-1} were not different from each other statistically .

Root with rhizome: On perusal of the data (Table 16) it is seen that there was consistent fall in fresh weight of root with rhizome with the increase in salinity level.

A ^{reduction in} fresh weight of root with rhizome (lower) was recorded at 12 dsm^{-1} and above as compared to earlier treatments. The effects of 15 and 18 dsm^{-1} were not statistically different from each other.

4.2.2.10 Effect on dry weight of top and root with rhizome

Top: A significant reduction in dry weight of top was recorded from 9 dsm^{-1} and above (Table 16). The salinity levels 15 and 18 dsm^{-1} showed greater reduction in top dry weight. The effects of 15 and 18 dsm^{-1} were similar with each other and these levels differed from other levels.

Root with rhizome : It evident from Table 16 that the root with rhizome weight was reduced at 9,12,15 and 18 dsm^{-1} as compared to 3 , 6 dsm^{-1} and control. The effects of 15 and 18 dsm^{-1} were different from each other.

4.3 Effect of chlorides on growth

4.3.1 Ardhapuri banana

4.3.1.1. Effect on plant height.

The periodic height of the plants of Ardhapuri variety of banana was measured under different chloride levels.

It is evident from Table 17 that the height of the plant at 6,12 me/l of chloride level and control did not differ significantly. As the chloride level was increased there was decrease in plant height. The plants at 30 me/l of chloride level did not survive after 300 days of planting while after 240 days of planting the plants treated with 36 me/l could not survive. The adverse effects of chloride levels started 120 days after planting.

4.3.1.2 Effect on number of leaves per plant

The data presented in Table 17 revealed that the chloride level 6,12 me/l and control were statistically similar and these levels produced more number of leaves than other levels. The effects of chlorides at 18 and 24 me/l were not different from each other. A significant severe effect was observed from 60 days after planting. The plants at 30 and 36 me/l almost stopped producing leaves after 180 days of planting.

Table 17: Effect of chlorides on pseudostem height (cm)
Number of leaves and pseudostem diameter (mm)
of Aardhapuri banana.

Treatments	Days after planting					
	60	120	180	240	300	360
Pseudostem height						
C ₀	29.00	49.00	75.67	94.50	105.00	110.00
C ₁	30.20	49.00	73.15	92.66	104.00	107.00
C ₂	28.50	45.80	70.00	87.67	98.00	99.95
C ₃	27.75	43.30	66.25	83.43	91.40	92.00
C ₄	27.00	49.78	59.85	73.37	74.00	74.00
C ₅	25.14	34.40	51.55	53.00	53.00	-
C ₆	23.24	30.50	43.00	43.00	-	-
S.E. [†]	0.97	1.79	3.88	4.99	7.43	7.89
C.D.	2.87	5.29	11.44	13.24	15.68	16.93
Number of leaves						
C ₀	6.33	11.00	14.00	16.33	18.00	18.00
C ₁	6.00	11.00	15.00	16.00	18.00	18.00
C ₂	5.63	9.00	13.33	14.67	15.00	15.00
C ₃	5.00	9.00	11.00	12.00	12.00	12.00
C ₄	5.00	7.00	10.33	11.00	11.00	11.00
C ₅	4.00	6.33	8.67	9.00	9.00	-
C ₆	3.67	5.67	6.33	6.33	-	-
S.E. [†]	0.41	0.06	0.56	1.39	1.74	1.97
C.D.	1.21	0.19	0.65	4.10	3.67	4.22
Pseudostem diameter						
C ₀	33.00	46.00	63.50	85.00	95.67	97.00
C ₁	32.00	45.50	65.50	84.00	94.50	97.00
C ₂	30.38	44.00	60.00	80.10	82.00	83.00
C ₃	29.40	44.00	56.00	74.50	77.00	77.00
C ₄	28.10	40.00	51.00	69.17	70.00	70.00
C ₅	24.67	37.32	44.00	58.00	59.00	-
C ₆	22.10	30.12	39.00	39.00	-	-
S.E. [†]	0.73	2.11	5.11	4.72	10.95	10.77
C.D.	2.17	6.24	15.10	13.94	23.11	23.11

4.3.1.3 Effect on stem diameter

It is evident from the data presented in Table 17 that the chloride level 6,12 me/l and control showed greater increase in the stem diameter than 18 and 24 me/l. The increase in the stem diameter of plants started getting adversely affected from 240 days. The increase in stem diameter was almost reduced after 240 days in 30 and 36 me/l.

4.3.1.4 Effect on plant spread.

The data regarding plant spread has been presented in Table 18. It is evident from the results that chloride levels upto 18 me/l did not differ significantly the plant spread. The effects of chloride at 30 and 36 me/l were not different statistically from each other.

4.3.1.5 Effect on leaf area

The total leaf area per plant decreased with the increase in chloride level. The decline was more pronounced at 30 and 36 me/l. These levels had lower leaf area than other chloride levels and control (Table 18).

4.3.1.6 Effect on root length.

It is evident from the data (Table 18) that the chloride levels 6,12 me/l and control were statistically similar with each other. The differences between levels



Plate 13: Effect of chlorides on top growth of banana plant cv. Ardhapuri (after 210 days of planting).

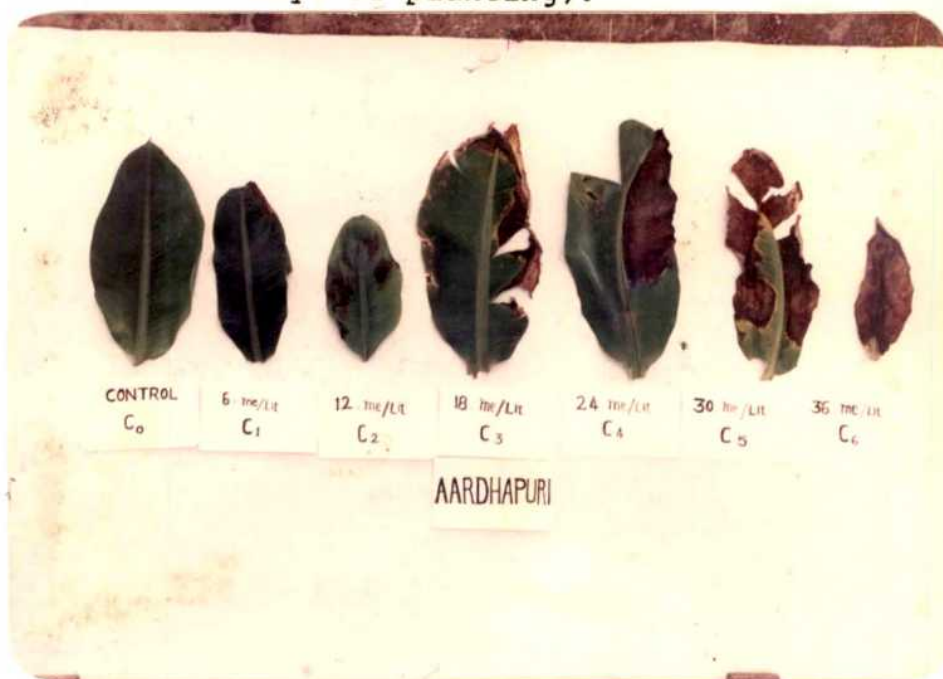


Plate 14: Leaf injury caused by soil chlorides cv. Ardhapuri banana.

30 and 36 me/l were also significant. The root length at chloride level 36 me/l was the lowest than all other levels

Table 18 Effect of chlorides on plant spread (cm), total leaf area (Sq.m), length of root (cm) and per cent mortality of Ardhapuri banana

Treatments	Plant spread (cm)	Total leaf area(sq.m)	Root length (cm)	Mortality (%)
C ₀	85.00	9.19	91.00	00.00
C ₁	82.35	8.98	90.00	00.00
C ₂	79.69	8.69	86.15	00.00
C ₃	74.32	8.34	81.40	12.50
C ₄	66.53	7.12	75.33	25.00
C ₅	56.67	6.27	68.14	75.00
C ₆	47.57	4.96	48.80	100.00
S.E.	5.53	0.62	2.82	-
C.D.	16.31	1.84	8.33	-

4.3.1.7 Effect on plant mortality

The results regarding plant mortality are presented in Table 18 and shown graphically in Fig.3. Ardhapuri plants were worst affected at 30 and 36 me/l. The adverse effects of chlorides started from 120 days

onwards after planting. The chloride level 6,12 me/l and control did not show any kind of mortality symptom.

4.3.1.8 Effect on fresh weight of whole plant

The data on fresh weight of whole plant as affected by various chloride levels are presented in Table 19. A sharp drop in fresh weight of whole plant was recorded at 30 and 36 me/l and these levels showed lower fresh weight of plant than other treatments. the fresh weight of whole plant at chloride level 36 me/l was lowest which was also different from 30 me/l.

Table 19: Effect of chlorides on fresh weight of whole plant (g) fresh and dry weight of top and root with rhizome of Ardhapuri banana

Treat ments	Fresh weight of whole plant(g)	Fresh weight of top (g)	Fresh weight of root +rhizome (g)	Dry weight of top(g)	Dry weight of root + rhizome(g)
C ₀	3250.5	1525.0	1725.0	775.5	987.3
C ₁	3200.0	1465.5	1734.5	770.0	970.0
C ₂	3080.0	1434.0	1646.0	636.5	884.0
C ₃	2806.6	1405.0	1401.6	669.0	796.6
C ₄	2312.5	1200.00	1112.5	571.0	636.5
C ₅	1900.0	890.5	1009.5	539.0	587.4
C ₆	1748.2	843.8	904.5	513.0	488.0
S.E	47.2	27.2	26.6	11.7	11.1
C.D	143.3	80.2	78.6	35.6	33.7

4.3.1.9 Effect of fresh weight of top and root with rhizome

Top : It is evident from data (Table 19) that the chloride level 6,12 me/l and control were statistically similar with each other and superior to rest of levels. The effects of chloride levels 30 and 36 were different from each other.

Root with rhizom: On perusal of the data (Table 19) it is seen that there was no significant difference between control and chloride level 6 me/l. Whereas chloride level 30 and 36 me/l produced lower root weight than other levels .

4.3.1.10 Effect of dry weight on top and root with rhizome

Top: The dry weight of top decreased with the increase in chloride level (Table 19). The dry weight of top at chloride level 30 and 36 me/l was lower than control and other levels. The chloride levels upto 12 me/l were similar with each other.

Root with rhizome: It may be seen from the data (Table 19) that the root weight was severely reduced at 30 and 36 me/l of chloride level as compared to control and other chloride levels which were different from each other.



Plate 15: Effect of soil chlorides on root growth of banana cv. Ardhapuri (after 240 days of planting).



Plate 16: Effect of chlorides on root growth of banana cv. Basrai (after 360 days of planting).

4.3.2 Basrai banana

4.3.2.1 Effect on plant height

Periodic observations on height of Basrai banana over the initial observation under different chloride levels are given in Table 19. The adverse effects of chlorides started from 18 me/l onwards after 120 days of planting. The chloride levels 6,12 me/l control were statistically similar while the increase in chloride level decreased height of the plant. The plants were adversely affected after 300 days, 240 days and 180 days after planting at chloride levels 24,30 and 36 me/l respectively.

4.2.2.2 Effect on number of leaves.

It is evident from the data (Table 19) that no significant differences between control and chloride levels of 6 and 12 me/l. However they showed superior preformance over 18 me/l of chloride level. The adverse effect on number of leaves was started 120 days after planting. At chloride level of 24,30 and 36 me/l, the production of leaves ceased after 180 days of planting.

4.3.2.3 Effect on diameter of stem.

The effect of diffecrent levels of chlorides on stem diameter of Basrai banana is expressed in Table 19. The plants under control, 6 and 12 me/l of chloride

Table 19 : Periodic increase in plant height, numbers of leaves and stem diameter as influenced by chloride levels of Basrai banana.

Treatments	Days after planting					
	60	120	180	240	300	360
Plant height						
C ₀	26.15	47.00	73.00	91.30	99.00	100.33
C ₁	28.00	49.30	72.67	90.00	97.00	97.83
C ₂	26.60	45.20	66.41	82.11	86.37	87.25
C ₃	24.18	42.30	60.14	73.62	75.00	75.00
C ₄	24.00	39.00	52.40	55.00	55.00	-
C ₅	21.75	34.65	46.35	48.00	-	-
C ₆	20.80	29.30	36.00	-	-	-
S.E. $\pm$	0.89	2.13	6.48	6.42	6.93	7.00
C.D.	2.62	6.28	19.11	19.16	20.99	21.77
Number of leaves						
C ₀	6.33	11.33	14.33	16.33	18.00	18.00
C ₁	6.33	11.00	15.00	16.33	16.66	16.66
C ₂	6.00	10.66	13.00	14.66	15.00	15.00
C ₃	5.66	10.66	12.00	12.00	12.00	12.00
C ₄	5.33	7.33	10.33	10.33	10.33	-
C ₅	4.33	7.00	9.00	9.00	-	-
C ₆	3.66	5.63	6.00	-	-	-
S.E. $\pm$	0.30	1.05	1.36	1.59	1.65	1.71
C.D.	0.88	3.09	4.03	4.73	5.01	5.31
Stem diameter						
C ₀	31.68	43.50	63.00	82.33	94.00	97.66
C ₁	31.00	43.00	63.00	82.00	92.33	96.00
C ₂	29.59	41.12	59.54	77.14	89.48	90.01
C ₃	27.18	38.07	55.12	71.68	81.03	84.17
C ₄	24.32	33.11	48.83	49.93	50.00	-
C ₅	21.98	29.98	43.00	43.00	-	-
C ₆	20.03	27.51	34.00	-	-	-
S.E. $\pm$	2.00	2.73	5.43	11.06	4.67	4.27
C.D.	5.90	8.08	16.03	32.96	14.17	13.28

levels showed significantly greater increase in the stem diameter of plants than rest of the chloride levels. The adverse effect on stem diameter started after 120 days of planting. The increase in stem diameter was stopped at 240 days and 180 days of planting for the chloride levels of 30 and 36 me/l.

4.3.2.4 Effect on plant spread.

The plant spread under different treatments have been presented in Table 20. The plant spread under control, chloride levels 6 and 12 me/l did not differ significantly and they had larger spread than those under 18 me/l. The spread of the plants for the treatment levels 24,30 and 36 me/l was recorded at 300,240 and 180 days after planting, respectively.

4.3.2.5 Effect on leaf area.

The total leaf area per plant (Table 20) decreased with increase in chloride level. The decrease was more pronounced at 18,24,30 and 36 me/l of chloride levels. The chloride levels 6 and 12 me/l and control were statistically similar and they had more leaf area as compared to 18 me/l. Lower leaf area was recorded at 36 me/l.

4.3.2.6 Effect on root length.

The data pertaining to the root length as affected by different chloride levels (Table 20) showed



Plate 17: Effect of soil chlorides on top growth of banana plant cv. Basrai (after 210 days of planting).

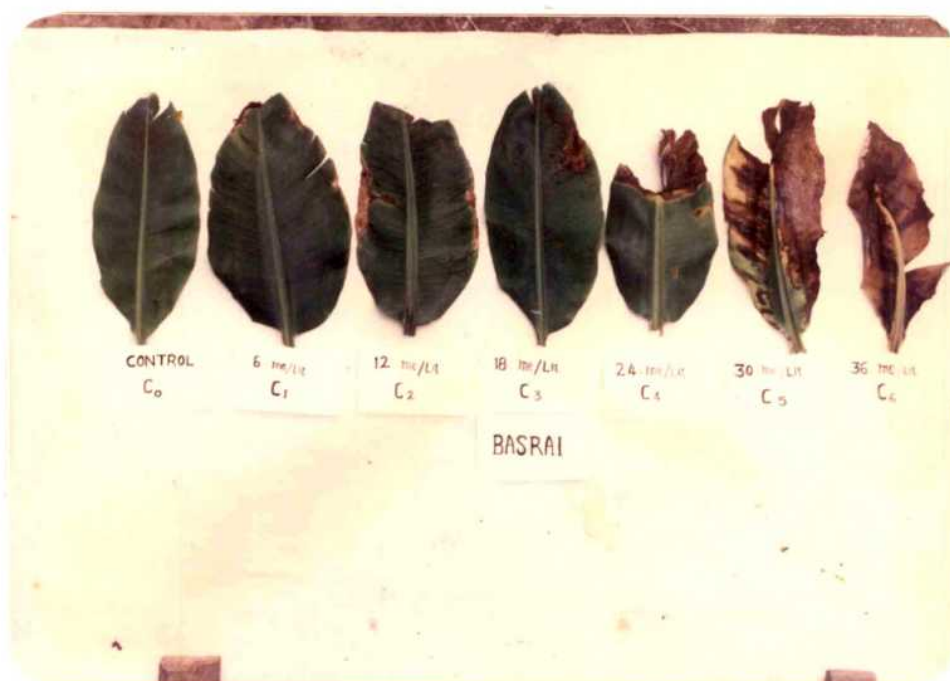


Plate 18: Leaf injury caused by soil chlorides cv. Basrai banana.

that the root length significantly declined with increase in the levels of chlorides. It was least in 36 me/l. The effects of chloride levels upto 18 me/l were not different from each other.

Table 20: Effect of chlorides on plant spread (cm), total leaf area (Sq.m) root length (cm) and per cent mortality of Basrai banana

Treatments	Plant spread (cm)	Total leaf area(sq.m)	Root length (cm)	Mortality (%)
C ₀	73.25	8.44	89.50	00.00
C ₁	70.50	8.28	86.25	00.00
C ₂	65.80	7.86	81.50	12.50
C ₃	61.25	7.23	78.00	50.00
C ₄	55.30	6.72	68.80	100.00
C ₅	48.42	5.21	64.25	100.00
C ₆	43.25	3.61	54.00	100.00
S.E.	2.79	0.21	4.16	-
C.D	8.24	0.62	12.27	-

4.3.2.7 Effect on plant mortality.

The data regarding plant mortality are presented in Table 20 and shown graphically in Fig. 7. The plants under 8 me/l of chloride level did not show any kind of

mortality. The mortality symptoms were started from chloride level of 12 me/l after 120 days of planting. The plants were worst affected at chloride level of 12 and 18 me/l while plants of chloride level 24, 30 and 36 me/l did not survive after 300, 240 and 180 days respectively.

4.3.2.8 Effect on fresh weight of whole plant.

The data on fresh weight of whole plant as affected by different chloride levels are presented in Table 21. The significant drop in fresh weight of whole plant was observed after 18 me/l of chloride level. The chloride levels 6 and 12 me/l and control were statistically significant with each other. The fresh weight of whole plant for the levels 24, 30 and 36 me/l was recorded at 300, 240 and 180 days after planting.

4.3.2.9 Effect on fresh weight of top and root (with rhizome)

Top; It is evident from the data (Table 21) that chloride levels 6, 12 me/l and control were similar and they produced more fresh weight of top than 18, 24, 30 and 36 me/l. The effects of 30 and 36 me/l were similar.

Root with rhizome: There was consistent fall in fresh weight of root with rhizome with the increase in chloride level (Table 21). A significant reduction in fresh weight of root with rhizome was seen from 18 me/l. The levels

24,30 and 36 were not different from each other statistically. The fresh weight of root with rhizome for the treatments 24,30 and 36 me/l was recorded at 300, 240 and 180 days after planting.

Table 21 : Effect of chloride on fresh weight of whole plant(g) fresh and dry weight of top and root with rhizome of Basrai banana.

Treat ments	Fresh weight of whole plant(g)	Fresh weight of top (g)	Fresh weight of root rhizome(g)	Dry weight of top(g)	Dry weight of root + rhizome(g)
C ₀	3106.0	1450.0	1656.0	652.5	848.3
C ₁	3000.0	1420.0	1580.0	838.8	758.3
C ₂	2720.8	1345.5	1375.0	580.2	660.0
C ₃	2310.8	1105.8	1205.0	510.5	625.0
C ₄	1930.5	922.0	1008.5	473.0	560.5
C ₅	1760.3	830.0	930.3	425.0	499.5
C ₆	1510.5	740.0	770.5	380.5	395.2
S.E	133.3	38.3	96.1	26.5	68.1
C.D-	393.3	113.2	283.2	78.1	201.1

4.3.2.10 Effect on dry weight of top and root with rhizome

Top :From the perusal of the data (Table 21), it is

evident that the dry weight of top was recorded low at chloride level of 30 and 36 me/l. The effects of 30 and 36 me/l were similar .

Toot with rhizome: It may be seen from the data (Table 21) that the dry weight of root under chloride level of 8,16 me/l and control were statistically similar and were significantly superior to rest of the treatments.

The dry weight of top and root with rhizome for the treatments 24, 30 and 36 me/l was recorded at 300, 240 and 180 days after planting, respectively

4.4 Effect of bicarbonates on growth.

4.4.1 Ardhapuri banana

4.4.1.1 Effect on plant height

Periodic observations on height of Ardhapuri banana plants under various levels of bicarbonate are given in Table 23. The bicarbonate levels 5,10,15 me/l and control were statistically similar and superior to 25 and 30 me/l in general with the increase in bicarbonate levels, there was decrease in plant height. The plants at 30 me/l level of bicarbonate could not survive after 300 days of planting.

4.4.1.2 Effect on number of leaves per plant

On perusal of the data (Table 23) it is evident that the plants under bicarbonate levels 5,10,15 me/l and

control were statistically similar and showed superior performance over 20,25 and 30 me/l. The effects of 20 and 25 me/l were statistically similar. The adverse effects of bicarbonates started from 120 days onwards. The plants of 30 me/l did not produced leaves after 300 days of planting.

4.4.1.3 Effect on stem diameter

It is further seen from the data (Table 23) that the bicarbonate levels 5,10,15 me/l and control were statistically similar and these treatments showed greater increase in stem diameter than those under higher levels.

The effects of 20 and 25 me/l were different from each other after 240 days. The plants under 30 me/l did not survive after 300 days of planting.

4.4.1.4 Effect on plant spread.

The data pertaining to the plants spread under various bicarbonate levels are presented in Table 24. The plant spread at bicarbonate levels, 5,10,15 and 20 me/l and control were statistically similar and showed more spread over 25 and 30 me/l . The effects of 25 and 30 me/l were similar. The plant spread for the level of 30 me/l was recorded 300 days of planting.

4.4.1.5 Effect on leaf area per plant

The total leaf area (Table 24) per plant decreased with the increase in bicarbonate level. The control,

Table 23 : Effect of bicarbonate levels on pseudostem height (cm), number of leaves and pseudostem diameter (mm) of Ardhapuri banana.

Treatments	Days after planting					
	60	120	180	240	300	360
Pseudostem height						
B ₀	28.33	51.30	76.00	96.02	106.00	111.00
B ₁	29.33	51.50	76.00	95.10	104.50	108.03
B ₂	28.00	50.67	74.53	91.18	99.58	101.01
B ₃	28.17	48.53	69.33	86.27	94.00	96.00
B ₄	27.67	45.17	60.07	78.50	87.50	88.00
B ₅	27.00	41.27	59.57	68.32	73.67	74.00
B ₆	25.33	39.20	52.28	56.67	57.00	-
S.E.±	1.03	3.07	3.33	3.39	3.96	5.24
C.D.	N.S.	9.07	9.82	10.00	11.68	15.48
Number of leaves						
B ₀	6.33	10.33	14.66	16.33	18.33	18.33
B ₁	6.00	10.33	14.33	16.33	17.33	17.67
B ₂	6.67	10.00	13.00	14.67	15.67	16.00
B ₃	6.33	9.00	11.33	14.00	14.33	14.67
B ₄	6.33	8.33	10.00	12.00	12.33	12.33
B ₅	6.00	7.33	8.33	8.33	10.00	10.00
B ₆	5.67	6.33	7.33	7.67	7.67	-
S.E.±	0.33	0.72	1.49	1.98	2.31	2.43
C.D.	N.S.	2.12	4.39	5.84	6.81	7.17
Pseudostem diameter						
B ₀	32.50	46.31	64.24	86.28	96.00	99.12
B ₁	31.50	44.32	63.42	86.00	95.33	98.10
B ₂	32.00	45.96	61.20	84.25	92.12	96.28
B ₃	31.28	42.03	58.00	78.32	87.40	90.02
B ₄	31.50	43.12	53.50	70.00	75.18	76.10
B ₅	30.67	45.32	51.12	63.98	68.00	68.00
B ₆	28.03	43.00	44.48	46.05	46.09	-
S.E.±	1.60	1.60	4.60	5.86	7.47	4.01
C.D.	4.72	4.72	13.57	15.26	22.03	11.83



Plate 19: Effect of bicarbonates on top growth of banana plant cv. Ardhapuri (after 240 days of planting).

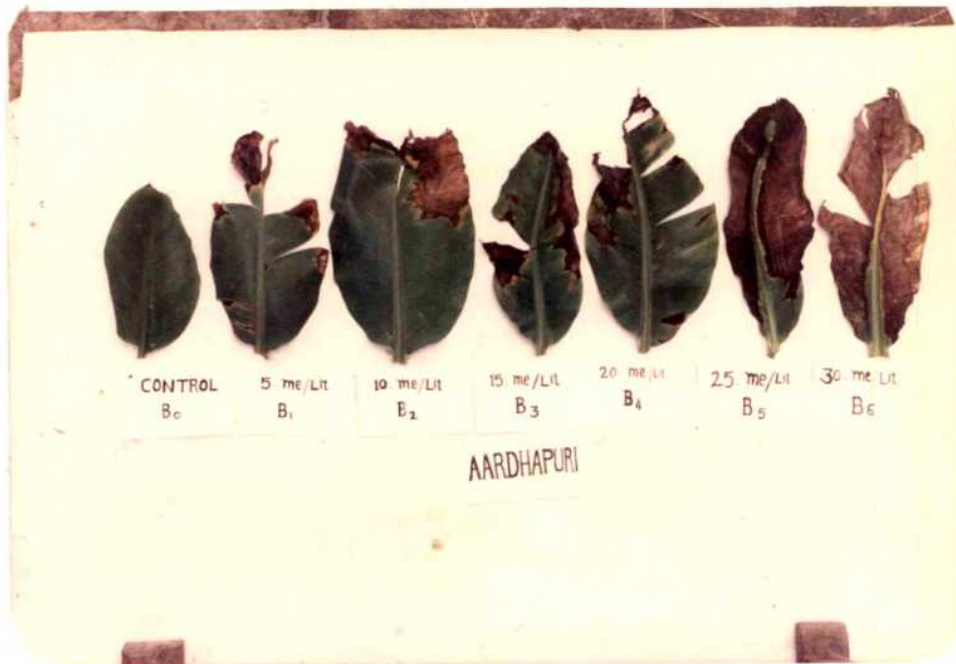


Plate 20: Leaf injury caused by bicarbonates cv. Ardhapuri banana.

bicarbonate level 5,10 and 15 me/l were statistically similar and these levels showed more leaf area than other levels. The leaf area for the treatment of 30 me/l was calculated ^{at} 300 days of planting.

Table 24 : Effect of bicarbonate levels on plant spread (cm), total leaf area (sq.m), root length (cm) and mortality of Ardhapuri banana.

Treatments	Plant spread (cm)	Total leaf area(sq.m)	Root length (cm)	Mortality (%)
B ₀	86.10	9.23	91.05	00.00
B ₁	86.23	8.94	89.30	00.00
B ₂	84.93	8.72	87.50	00.00
B ₃	80.33	7.83	82.40	00.00
B ₄	73.67	7.10	77.50	13.00
B ₅	69.00	6.30	71.36	44.50
B ₆	52.30	5.86	65.20	100.00
S.E.	4.44	0.59	4.57	-
C.D.	13.11	1.74	13.49	-

4.4.1.6 Effect on root length.

It is evident (Table 24) that there was decrease in root length with the increase in bicarbonate level. However, the extent of root length reduction was greater

at 25 and 30 me/l. The bicarbonate level of 30 me/l of 30 me/l adversely affected plants after 300 days of planting.

4.4.1.7 Effect of mortality

The data regarding plant mortality has been given in Table 24 and shown graphically in Fig.2. The plants under 5,10 and 15 me/l did not show any kind of mortality. The mortality symptoms started from 20 me/l onwards. The plants were worst affected at the levels of 25 and 30 me/l. After 300 days of planting the plants under 30 me/l of bicarbonate level did not survive.

4.4.1.8 Effect of fresh weight of whole plant.

There was decrease in fresh weight of whole plant with the increase in bicarbonate level (Table 25). A significantly low fresh weight of whole plant was recorded at 25 and 30 me/l bicarbonate level. The fresh weight at bicarbonate levels 5,10,15,20 me/l and control were statistically similar and superior to ^{that at} 25 and 30 me/l. The fresh weight of whole plant was recorded at 300 days of planting treated with 30 me/l.

4.4.1.9 Effect of fresh weight of top and root with rhizome

Top: It is evident from the data (Table 25) that the fresh weight of top at bicarbonate levels 5,10,15,20 me/l and control were statistically similar and they produced

more fresh weight of top as compared to 25 and 30 me/l. Plants at level of 30 me/l could not survive after 300 day of planting.

Root with rhizome: The fresh weight of root with rhizome decreased with increase in bicarbonate level (Table 25). The fall in fresh weight was more pronounced at 25 and 30 me/l of bicarbonate level. The bicarbonates levels upto 20 me/l and control were similar with each other.

Table 25 : Effect of bicarbonate levels on fresh weight of whole plant(g), fresh and dry weight of top and root with rhizome(g) of Ardhapuri.

Treat ment	Fresh weight of whole plant(g)	Fresh weight of top (g)	Fresh weight of root rhizome(g)	D-ry weight of top(g)	Dry weight of root + rhizome(g)
B	3190.5	1495.0	1695.0	658.5	855.0
B	3120.0	1430.5	1689.5	648.0	840.0
B	3000.0	1375.0	1625.0	638.0	760.0
B	2810.0	1310.0	1500.0	603.5	710.0
B	2750.5	1283.5	1467.0	575.0	660.5
B	2310.8	1200.0	1110.8	518.5	630.0
B	2050.3	1070.8	979.5	480.0	575.5
S.E	153.3	72.7	77.4	18.1	51.2
C.D	452.3	214.5	228.3	53.3	151.1



Plate 21: Effect of soil bicarbonats on root growth of banana cv. Ardhapuri (after 300 days of planting).



Plate 22: Effect of bicarbonates on root growth of banana cv. Basrai (after 240 days of planting).

4.4.1.10 Effect on dry weight of top and root with rhizome

Top: A significant reduction in dry weight of top was recorded at 20,25 and 30 me/l levels over other levels and control (Table 25). The bicarbonate levels 5,10,15 me/l and control were similar with each other and superior over 20,25 and 30 me/l. The dry weight of top was recorded at 300 days after planting under 30 me/l of bicarbonate level.

Root with rhizome: On perusal of the data in Table 25, in it is seen that with the increase in bicarbonate level there was decrease in dry weight of root with rhizome. The fall in dry weight was pronounced at 20,25 and 30 me/l. The bicarbonate levels upto 15 me/l and control were similar with each other statistically.

4.4.2 Basrai banana

4.4.2.1 Effect on plant height

Periodic observation of pseudostem height of Basrai banana are given in Table 26. The plants were worst affected at 25 and 30 me/l and they showed lower plant height in comparison to other levels and control. The effects of these levels (5,10,15,20 me/l and control) were not statistically different from each other.

4.2.2.2 Effect on number of leaves/plant

There was decrease in number of leaves with the

Table 26 : Effect of bicarbonate levels on pseudostem height (cm), number of leaves and pseudostem diameter (mm) of Basrai banana.

Treatments	Days after planting					
	60	120	180	240	300	360
Pseudostem height (cm)						
B ₀	26.15	46.50	72.67	91.30	98.90	101.00
B ₁	25.83	46.90	71.40	90.15	97.18	100.00
B ₂	25.50	45.50	68.00	88.08	94.00	96.50
B ₃	24.67	43.50	65.50	81.30	88.50	89.50
B ₄	24.00	40.00	61.30	74.50	84.00	85.00
B ₅	23.50	38.50	53.00	65.00	67.00	67.00
B ₆	22.00	34.33	47.50	55.00	55.00	55.00
S.E.†	0.99	1.65	4.21	7.00	5.46	5.49
C.D.	2.92	4.87	12.42	20.65	16.12	16.21
Number of leaves						
B ₀	6.33	11.00	14.33	16.33	18.33	18.67
B ₁	6.00	11.00	14.33	16.67	18.33	18.33
B ₂	5.67	10.33	14.00	15.33	15.67	15.33
B ₃	5.33	10.67	11.67	13.00	14.00	14.00
B ₄	5.00	6.67	10.67	10.33	10.67	10.67
B ₅	4.33	6.67	9.33	10.00	10.00	10.00
B ₆	4.00	6.00	8.00	8.00	8.33	8.00
S.E.†	0.56	0.91	1.24	1.45	1.73	1.80
C.D.	1.65	2.68	3.66	4.28	5.10	5.32
Pseudostem diameter (mm)						
B ₀	32.67	46.00	62.00	86.00	94.00	98.00
B ₁	32.67	45.50	62.00	84.50	94.00	97.00
B ₂	31.33	43.33	60.50	82.50	92.00	95.00
B ₃	30.33	40.00	58.30	78.00	83.00	84.50
B ₄	28.96	37.00	53.50	70.50	78.00	78.50
B ₅	25.67	33.33	48.00	60.00	63.00	63.00
B ₆	22.50	29.50	39.00	43.00	45.00	45.00
S.E.†	1.54	2.32	3.34	3.42	3.67	3.83
C.D.	4.67	6.85	9.86	10.09	10.83	11.30

increase in bicarbonate level. The treatment effects were conspicuously seen from 120 days after planting. The bicarbonate levels 5,10,15 me/l and control were statistically similar and superior to 20,25 and 30 me/l. The effects of 20,25 and 30 me/l were not different from each other.

4.4.2.3 Effect on stem diameter.

From Table 26 it is evident that the plants under control and bicarbonate level 5,10 me/l and control were similar and superior to rest of the treatments. The effects of 15,20,25 and 30 me/l were conspicuous from 240 days onwards.

4.4.2.4 Effect on plant spread

It is evident from the Table 27 That bicarbonate levels upto 20 me/l did not affect significantly the plant spread. The effects of bicarbonate level 25 and 30 me/l were different from each other.

4.4.2.5 Effect on leaf area/plant

The total leaf area per plant (Table 27) decrease with the increase in bicarbonate level. The decline was more pronounced of 25 and 30 me/l. The leaf area of the plants treated with 5,10,15,20 me/l and control was statistically similar.

4.4.2.6 Effect on root length

Table 27 revealed that there was corresponding decrease in root length with increase in bicarbonate



Plate 23: Effect of soil bicarbonates on top growth of banana plant cv. Basrai (after 240 days of planting).

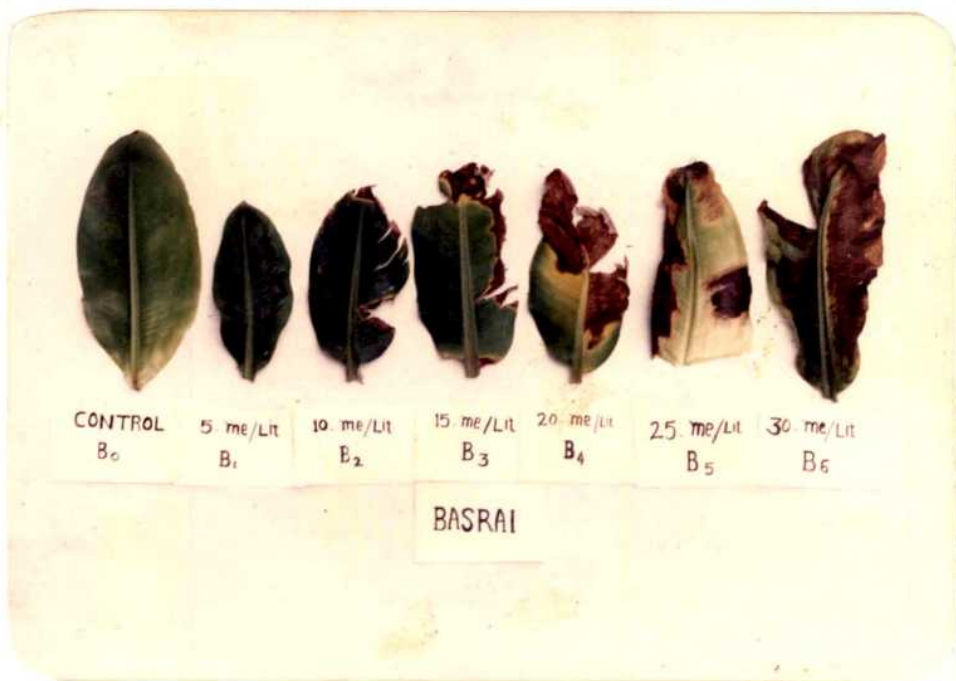


Plate 24: Leaf injury caused by bicarbonates cv. Basrai banana.

level. However extent of root length reduction was more pronounced at 25 and 30 me/l. The effects of these levels were also different from each other.

4.4.2.7 Effect on plant mortality.

The data regarding plant mortality are given in Table 27. The plants at bicarbonate level 5,10 and 15 me/l did not show any kind of mortality symptoms. The mortality symptoms were started from 15 me/l and after 180 days of planting.

Table 27 : Effect of bicarbonate levels on plant spread (cm), total leaf area (sq.m), root length (cm) and mortality of Basrai banana.

Treatments	Plant spread (cm)	Total leaf (Sq.m)	Root length (cm)	Mortality (%)
B ₀	72.66	8.42	89.50	00.00
B ₁	71.50	8.30	87.50	00.00
B ₂	70.50	8.12	86.00	00.00
B ₃	67.35	7.74	83.25	00.00
B ₄	61.50	6.92	79.50	12.50
B ₅	56.33	5.81	70.00	50.00
B ₆	49.80	4.80	61.50	75.00
S.E	4.08	0.55	2.31	-
C.D	11.94	1.62	6.81	-

4.4.2.8 Effect of fresh weight of whole plant

It is observed (Table 28) that there was decrease in fresh weight of whole plant with the increase in bicarbonate levels. The bicarbonate levels upto 20 me/l and control were not different from each other and superior to 25 and 30 me/l. The lowest fresh weight of whole plant was recorded at 30 me/l.

Table 28 : Effect of bicarbonate levels on fresh weight of whole plant (g), fresh and dry weight of top and root with rhizome of Basrai banana

Treat- ment	Fresh weight of whole plant(g)	Fresh weight of top (g)	Fresh weight of root +rhizome(g)	Dry weight of top(g)	Dry weight of root + rhizome(g)
B ₀	3100.0	1420.5	1645.5	650.5	838.0
B ₁	3030.0	1385.0	1605.0	618.5	825.5
B ₂	2900.0	1345.0	1555.00	555.5	789.0
B ₃	2750.5	1265.3	1485.1	515.00	680.0
B ₄	2500.0	1120.5	1379.5	480.0	630.0
B ₅	2120.0	1040.0	1080.0	425.0	550.0
B ₆	1920.7	938.5	982.2	402.5	419.5
S.E	204.0	103.6	100.8	47.2	55.3
C.D	601.9	305.5	297.3	139.2	163.0

4.4.2.9 Effect on fresh weight of top and root with rhizome

Top: It is observed from the data (Table 28) that the bicarbonate level 5,10,15,20 me/l and control were statistically not different from each other. These levels recorded more fresh weight of top of compared to 25 and 30 me/l. The effect of 25 and 30 me/l was not statistically different from each other.

Root with rhizome: The results presented in Table 28 showed that the decrease in fresh weight of root with rhizome was more pronounced at 25 and 30 me/l over control and other levels. The effects of 25 and 30 me/l were not different from each other.

4.4.2.10 Effect of dry weight of top and root with rhizome

Top: From the persual of the data (Table 28) it is evident that the bicarbonate levels 20,25 and 30 me/l produced lower dry weight of top as compared to control and rest of the treatments.

Root with rhizome: The bicarbonate levels upto 15 me/l and control were statistically similar and they recorded more dry weight as compared to 20,25 and 30 me/l. The effects of 20,25 and 30 me/l were not different from each other statistically.

4.5 Effect of sulphate levels on plant growth

The effect of different levels of sulphate, namely 0,7,14,21,28,35 and 42 me/l designated as sl_0 , sl_1 , sl_2 , sl_3 , sl_4 , sl_5 and sl_6 respectively are presented below.

4.5.1 Ardhapuri banana

4.5.1.1 Effect of plant height.

Periodic observations on the height of Ardhapuri plants under different sulphate levels are presented in Table 29. The adverse effects started at 28 me/l of sulphate level. The plants under 35 and 42 me/l were severely affected as compared to rest of the treatments. The effects of sulphate levels 7,14,21,28 me/l and control were statistically similar. The plants treated with 42 me/l of sulphate did not survive 240 days after planting.

4.5.1.2 Effect on number of leaves

With the increase in sulphate levels, increase in number of leaves per plant decreased (Table 29). Plants at sulphate level of 42 me/l could not produce leaves 240 days after planting. The sulphate levels 7,14,21 me/l and control were statistically similar and they were superior to sulphate levels 28 and 35 me/l in respect of number of leaves. the effects of sulphate

Table 29 : Effect of sulphate levels on pseudostem height (cm), number of leaves and pseudostem diameter (mm) of Ardhapuri banana.

Treatments	Days after planting					
	60	120	180	240	300	360
Pseudostem height (cm)						
SL ₀	29.12	49.50	75.30	94.80	105.00	110.00
SL ₁	27.38	48.30	75.00	93.12	103.50	108.00
SL ₂	28.50	44.50	71.08	89.50	100.08	102.50
SL ₃	28.00	40.15	67.32	85.38	94.50	96.32
SL ₄	27.67	39.50	63.28	78.03	80.30	81.00
SL ₅	25.67	35.25	57.50	63.36	65.00	65.00
SL ₆	21.00	31.63	53.15	56.15	-	-
S.E. _t	0.71	1.14	2.41	3.92	9.26	10.21
C.D.	2.09	3.63	7.11	11.56	27.33	30.13
Number of leaves						
SL ₀	6.33	11.33	14.00	17.00	18.33	18.33
SL ₁	6.00	11.00	13.67	15.67	17.67	17.67
SL ₂	5.33	10.00	12.67	15.00	16.00	16.00
SL ₃	5.00	10.00	12.00	13.67	14.00	14.00
SL ₄	5.00	8.66	10.00	11.33	11.67	11.67
SL ₅	4.33	7.00	9.00	10.00	10.00	10.00
SL ₆	4.00	6.00	6.33	6.66	-	-
S.E. _t	0.32	0.64	0.75	1.15	1.60	1.73
C.D.	0.94	1.89	2.21	3.39	4.72	5.11
Pseudostem diameter (mm)						
SL ₀	33.00	46.50	63.50	84.33	95.33	98.67
SL ₁	32.33	44.67	62.33	83.00	93.83	98.00
SL ₂	31.67	41.67	60.00	80.50	90.00	95.33
SL ₃	30.67	38.83	57.33	76.83	84.50	89.67
SL ₄	28.33	35.67	53.00	71.33	78.33	80.33
SL ₅	25.00	32.33	49.63	59.67	59.70	59.70
SL ₆	22.50	29.50	41.33	41.33	-	-
S.E. _t	1.41	2.32	3.47	2.06	2.44	2.98
C.D.	4.16	6.84	10.24	6.07	7.21	8.78

levels 28 and 35 me/l were not different from each other

4.5.1.3 Effect on stem diameter.

It is evident from Table 29, that the plants under control, sulphate levels 7 and 14 me/l recorded greater increase in the stem diameter than other sulphate levels.

The effects of 28 and 35 me/l were similar and they were significantly lower over control. The plants under sulphate level 42 me/l died 240 days of planting.

4.5.1.4 Effect on plant spread.

The plant spread under control, sulphate level 7, 14 and 21 me/l was statistically similar and they were produced large spread than those under other levels. The effects of 35 and 42 me/l were similar and showed severe reduction over previous treatments (table 30).

4.5.1.5 Effect on leaf area

The sulphate level 7, 14, 21, and 28 me/l and control were statistically similar with each other (Table 30). The effects of 35 and 42 me/l were similar and showed severe effect over control and sulphate level 7, 14, 21 and 28 me/l. The leaf area was recorded 240 days after planting for the plants treated at 42 me/l.

4.5.1.6 Effect on root length.

It is evident from Table 30 that the effects of sulphate levels 7 and 14 although similar with each other



Plate 25: Effect of soil sulphates on top growth of banana plant cv. Ardhapuri (after 210 days of planting).

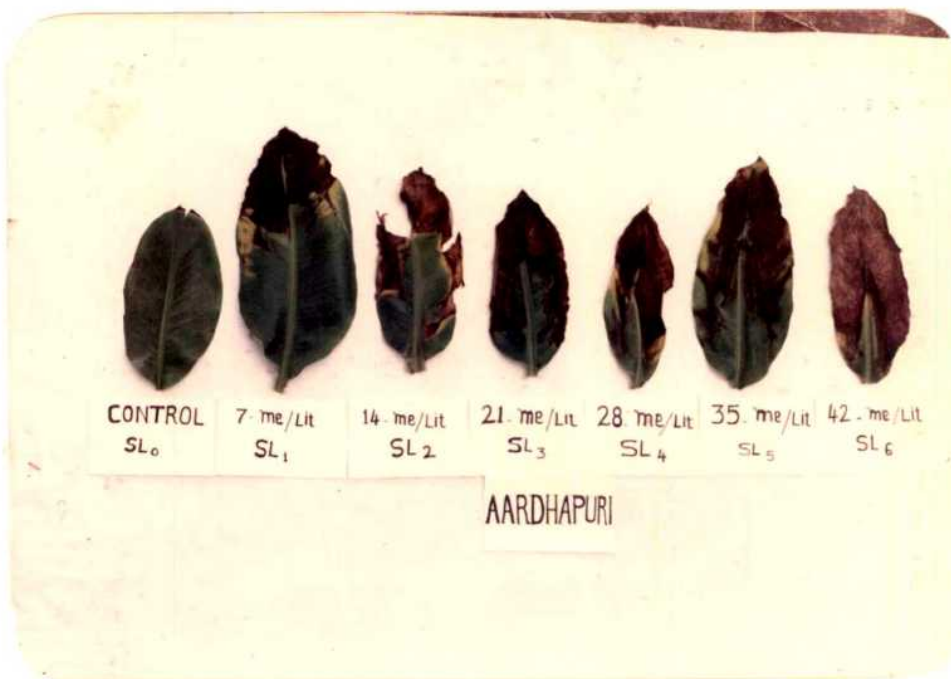


Plate 26: Leaf injury caused by sulphates cv. Ardhapuri banana.



Plate 27: Effect of soil sulphates on root growth of banana cv. Ardhapuri (after 240 days of planting).



Plate 28: Effect of soil sulphates on root growth of banana cv. Basrai (after 360 days of planting).

exhibited more root length than remaining higher sulphate levels. The lowest root length was at sulphate level of 42 me/l which was recorded at 240 days of planting.

Table 30 : Effect of sulphate levels on plant spread (cm) total leaf area (sq.m.) root length (cm) and per cent mortality of Ardhapuri banana

Treatments	Plant spread (cm)	Total leaf area (sq.m)	root length (cm)	Mortality (%)
SL ₀	87.12	9.36	91.50	00.00
SL ₁	85.38	9.08	89.80	00.00
SL ₂	82.28	8.79	86.00	00.00
SL ₃	76.33	8.14	81.38	12.50
SL ₄	70.78	7.49	79.20	25.00
SL ₅	58.43	6.68	74.80	75.00
SL ₆	48.33	5.33	67.20	100.00
S.E	4.63	0.69	4.53	-
C.D	13.67	2.05	13.37	-

4.5.1.7 Effect on plant mortality.

The data regarding plant mortality have been presented in Table 30. The plants under sulphate level 7 and 14 me/l did not showed any kind of mortality. Mortality symptoms started from sulphate level of 21 me/l

onwards after 60 days of planting. Plants were worst affected at sulphate level of 35 and 42 me/l. The plants at 42 me/l died 240 days of planting.

4.5.1.8. Effect on fresh weight of whole plant

It is evident from the Table 31 that a significant drop in fresh weight of whole plant was recorded at sulphate level 21,28,36 and 42 me/l. These levels produced lower fresh weight as compared to sulphate level 7 and 14 me/l. The fresh weight of the plant for the treatment of 42 me/l was recorded at 240 days of planting.

4.5.1.9 Effect on fresh weight of top and root with rhizome.

Top: A marked reduction in fresh weight of top for each level was recorded at 21,28,35 and 42 me/l. These levels produced lower fresh weight as compared to sulphate level 7,14 me/l and control (Table 31).

Root with rhizome: It is observed from the Table 31, that there was consistent fall in fresh weight of root with the increase in sulphate level. The fall in fresh weight of root with rhizome was statistically different from 21,28,35 and 42 me/l as compared to control and 14 me/l of sulphate level. The fresh weight of root with rhizome for the treatment 42 me/l was recorded at 240 days of planting.

Table 31 : Effect of sulphate levels on fresh weight of whole plant (g) fresh and dry weight of top and root with rhizome of Ardhapuri banana

Treat- ment	Fresh weight of whole plant(g)	Fresh weight of top (g)	Fresh weight of root +rhizome(g)	Dry weight of top(g)	Dry weight of root + rhizome(g)
SL ₀	3300.0	1500.5	1799.5	675.0	845.5
SL ₁	3200.5	1420.4	1780.1	640.0	836.5
SL ₂	3050.0	1405.1	1644.9	632.5	775.0
SL ₃	2826.3	1305.0	1121.3	587.5	715.0
SL ₄	2200.1	980.7	1219.5	445.0	575.0
SL ₅	1785.0	844.5	940.5	409.5	415.0
SL ₆	1650.0	760.6	889.4	345.0	420.0
S.E	129.4	33.1	59.8	23.8	32.8
C.D.	392.5	100.5	181.3	70.3	96.9

4.5.1.10 Effect on dry weight of top and root with rhizome

Top: From the perusal of the data (Table 31) it is evident that the decrease in dry weight of top at sulphate level 21, 28, 35 and 42 me/l was statistically different from 7 and 14 me/l and control. These levels recorded lower weight as compared to control, sulphate level 7 & 14 me/l

After 240 days of planting plants under treatment of 42 me/l were died.

Root with rhizome: It may be seen from data (Table 31) that with the increase in sulphate level there was decrease in dry weight of root with rhizome. The dry weight under sulphate levels 21,28,35 and 42 me/l was low as compared to control and other sulphate level. The dry weight was recorded at 240 days of planting.

4.5.2 Basrai banana:

4.5.2.1 Effect on pseudostem height

Periodic height observations of Basrai plants under different sulphate levels are presented in Table 32. A significant adverse effect was apparent from 120 days of planting. Plants at sulphate level 35 and 42 me/l were severely affected. The sulphate level 7,14 21,28 me/l and control were statistically similar with each other and they showed more height as compared to sulphate level 35 and 42 me/l.

4.5.2.2 Effect on number of leaves.

The data presented in Table 32 reveal that the sulphate level 7,14,21 me/l and control were statistically similar and these levels produced more number of leaves than sulphate levels 28,35 and 42 me/l. The effects of 35 and 42 me/l were not different from each other. A significant severe effect was observed 180 days after planting.

Table 32 : Effect of sulphate levels on pseudostem height (cm), number of leaves and pseudostem diameter (mm) of Basrai banana.

Treatments	Days after planting					
	60	120	180	240	300	360
Pseudostem height (cm)						
SL ₀	26.00	48.33	72.50	88.50	97.50	102.00
SL ₁	26.00	48.00	72.00	87.50	97.00	100.50
SL ₂	25.53	46.20	70.00	85.00	94.00	98.50
SL ₃	24.67	43.50	67.67	81.50	89.50	92.00
SL ₄	23.50	41.00	65.00	76.80	83.00	84.00
SL ₅	21.43	38.00	58.00	66.68	73.00	74.00
SL ₆	20.00	31.50	59.00	58.50	64.00	64.00
S.E. _t	0.81	1.48	2.25	2.96	3.52	3.88
C.D.	2.38	4.38	6.64	8.73	10.40	11.41
Number of leaves						
SL ₀	6.33	11.33	14.00	16.67	18.33	18.67
SL ₁	6.00	11.33	14.00	15.67	17.67	17.67
SL ₂	5.67	10.33	13.00	14.00	14.33	14.33
SL ₃	5.67	10.33	12.33	11.67	12.00	12.00
SL ₄	5.00	8.00	10.00	10.67	10.67	10.67
SL ₅	4.67	7.00	9.00	9.33	9.67	9.67
SL ₆	4.00	6.00	7.33	7.67	7.67	7.67
S.E. _t	0.50	0.98	1.69	1.77	2.37	2.41
C.D.	1.48	2.89	4.99	5.21	6.98	7.12
Pseudostem diameter (mm)						
SL ₀	32.00	44.00	62.83	83.67	95.33	97.50
SL ₁	31.67	43.83	62.33	82.67	94.67	97.00
SL ₂	30.83	42.33	61.00	78.00	93.00	95.00
SL ₃	29.00	40.00	58.67	73.33	88.00	90.33
SL ₄	27.50	39.00	53.00	66.33	82.00	83.50
SL ₅	25.00	36.50	50.00	61.00	70.00	70.00
SL ₆	22.50	32.50	41.50	43.50	46.50	46.50
S.E. _t	1.64	1.79	1.98	2.38	2.43	2.38
C.D.	4.98	5.43	6.00	7.21	7.36	7.22

4.5.2.3 Effect on pseudostem diameter.

It is evident from the data presented in Table 32 that the sulphate level 7,14,21 me/l and control showed greater increase in the stem diameter than rest of the levels. The increase in the stem diameter of plants started ; adversely affected from 120 days.

4.5.2.4 Effect on plant spread.

It is evident from table 33 that sulphate levels upto 21 me/l did not affect significantly the plant spread. The effects of sulphate level 35 and 42 me/l different from each other.

4.5.2.5. Effect on leaf area/plant

It is evident from the data (Table 34) that the sulphate levels 7,14,21 me/l and control produced more leaf area as compared to rest of the levels. The decline was more pronounced at sulphate level 35 and 42 me/l. These levels (28,35 and 42 me/l sulphate level) had lower leaf area than other sulphate levels and control.

4.5.2.6 Effect on root length

It is seen from the data (Table 33) that the sulphate levels, 7,14,21,28 me/l and control were statistically similar with each other. The root length at 42 me/l of sulphate level was the lowest than all other treatments.

4.5.2.7 Effect on plant mortality

The data regarding plant mortality are presented in table



Plate 29: Effect of sulphates on top growth of banana plants cv. Basrai (After 240 days of planting).

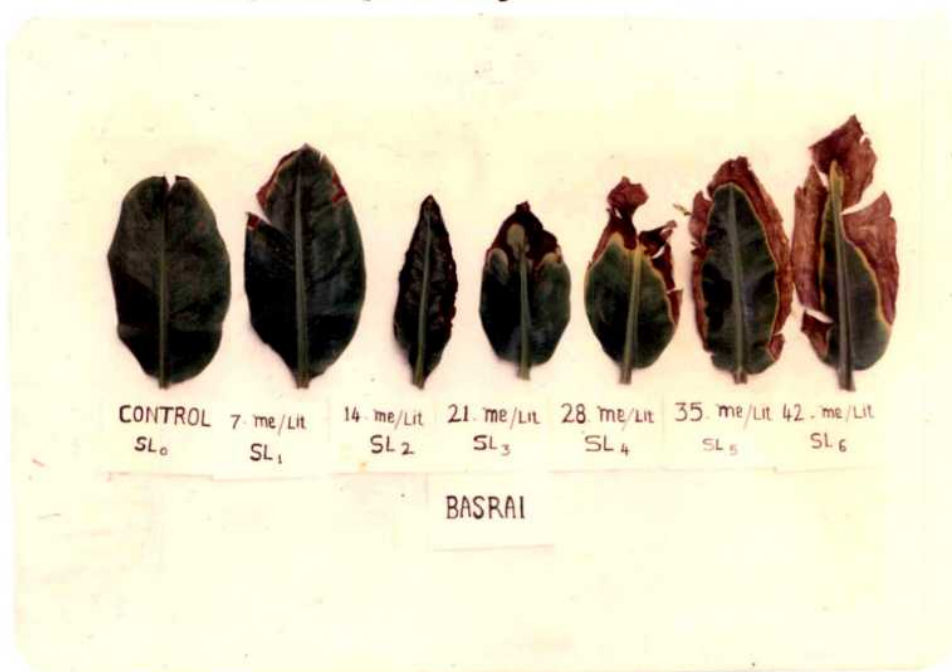


Plate 30: Leaf injury caused by soil sulphates cv. Basrai banana.

33 and shown graphically in Fig. 1. Basrai plants were worst affected of sulphate level 35 and 42 me/l. The adverse effects of sulphate levels started from 180 days onwards after planting. The sulphate level 7,14,21 me/l and control did not show any kind of mortality.

Table 33 : Effect of sulphate on plant spread (cm), total leaf area (sq.m), root length (cm.) and per cent mortality of Basrai banana

Treatment	Plant spread (cm)	Total leaf area(sq.m)	Root length (cm)	Mortality (%)
SL ₀	75.36	8.33	91.00	00.00
SL ₁	72.43	8.09	88.30	00.00
SL ₂	70.12	7.78	85.00	00.00
SL ₃	66.36	7.22	80.30	12.50
SL ₄	61.50	6.79	78.20	25.00
SL ₅	53.22	5.97	74.20	50.00
SL ₆	41.28	4.09	70.50	75.00
S.E	3.25	0.42	4.75	-
C.D	9.58	1.23	14.03	-

4.5.2.8 Effect of fresh weight of whole plant

The data on fresh weight of whole plant of affected by various sulphate levels are presented in Table 34. A sharp drop in fresh weight of whole plant was

recorded at sulphate level 35 and 42 me/l and these levels showed lower fresh weight of above plant than other treatments. The fresh weight of whole plant at sulphate level 7,14, 21 me/l and control were statistically significant.

Table 34 : Effect of sulphate levels on fresh weight of whole plant (g), fresh and dry weight of top and root with rhizome of Basrai banana

Treat ment	Fresh weight of whole plant(g)	Fresh weight of top (g)	Fresh weight of root+ rhizome(g)	Dry weight of top(g)	Dry weight of root + rhizome(g)
SL	3100.0	1420.5	1679.5	653.5	808.0
SL	3010.0	1340.0	1670.0	644.0	782.5
SL	2940.5	1310.0	1630.5	605.0	760.0
SL	2750.0	1170.5	1579.5	535.0	722.0
SL	2350.0	1100.0	1250.0	507.0	600.0
SL	1880.0	830.0	1050.0	382.0	505.0
SL	1705.3	700.5	1004.8	320.0	480.0
S.E	117.2	54.8	77.7	41.1	33.6
C.D	355.7	166.3	235.8	121.2	99.2

4.5.2.9 Effect of fresh weight of top and root with rhizome

Top: It is evident from data (Table 34) that the

sulphate level 7,14 me/l and control were statistically significant from each other and superior to 21,28,35 and 42 me/l

Root with rhizome: On perusal of the data (Table 34), it is seen that there was no significant difference between control and sulphate levels 7,14 me/l, whereas sulphate levels 21,28,35 and 42 me/l produced lower root weight than other levels which were also different from each other.

4.5.2.10 Effect on dry weight of top and root with rhizome.

Top: The dry weight of top decreased with the increase in sulphate level (Table 34). The dry weight of top at sulphate level 35 and 42 me/l were lower than control and other levels. The sulphate levels upto 21 me/l were similar with each other.

Root with rhizome: It may be seen from the data (Table 34) that the root weight was severely affected at sulphate level 35 and 42 me/l as compared to control and other sulphate levels, which were not different from each other. The sulphate levels 7,14,21 me/l and control were statistically similar with each other.

4.6. Effect of exchangeable sodium percentage on the chemical composition of banana.

4.6.1 Ardhapuri banana

The data on the chemical composition of leaves and roots as affected by various ESP levels are presented in Table 35 and 36.

4.6.1.1 Chlorophyll

The total chlorophyll content of leaves (Table 35) decreased with the successive increase in ESP levels.

The decline was significant from ESP 24 onwards over control, ESP 8 and 16. The effect was more drastic and ESP 40 and 48.

4.6.1.2 Nitrogen

Leaves : It is observed from Table 35 that N content of leaves increased consistently with the increase in ESP level. The N content was significantly increased at and above ESP 16 over control while it was drastically reduced at ESP 48.

Root: The root-N showed decreasing trend with increasing ESP level. The ESP 40 and 48 recorded low N content that 8,16,24 level of ESP and control.

4.6.1.3 Phosphours

Leaves: The P content (Table 35) of leaves decreased with the increase in ESP. The decrease was more pronounced at ESP 40 and 48.

Table 35 : Effect of ESP on the chlorophyll content (mg/g) of leaves, and macronutrient content (per cent) of leaves and roots of Ardhapuri banana.

Treatments	Chlorophyll (mg/g)			Per cent of					
	'a'	'b'	Total N	P	K	Ca	Mg	Na	
Leaves									
Control	11.42	11.49	22.91	2.11	0.51	3.03	0.98	0.48	0.21
ESP ₈	11.42	11.51	22.93	2.11	0.50	3.05	0.96	0.49	0.23
ESP ₁₆	11.18	11.29	22.47	2.19	0.48	2.87	0.89	0.45	0.33
ESP ₂₄	10.02	11.11	21.13	2.30	0.45	2.65	0.80	0.40	0.48
ESP ₃₂	9.90	10.00	19.90	2.34	0.43	2.47	0.67	0.34	0.59
ESP ₄₀	8.39	8.62	17.01	2.39	0.41	2.30	0.55	0.26	0.70
ESP ₄₈	7.83	7.94	15.77	2.16	0.38	2.08	0.45	0.20	0.81
S.E.±	0.52	0.16	0.23	0.10	0.02	0.13	0.07	0.02	0.07
C.D.	1.53	0.46	1.93	0.29	0.07	0.38	0.21	0.07	0.21
Roots									
Control				2.63	0.32	2.25	0.61	0.28	0.41
ESP ₀₈				2.52	0.32	2.23	0.58	0.28	0.48
ESP ₁₆				2.49	0.30	2.18	0.54	0.25	0.53
ESP ₂₄				2.49	0.26	2.03	0.48	0.23	0.60
ESP ₃₂				2.36	0.25	1.87	0.39	0.21	0.71
ESP ₄₀				2.29	0.22	1.71	0.31	0.20	0.79
ESP ₄₈				2.24	0.19	1.57	0.26	0.17	0.84
S.E.±				0.09	0.03	0.09	0.04	0.02	0.02
C.D.				0.27	0.09	0.26	0.14	0.05	0.06

Roots: The P content of roots was significantly low at highest level of ESP than control and other ESP levels.

4.6.1.4 Potassium

Leaves: There was decrease in K content (Table 35) of leaves with the increase in ESP. The decrease was more pronounced at the ESP 32, 40 and 48. These levels showed low K content as compared to control and other ESP levels.

Roots: Root-K also decreased with the increase in ESP. It was significantly low at higher ESP levels (i.e. at ESP level 32 onwards) over control, ESP 8, 16 and 24.

4.6.1.5 Calcium

Leaves: In general, there was decrease in the Ca content of leaves with the increase in ESP (Table 35). The Ca content of leaves was high at ESP 8 and control than other ESP levels.

Roots: The Ca content of roots significantly declined from ESP 16 control than other ESP levels.

4.6.1.6 Magnesium

Leaves: Table 35 showed that the ESP 8 and control were similar and recorded more Mg content in leaves than other ESP levels.

Roots: The Mg content of roots was significantly reduced at and above ESP 24 as compared to control and ESP 8 and 16.

4.6.1.7 Sodium

Leaves: The Na content (Table 35) of leaves increased with successive increase in ESP levels. A significantly more Na content was recorded from ESP 24 onwards.

Roots: Root Na increased with the increase in ESP level. A significantly more Na content of roots was observed under all ESP levels as compared to control.

4.6.1.8 Ca: Na

Leaves: There was a significant decrease in Ca:Na with each increment level of ESP over control and previous lower level (Table 36).

Roots: The decrease in Ca: Na with the increase in ESP levels was also seen in roots. Plants under control had significantly high ratio than other ESP levels except ESP

4.6.1.9 Ca+Mg+K : Na

Leaves: The Ca + Mg + K : Na decreased significantly with successive increase in ESP level over control except ESP 8 and 16 (Table 36).

Roots: There was consistent decline in Ca + Mg + K : Na with the increase in ESP. The decline was more pronounced at higher ESP levels.

4.6.1.10 Zinc

Leaves: It is evident from the data (Table 36) that with the increase in ESP levels there was decrease in Zn content of leaves. The Zn content of the leaves was significantly decreased from ESP 24 and above.

Table 36 : Effect of ESP on Ca:Na and Ca+Mg+K:Na and micro-nutrient content^(ppm) of leaves and roots of Ardhapuri banana.

Treatments	Ca:Na	Ca+Mg+K:Na	ppm			
			Zn	Fe	Mn	Cu
Leaves						
Control	4.60	22.05	45.83	156.00	504.00	29.00
ESP8	4.33	21.28	45.98	153.00	400.00	28.75
ESP16	3.07	15.25	42.20	140.00	385.00	30.12
ESP24	2.28	11.03	38.40	124.00	363.00	31.20
ESP32	1.33	6.56	34.00	114.00	335.00	31.20
ESP40	0.98	5.63	32.18	103.00	313.00	30.10
ESP48	0.65	4.22	31.19	95.00	282.00	31.20
S.E. _t	0.54	2.45	2.19	18.38	24.76	0.84
C.D.	1.60	7.23	6.31	54.21	73.04	N.S.
Roots						
Control	1.49	7.66	89.04	290.00	689.00	35.30
ESP8	1.21	6.44	91.28	284.00	684.00	36.75
ESP16	1.02	5.60	85.17	270.00	668.00	32.10
ESP24	0.80	4.57	76.00	252.00	649.00	29.20
ESP32	0.55	3.48	64.00	228.00	631.00	22.13
ESP40	0.39	2.81	55.38	208.00	589.00	21.03
ESP48	0.30	2.38	48.36	187.00	568.00	18.38
S.E. _t	0.17	0.71	5.52	12.99	14.36	4.13
C.D.	0.50	2.11	16.27	38.31	42.36	12.17

Roots: The Zn content of roots was high under control plants than other ESP levels.

4.6.1.11 Iron

Leaves: The data presented in Table 36 showed that the Fe content of leaves decreased with the increase in ESP. The Fe content was significantly low at ESP 40 and 48 than control and other treatments.

Roots: The Fe content of roots was significantly reduced from ESP 24 onwards over control.

4.6.1.12 Manganese

Leaves: The Mn content of leaves (Table 36) of the ESP 32,40 and 48 was significantly lower as compared to control.

Roots: There was consistent decrease in Mn content of roots with the increase in ESP levels. The decrease was more pronounced at ESP 48.

4.6.1.13 Copper.

Leaves: The Cu content of leaves (Table 36) did not differ significantly due to various ESP levels.

Roots: The Cu content of roots was low at the higher levels of ESP (i.e. of ESP 32,40 and 48) than control and Esp 8,16 and 24.

4.6.2 Basrai banana.

The data pertaining to the chemical composition of leaves and roots as affected by various ESP levels are presented in Table 37 and 38.

4.6.2.1 Chlorophyll.

It is evident from the data (Yable 37) that the increase in ESP level decreased the total chlorophyll content of leaves. The total chlorophyll content was significantly low at and above ESP 24 and reducing effect was more pronounced at ESP 48.

4.6.2.2 Nitrogen.

Leaves: The N content (Table 37) of leaves increased with the increase in ESP level upto ESP 40, beyond that limit it was reduced.

Roots: The N content of roots at ESP 32, 40 and 48 was significantly low than control, while the ESP 8, 16 and 24 were similar with each other.

4.6.2.3 Phosphorus.

Leaves: The P content (Table 37) of leaves decreased with the increase in ESP level. It was high at ESP 8 and 16 as compared to other levels and control.

Roots: The P content of roots was also significantly low at the higher levels of ESP (i.e. at ESP 40 and 48) as compared to rest of the treatments.

4.6.2.4 Potassium

Leaves: There was significant reduction in the K content (Table 37) of leaves with each increase in ESP level over control.

Roots: Root-K decreased with the increase in ESP LEVEL. A significant decline was observed from ESP 24 onwards.

Table 37 ;Effect of ESP on chlorophyll content (mg/g) of leaves and micronutrient content (per cent) of leaves and roots of Basrai banana.

Treatment	Chlorophyll (mg/g)			Per cent					
	'a'	'b'	Total	N	P	K	Ca	Mg	Na
Leaves									
Control	9.69	9.81	19.50	2.05	0.49	3.04	0.89	0.45	0.20
ESP ₈	9.61	9.71	19.31	2.07	0.51	3.06	0.88	0.45	0.23
ESP ₁₆	9.47	9.58	19.05	2.15	0.53	3.01	0.86	0.47	0.33
ESP ₂₄	9.37	9.50	18.89	2.22	0.48	2.68	0.79	0.38	0.43
ESP ₃₂	9.01	9.11	18.12	2.20	0.37	2.42	0.69	0.31	0.52
ESP ₄₀	8.09	8.20	16.29	2.11	0.31	2.21	0.51	0.26	0.59
ESP ₄₈	7.69	7.79	15.48	2.07	0.30	1.97	0.39	0.19	0.68
S.E. $\pm$	0.13	0.17	0.28	0.06	0.02	0.14	0.05	0.02	0.07
C.D.	0.38	0.51	0.84	0.18	0.06	0.42	0.16	0.06	0.21
Roots									
Control				2.69	0.30	2.19	0.61	0.30	0.38
ESP ₀₈				2.64	0.38	2.23	0.61	0.28	0.44
ESP ₁₆				2.52	0.30	2.11	0.53	0.24	0.50
ESP ₂₄				2.46	0.27	2.03	0.48	0.21	0.60
ESP ₃₂				2.31	0.25	1.91	0.43	0.18	0.74
ESP ₄₀				2.18	0.24	1.67	0.30	0.16	0.83
ESP ₄₈				2.08	0.21	1.49	0.21	0.16	0.92
S.E. $\pm$				0.07	0.01	0.06	0.04	0.03	0.03
C.D.				0.23	0.04	0.19	0.11	0.09	0.09

4.6.2.5 Calcium.

Leaves: The data presented in Table 37 showed that the Ca content of leaves was high under control as compared to all ESP levels.

Roots: The Ca content of roots was significantly low at ESP 32,40 and 48 as compared to ESP 8,16,24 and control.

4.6.2.6 Magnesium.

Leaves: The Mg content of leaves (Table 37) decreased with the increase in ESP. It was significantly low at ESP 24 and above. There was also significant difference between the treatment ESP 40 and 48.

Roots: There was significant reduction in root-Mg with each increment in ESP level above ESP 24.

4.6.2.7 Sodium

Leaves: The Na content (Table 37) of leaves increased with the increase in ESP levels. A significantly more Na content was recorded at all ESP levels over control.

Roots: Root Na increased with the increase in ESP levels.

A significant increase in Na content of roots was observed at ESP 16 onwards.

4.6.2.8 Ca:Na

Leaves: There is a corresponding decrease (Table 38) in leaf Ca:Na with the increase in ESP. The ESP 8,16 and control had significantly higher over rest of the treatments.

Roots: A progressive decline in the Ca: Na with the increase in ESP was observed. All the treatments showed significant differences with successive increase in level of ESP except ESP 8 and 16.

4.6.2.9 Ca + Mg + K : Na.

Leaves: A corresponding decrease (Table 38) in Ca + Mg + K : Na with the increase in ESP was recorded. The ESP 8,16 and control were significantly superior to rest of the ESP levels.

Roots: A consistent decrease in Ca + Mg + K : Na was observed with successive increase in ESP. All treatments differed significantly with each other in all regards except ESP 8 and 16.

4.6.2.10 Zinc.

Leaves: From the data (Table 38) it is seen that Zn content of leaves was high under control and ESP 8 than all ESP levels.

Roots: The Zinc content of roots of ESP 40 and 48 was significantly low as compared to control and other ESPs.

4.6.2.11 Iron

Leaves: It is evident from the data (Table 38) that there was significant decline in Fe content of leaves at and above ESP 24. The difference between control, ESP 8 and 16 was non significant but ESP 32, 40 and 48 differed with each other.

Table 38 : Effect of ESP on Ca:Mg and Ca+Mg+K:Na and micronutrient content^(ppm) of leaves and roots of Basrai banana.

Treatments	Ca:Na	Ca+Mg+K:Na	ppm			
			Zn	Fe	Mn	Cu
Leaves						
Control	4.45	21.90	42.34	149.00	401.00	26.00
ESP8	3.52	19.08	42.74	144.00	395.00	26.00
ESP16	2.61	13.15	39.23	137.00	392.00	24.00
ESP24	1.83	8.95	31.00	121.00	385.00	23.00
ESP32	1.32	6.57	29.41	111.00	383.00	20.00
ESP40	0.86	5.00	24.21	103.00	373.00	17.00
ESP48	0.57	3.75	21.86	95.00	365.00	17.00
S.E.†	0.65	3.06	1.79	1.06	11.89	4.08
C.D.	1.93	9.03	5.29	31.30	N.S.	N.S.
Roots						
Control	1.60	8.16	92.21	283.00	678.00	30.90
ESP8	1.38	7.04	87.02	280.00	671.00	30.60
ESP16	1.06	5.76	75.30	268.00	655.00	28.40
ESP24	0.80	4.53	74.00	251.00	625.00	26.90
ESP32	0.58	3.40	64.21	232.00	606.00	26.00
ESP40	0.36	2.56	54.00	209.00	568.00	23.40
ESP48	0.22	2.02	43.18	178.00	534.00	20.10
S.E.†	0.55	0.86	5.83	10.99	12.96	3.75
C.D.	1.63	2.54	17.21	32.41	38.09	N.S.

4.6.2.12 Manganese.

Leaves: The Mn content of leaves (Table 38) was high at ESP 8 and control, but it was non-significant with each other for all the treatments.

Roots: A significant decrease in Mn Content of roots was recorded from ESP 24 and above. The effect was more pronounced at ESP 48.

4.6.2.13 Copper.

Leaves: There was a decrease in Cu content (Table 38) of leaves with the increase in ESP. The decreasing effect was more sharp at ESP 40 and 48.

Roots: The Cu content of roots was declined with every incremental level over initial ESP levels.

4.7 Effect of salinity on the physiological and Chemical composition of banana plant

4.7.1 Ardhapuri banana.

The data regarding chemical composition of leaves and roots as affected by salinity levels are presented in Table 39 and 40.

4.7.1.1 Chlorophyll.

From the data (Table 39) it is evident that the total chlorophyll content of leaves declined with the increasing salinity levels. The decrease was more Pronounced at 15 and 18 dsm⁻¹.

4.7.1.2 Nitrogen

Leaves: It was interesting to note that with increasing

salinity levels, N content of leaves decreased consistently. But it did not significantly differ due to various salinity levels.

Roots: The N content in roots was found to be declined with increasing level of salinity. The decline was significant from 9 dsm^{-1} onwards over control and other levels. The lowest salinity treatment indicated significantly higher N.

4.7.1.3 Phosphorus.

Leaves: From the data (Table 39) it is seen that P content was lower at higher salinity levels (i.e. at 15 and 18 dsm^{-1}) as compared to control.

Roots: It is evident from the data that P content of roots was also significantly declined from 9 dsm^{-1} onwards. Low P content was observed at higher salinity levels as compared to control and lower levels (i.e. at 3 and 6 dsm^{-1})

4.7.1.4 Potassium

Leaves: In general, There was decrease in K content of leaves with the increase in salinity. The K content of all salinity levels was low as compared to control (Table 39).

Roots: The K content of leaves declined significantly at and above 12 dsm^{-1} over control, 3, 6 and 9 dsm^{-1} .

4.7.1.5 Calcium

Leaves: The Ca content (Table 39) of leaves significantly

Table 39 :Effect of salinity on chlorophyll content (mg/g) of leaves and macromutrient content (percent .) of leaves and roots of Ardhapuri banana.

Treatment	Chlorophyll (mg/g)			Per cent					
	'a'	'b'	Total	N	P	K	c	Mg	Na
Leaves									
S ₀	11.39	11.48	22.87	2.09	0.49	3.03	0.97	0.49	0.21
S ₁	11.34	11.46	22.87	2.09	0.46	2.03	0.92	0.46	0.23
S ₂	11.19	11.35	22.54	1.98	0.45	2.89	0.87	0.44	0.29
S ₃	10.93	11.23	22.16	1.88	0.42	2.69	0.82	0.41	0.38
S ₄	9.79	9.91	19.70	1.78	0.37	2.43	0.70	0.35	0.45
S ₅	9.03	9.13	18.16	1.72	0.34	2.21	0.63	0.31	0.54
S ₆	8.78	8.90	17.78	1.69	0.31	2.11	0.58	0.25	0.68
S.E.†	0.05	0.04	0.09	0.14	0.03	0.13	0.04	0.01	0.02
C.D.	0.14	0.11	0.28	N.S.	0.09	0.33	0.11	0.05	0.07
Roots									
S ₀				2.63	0.31	2.27	0.62	0.29	0.38
S ₁				2.66	0.31	2.27	0.62	0.29	0.41
S ₂				2.54	0.30	2.21	0.54	0.26	0.48
S ₃				2.46	0.28	2.14	0.46	0.21	0.55
S ₄				2.39	0.25	1.92	0.39	0.19	0.62
S ₅				2.35	0.23	1.83	0.35	0.17	0.70
S ₆				2.31	0.21	1.68	0.30	0.16	0.73
S.E.†				0.05	0.01	0.09	0.12	0.01	0.06
C.D.				0.16	0.04	0.27	N.S.	0.05	0.18

decreased at and above 12 dsm^{-1} over control, 3,6 and 9 dsm^{-1} . In general, a decreasing trend in Ca content was recorded with increasing salinity levels.

Roots: It is evident from the data that increase in salinity levels 3,6 dsm^{-1} and control showed more Ca than other treatments.

4.7.1.6 Magnesium

Leaves : It is observed from the data (Table 39) that the Mg content of leaves decreased with the increased salinity. The plants under control showed more Mg content than all other treatments. The salinity levels of 15 and 18 dsm^{-1} were also different from each other.

Roots: There was significant fall in the Mg content of roots from 9 dsm^{-1} onwards as compared with control, 3 and 6 dsm^{-1} .

4.7.1.7 Sodium.

Leaves: It is observed from the data (Table 39) that the Na content of leaves increased with the increase in the levels of salinity. It was significantly more at the level of 12,15 and 18 dsm^{-1} than other salinity levels.

Roots: The Na content of roots also increased with the increase in salinity. The sodium content was highest in the 18 dsm^{-1} level level followed by 15 dsm^{-1} .

4.7.1.8 Zinc.

Leaves: The Zn content of leaves was high in the control

Table 40 : Effect of salinity on micronutrient content (ppm) of leaves and roots of Ardhapuri banana.

Treatments	ppm			
	Zn	Fe	Mn	Cu
Leaves				
S ₀	46.01	159.00	404.00	29.10
S ₁	45.60	164.00	408.00	28.00
S ₂	39.37	137.00	413.00	25.12
S ₃	36.52	120.00	401.00	23.10
S ₄	33.00	108.00	363.00	22.04
S ₅	30.32	97.00	348.00	21.00
S ₆	29.32	88.00	323.00	20.67
S.E.†	3.82	15.00	4.78	3.06
C.D.	11.28	44.25	14.11	N.S.
Roots				
S ₀	89.04	292.00	685.00	36.00
S ₁	92.00	280.00	686.00	34.75
S ₂	90.17	266.00	678.00	31.20
S ₃	86.13	249.00	669.00	32.00
S ₄	79.17	228.00	644.00	28.17
S ₅	66.31	194.00	621.00	23.50
S ₆	54.19	173.00	587.00	22.17
S.E.†	2.45	16.13	6.20	5.37
C.D.	7.23	48.10	18.30	N.S.

and 3 dsm⁻¹ level as compared to rest of the treatments.

Roots: The Zn content of roots was significantly reduced from 12 dsm⁻¹ onwards. The reducing effect was more pronounced at 18 dsm⁻¹ level.

4.7.1.9 Iron.

Leaves: The Fe content of roots at the salinity levels 15 and 18 dsm⁻¹ was significantly lower than other levels.

Roots : The Fe content of roots at the salinity levels 15 and 18 dsm⁻¹ was significantly lower than other levels.

4.7.1.10 Manganese.

Leaves: The Mn content (Table 40 of leaves under control and salinity levels of 3, 6 and 9 dsm⁻¹ was significantly high as compared to other treatments.

Roots: The Mn content of roots was low in all salinity levels except 3 dsm⁻¹ and control. The salinity levels 3 and 6 dsm⁻¹ were also different from each other.

4.7.1.11 Copper.

Leaves: The Cu content of leaves did not differ significantly due to various salinity treatments (Table

Roots: In general, with the increase in salinity level, decrease in copper content was observed but root Cu did not differ significantly due to various salinity treatments

4.7.2 Basrai banana

The data regarding chemical composition of leaves

and roots as affected by salinity levels are given in Table 41 and 42. The chemical composition of leaves and roots for the salinity level 18 dsm^{-1} was recorded 300 days after planting.

4.7.2.1 Chlorophyll.

From the data (Table 41) it is seen that with the successive increase in salinity level there was decrease in the total chlorophyll content in leaves, but the salinity levels $3, 6, 9 \text{ dsm}^{-1}$ and control were statistically similar with each other.

4.7.2.2 Nitrogen.

Leaves: There was no significant difference in N content of leaves due to various ESP treatments (Table 41).

Roots: The N content of roots declined with increasing level of salinity. The salinity levels $3, 6 \text{ dsm}^{-1}$ and control were statistically similar and exhibited higher root N than other levels.

4.7.2.3 Phosphorus.

Leaves: There was significant difference between treatment at and above 12 dsm^{-1} of salinity levels (Table 41). Lowest P content was recorded at salinity level 18 dsm^{-1} .

Roots: The data presented in Table 41 show that there was a significant decrease in P content of roots from 12 dsm^{-1} onwards over control.

4.7.2.4 Potassium.

Leaves: In general, there was decrease in K content of

Table 41: Effect of salinity on chlorophyll content (mg/g) of leaves and macronutrient content (per cent) of leaves and roots of Basrai banana.

Treatment	Chlorophyll (mg/g)			Per cent					
	'a'	'b'	Total	N	P	K	Ca	Mg	Na
Leaves									
S ₀	9.71	9.82	19.53	2.05	0.50	3.03	0.89	0.47	0.21
S ₁	9.65	9.75	19.40	2.07	0.48	2.97	0.92	0.51	0.24
S ₂	9.54	9.56	19.10	2.11	0.44	2.91	0.84	0.43	0.32
S ₃	9.34	9.44	18.78	2.17	0.41	2.71	0.82	0.34	0.41
S ₄	8.78	8.89	17.67	2.32	0.35	2.38	0.73	0.30	0.59
S ₅	8.10	8.21	16.31	2.35	0.31	2.24	0.69	0.29	0.70
S ₆	7.49	7.61	15.10	2.26	0.29	2.13	0.61	0.29	0.72
S.E.†	0.14	0.15	0.30	0.11	0.02	0.07	0.05	0.05	0.03
C.D.	0.42	0.43	0.89	0.32	0.07	0.22	0.16	0.15	0.09
Roots									
S ₀				2.69	0.30	2.21	0.60	0.29	0.37
S ₁				2.63	0.29	2.21	0.59	0.29	0.40
S ₂				2.49	0.27	2.13	0.56	0.28	0.47
S ₃				2.43	0.24	2.03	0.51	0.26	0.56
S ₄				2.31	0.23	1.96	0.46	0.23	0.70
S ₅				2.29	0.20	1.80	0.38	0.21	0.75
S ₆				2.22	0.19	1.56	0.26	0.20	0.79
S.E.†				0.08	0.02	0.06	0.02	0.01	0.07
C.D.				0.24	0.06	0.18	0.07	0.04	0.21

leaves with the increase in salinity. At higher levels of salinity (15 and 18 dsm^{-1} the K content of leaves was low than other salinity levels and control (Table 41).

Roots: The K content of roots was significantly low in all salinity levels than control and 3 dsm^{-1} . The effect was more pronounced at 18 dsm^{-1} .

4.7.2.5 Calcium.

Leaves: The Ca content (Table 41) of leaves significantly decrease at and above 12 dsm^{-1} . In general, a decreasing trend in Ca content was recorded with increasing salinity levels.

Roots: It is evident from the data that with the increase in salinity there was decrease in Ca content of roots. The salinity level 3, dsm^{-1} and control recorded more Ca than rest of the treatments.

4.7.2.6 Magnesium.

Leaves: The data presented in Table 41 indicate that Mg content of leaves decreased with the increase in salinity. The Mg content of leaves significantly decreased from 12 dsm^{-1} onwards as compared to control.

Roots: The plants under control and 3 dsm^{-1} recorded higher root-K than those plants under rest of the treatment.

4.7.2.7 Sodium

Leaves: It is observed from the Table 41 that the Na

content of leaves increased with increase in salinity level. It was significantly more at the level of 12, 15 and 18 dsm^{-1} than other levels of salinity and control.

Roots: The Na content of roots also increased with the increase in salinity. The Na content was highest in the 18 dsm^{-1} level followed by 15 dsm^{-1} .

4.7.2.8 Zinc

Leaves: The data presented in Table 42 showed that the Zn content of leaves was high in control plants than all other salinity levels.

Roots: The Zn content of roots declined with increasing level of salinity. It was significantly lower at and above 9 dsm^{-1} over control, 3 and 6 dsm^{-1} .

4.7.2.9 Iron.

Leaves: A decrease in Fe content (Table 42) of leaves with the increase in salinity was observed. The Fe content of leaves was low at higher salinity levels (i.e. at 15 and 18 dsm^{-1}) as compared to control and previous levels.

Roots: The Fe content in roots was significantly high under control plants than other levels. The salinity levels 3, 6 dsm^{-1} and control were statistically similar.

4.7.2.10 Manganese

Leaves: The data (Table 42) revealed that the Mn content in leaves was significantly reduced from 12 dsm^{-1} onwards

Table 42 : Effect of salinity on micronutrient content (ppm) of leaves and roots of Basrai banana.

Treatments	ppm			
	Zn	Fe	Mn	Cu
Leaves				
S ₀	42.44	151.00	400.00	25.13
S ₁	41.20	151.00	395.00	25.00
S ₂	37.56	131.00	386.00	23.12
S ₃	31.28	117.00	371.00	20.03
S ₄	30.00	104.00	359.00	17.57
S ₅	28.37	97.00	350.00	16.21
S ₆	26.52	85.00	333.00	15.40
S.E.†	2.01	12.78	11.56	2.08
C.D.	5.93	37.70	34.10	6.13
Roots				
S ₀	93.00	284.00	675.00	30.00
S ₁	90.12	279.00	668.00	28.80
S ₂	79.37	262.00	645.00	26.00
S ₃	75.12	244.00	612.00	23.80
S ₄	68.37	219.00	579.00	22.90
S ₅	59.21	188.00	537.00	22.00
S ₆	46.13	167.00	507.00	21.30
S.E.†	4.85	12.95	10.96	2.36
C.D.	14.32	38.20	32.34	6.96

as compared to control and other levels.

Roots: The Mn content of roots was high under control plants than all other salinity levels. Lowest root Mn was recorded at salinity level of 15 and 18 dsm^{-1} .

4.7.2.11 Copper

Leaves: It is evident from the Table 42 that Cu content of leaves decreased with successive increase in salinity levels. The Cu content in leaves was low in all salinity levels as compared to control.

Roots: The Cu content of roots was significantly high in control 3 and 6 dsm^{-1} than all other levels. The decline was more pronounced at 18 dsm^{-1} .

4.8 Effect of chlorides on the chemical composition of banana plants.

4.8.1. Ardhapuri banana

The data with respect to chemical composition of leaves and roots as affected by chloride levels are given in Table 43 and 44. The chemical composition of the plants of chloride level 30 and 36 me/l was recorded after 300 and 240 days of planting, respectively because plants did not survived with the respective treatments.

4.8.1.1 Chlorophyll

From the data (Table 43) it is seen that total chlorophyll content of leaves decreased with the increase in chloride level. Significantly high chlorophyll

content was observed at chloride level 6 me/l and control than other levels. The decline was more sharp at 18 me/l onwards.

4.8.1.2 Nitrogen

Leaves: There was significant difference between leaf-N due to various chloride treatments (Table 43). In general, there was increase in N content upto 25 me/l as compared to control and previous treatments.

Roots : The N content of roots declined with increasing level of chloride. The chloride levels 6,12,18 me/l and control were statistically similar and exhibited higher root-N than other levels.

4.8.1.3 Phosphorus

Leaves: The P content (Table 43) of leaves significantly decreased at and above 18 me/l. In general, a decreasing trend in P content was recorded with increasing chloride level.

Roots: The data presented in Table 43 showed that there was a significant decrease in P content of roots from 24 me/l onwards over control.

4.8.1.4 Potassium.

Leaves: In general, there was decrease in K content of leaves with the increase in chloride. At higher levels of chloride (30 and 36 me/l) the K content of leaves was low than other chloride levels and control (Table 43).

Table 43: Effect of chloride levels on chlorophyll content (mg/g) of leaves and macronutrient content (per cent) of leaves and roots of Aradhapuri banana.

Treatment	Chlorophyll (mg/g)			Per cent					
	'a'	'b'	Total	N	P	K	Ca	Mg	Na
Leaves									
C ₀	11.39	11.49	22.88	2.07	0.52	3.04	0.97	0.49	0.21
C	11.31	11.41	22.72	2.13	0.50	3.03	0.94	0.53	0.26
C ₁	11.01	11.11	22.12	2.21	0.47	2.94	0.86	0.59	0.36
C ₂	10.68	10.79	21.47	2.23	0.42	2.71	0.78	0.59	0.49
C ₃	9.30	9.39	18.69	2.31	0.36	2.45	0.63	0.62	0.57
C ₄	8.48	8.50	16.98	2.08	0.33	2.13	0.51	0.60	0.63
C ₅	7.32	7.43	14.75	2.02	0.29	1.96	0.41	0.51	0.66
C ₆	0.06	0.05	0.11	0.11	0.03	0.12	0.07	0.01	0.01
S.E.†	0.18	0.15	0.32	0.32	0.10	0.34	0.22	0.04	0.03
C.D.									
Roots									
C ₀				2.63	0.33	2.24	0.63	0.29	0.40
C ₁				2.52	0.35	2.16	0.65	0.31	0.47
C ₂				2.38	0.34	2.08	0.69	0.34	0.58
C ₃				2.21	0.31	1.94	0.74	0.39	0.65
C ₄				2.07	0.28	1.80	0.80	0.34	0.71
C ₅				1.94	0.25	1.70	0.77	0.29	0.75
C ₆				1.83	0.24	1.64	0.71	0.26	0.78
S.E.†				0.15	0.01	0.06	0.03	0.03	0.00
C.D.				0.43	0.04	0.17	0.09	0.08	0.01

Roots: The K content of roots was significantly low in chloride levels 6,12 me/l and control. The effect was more pronounced at 36 me/l.

4.8.1.5 Calcium.

Leaves: The Ca content (Table 45) of leaves consistently decreased with the increase in chloride level. The decreasing effect was more prominent of chloride levels 30 and 36 me/l.

Roots: It is evident from the data that with the increase in chloride there was increase in Ca content of roots upto 24 me/l after wards it was decreased.

4.8.1.6 Magnesium.

Leaves: The data presented in Table 43 indicate that Mg content of leaves increased with the increase in chloride level upto 24 me/l. Lowest Mg content was recorded at 36 me/l.

Roots: The plants under control and chloride level 36 me/l recorded lowest root Mg as compared to other levels.

The chloride level 18 me/l recorded maximum Mg content.

4.8.1.7 Sodium.

Leaves: It is observed from the data (Table 43) that there was successive increase in Na content of leaves with increasing chloride levels.

Roots: The Na content of roots also progressively increased with the increase in chloride.

4.8.1.8 Zinc.

Leaves: The data presented in Table , shows that the content of leaves was high in control plants than all other chloride levels, but the results were non-significant.

Roots: The Zn content of roots declined with increasing level of chloride. It was significantly lower at and above 24 me/l over control, chloride level 6,12 and 18 me/l.

4.8.1.9 Iron

Leaves: A decrease in Fe content (Table 44) of leaves with the increase in chloride levels was observed. The Fe content of leaves was low at higher chloride levels (i.e. at 30 and 36 me/l) as compared to control and other levels

Roots: The Fe content of roots was significantly high under control and chloride level of 6 me/l than all other chloride levels.

4.8.1.10 Manganese

Leaves: The data (Table 44) revealed that the Mn content in leaves was significantly reduced from 18 me/l onwards as compared to control, 6 and 12 me/l chloride level.

Roots: The Mn content of roots was high under control plants than all other chloride levels. The chloride levels 6,12 me/l and control were statistically similar.

4.8.1.11 Copper

Leaves: It is evident from the Table 44 that Cu content

Table 44 : Effect of chloride levels on chlorine (per cent) and micronutrient content (ppm) of leaves and roots of Ardhapuri banana.

Treatment	ppm			
	Zn	Fe	Mn	Cu
Leaves				
C ₀	46.03	159.00	404.00	29.11
C ₁	46.00	157.00	403.00	29.01
C ₂	44.20	154.00	398.00	28.02
C ₃	41.33	150.00	393.00	25.31
C ₄	37.13	146.00	389.00	22.14
C ₅	34.20	141.00	378.00	21.10
C ₆	32.18	133.00	365.00	18.36
S.E.±	5.08	0.04	2.04	1.40
C.D.	N.S.	0.11	6.03	4.12
Roots				
C ₀	89.03	291.00	684.00	35.15
C ₁	87.37	284.00	680.00	35.00
C ₂	83.50	270.00	669.00	31.13
C ₃	78.12	255.00	650.00	27.50
C ₄	72.20	239.00	631.00	23.18
C ₅	63.13	222.00	605.00	21.12
C ₆	51.37	209.00	583.00	20.01
S.E.±	4.86	0.13	5.89	0.16
C.D.	14.35	0.39	17.37	0.48

of leaves decrease with successive increase in chloride levels. The Cu content of roots was significantly low in chloride levels viz., 24,30 and 36 me/l as compared to rest of the treatments.

Roots: The Cu content of roots was significantly high in control and chloride level 6 me/l plants than all other levels. The decline was more pronounced at 36 me/l

4.8.2 Basrai banana

The data pertaining to the physiological and chemical composition of leaves and roots as affected by various chloride levels are given in Table 43 and 44. The chemical composition of the plants treated with 24,30 and 36 me/l was registered 300, 240 and 180 days after planting, respectively.

4.8.2.1 Chlorophyll

From the data (Table 43) it is seen that increasing salinity decreased the total chlorophyll content of leaves. The total chlorophyll content of leaves was significantly high under control and salinity level 6 me/l than rest of the treatments.

4.8.2.2 Nitrogen

Leaves: The N content of leaves consistently increased with the increase in salinity levels upto 18 me/l. The N content was significantly low under control. Lowest Leaf-N was recorded at 30 and 36 me/l.

Roots: There was a reduction in the N content of roots under increased saline conditions. This reduction was significant from 18 me/l onwards over control, 6 and 12 me/l of chloride level.

4.8.2.3 Phosphorus

Leaves: There was a significant effect on P content of roots under increased saline condition. leaf P content of roots at the higher levels (i.e. at 24,30 and 36 me/l) as compared to control and other levels.

4.8.2.4 Potassium

Leaves: From the data (Table 45) it is seen that K content of leaves decreased with the increase in chloride level. The K content of leaves was significantly decreased at and above 18 me/l.

Roots: The control plants and those under 6,12,18 me/l registered higher root-K than those plants under rest of the chloride levels.

4.8.2.5 Calcium

Leaves: The Ca content (Table 45) of leaves was significantly low in chloride levels at and above 18 me/l. In general, there was decrease in Ca content with the increase in salinity levels.

Roots: The Ca content was less at higher levels (i.e at 30 and 36 me/l) in roots than that of control and other levels

Table 45 : Effect of chloride levels on chlorophyll content (Mg/g) of leaves and macronutrient content (Per cent) of leaves and roots of Basrai banana.

Treat. ment	Chlorophyll (mg/g)			Per cent					
	'a'	'b'	Total	N	P	K	Ca	mg	Na
Leaves									
C ₀	9.71	9.82	19.53	2.04	0.49	3.03	0.89	0.47	0.20
C ₁	9.68	9.79	19.47	2.11	0.46	2.97	0.88	0.47	0.25
C ₂	9.47	9.57	19.04	2.17	0.41	2.90	0.82	0.44	0.33
C ₃	9.04	9.14	18.18	2.15	0.39	2.69	0.77	0.36	0.45
C ₄	8.68	8.78	17.46	2.03	0.35	2.40	0.69	0.31	0.63
C ₅	8.24	8.35	16.59	1.90	0.29	2.18	0.58	0.27	0.72
C ₆	7.76	7.86	15.62	1.80	0.25	2.08	0.53	0.27	0.76
S.E. $\pm$	0.03	0.05	0.10	0.03	0.03	0.05	0.04	0.02	0.03
C.D.	0.09	0.14	0.30	0.11	0.09	0.15	0.13	0.07	0.11
Roots									
C ₀				2.69	0.30	2.22	0.62	0.29	0.36
C ₁				2.60	0.28	2.22	0.60	0.31	0.45
C ₂				2.52	0.26	2.08	0.57	0.35	0.52
C ₃				2.46	0.26	2.02	0.52	0.34	0.59
C ₄				2.32	0.22	1.96	0.46	0.27	0.70
C ₅				2.26	0.19	1.82	0.37	0.24	0.80
C ₆				2.17	0.17	1.63	0.33	0.20	0.83
S.E. $\pm$				0.067	0.017	0.084	0.02	0.02	0.05
C.D.				0.20	0.05	0.25	0.06	0.06	0.16

4.8.2.6 Magnesium

Leaves: It is seen from the data (Table 45) that the Mg content of leaves decreased with the increase in salinity. The plants under control showed more leaf Mg than all salinity levels.

Roots: There was significantly higher content of Mg of roots under control, 6 and 12 me/l than rest of the levels

4.8.2.7. Sodium

Leaves: It is observed from the data (Table 45) that the Na content of leaves decreased with increase in levels of chlorides. In general. It was significantly more at the levels of 30 and 36 me/l than other levels of chlorides.

Roots: The Na content of roots also progressively increased with the increase in chloride level. The Na content was highest in 36 me/l level followed by 30 me/l.

4.8.2.8 Zinc

Leaves: It is observed from the data (Table 45) that the Zn content of leaves was significantly high in control and 6 me/l than all chloride levels.

Roots: The Zn content of roots decreased significantly at and above 12 me/l over control and 6 me/l.

4.8.2.9 Iron

Leaves: The data (Table 45) revealed that the Fe content of leaves was significantly low in all chloride levels except control and 6 me/l. The reducing effect was more pronounced at higher levels.

Table 46 Effect of chloride levels on Micronutrient
content (ppm) of leaves and roots of Basrai
banana.

Treatment	PPM			
	Zn	Fe	Mn	Cu
Leaves				
C ₀	42.00	151	401	25.53
C ₁	39.38	148	397	25.00
C ₂	36.10	134	384	23.12
C ₃	34.13	111	367	21.89
C ₄	30.18	100	351	17.20
C ₅	27.03	93	324	14.78
C ₆	26.49	90	305	13.27
S.E.†	00.93	1.33	0.07	1.02
C.D	2.74	3.94	0.21	3.01
Roots				
C ₀	92.28	283	676	30.10
C ₁	91.00	277	670	30.10
C ₂	76.38	259	650	27.50
C ₃	73.10	239	603	22.13
C ₄	65.18	203	568	19.16
C ₅	57.14	185	525	19.11
C ₆	46.03	170	477	17.29
S.E.†	00.33	8.89	9.40	0.92
C.D	00.98	26.22	27.72	2.72

Roots: The Fe content of roots at the chloride levels 6,12 me/l and control. The reducing effect was more pronounced at higher levels.

4.8.2.10 Manganese

Leaves: The Mn content (Table 45) of leaves under control registered highest Mn content. In general, increasing level of chloride decreased Mn content of leaves.

Roots: The Mn content of roots decreased significantly from 18 me/l onwards. The decreasing effect was more sharp at higher chloride levels (i.e. at 30 and 36 me/l).

4.8.2.11 Copper

Leaves: It is evident from Table 45 that Cu content of leaves was significantly declined at and above 18 me/l of chloride level compared to other levels.

Roots: At higher levels of chloride (30 and 36 me/l) the root-Cu content was lowest as compared to control and other chloride levels. The effect was more pronounced at 36 me/l.

4.9 Effect of bicarbonate levels on physiological and chemical composition of banana plants.

4.9.1. Ardhapuri banana

The data regarding physiological and chemical composition of leaves and roots as influenced by bicarbonate levels are presented in Table 47 and 48. The

physiological and chemical composition of treatment level 30 me/l was registered after 300 days of planting.

4.9.1.1 Chlorophyll

The total chlorophyll content (Table 47) of leaves decreased with the increase in bicarbonate levels.

The total chlorophyll content of leaves was low at and above 15 me/l levels over the control and other levels.

4.9.1.2 Nitrogen

Leaves: The content of leaves was found to be decreased with increasing level of bicarbonate (Table 47) . The lowest leaf-N was recorded at 30 me/l.

Roots: It is observed from the data that the N content of roots was significantly decreased at and above 15 me/l.

4.9.1.3 Phosphorus

Leaves: The content of leaves was significantly high in control, 5,10,15 and 20 me/l as compared to rest of the treatments (Table 47).

Roots: There was significant reduction in the P content of roots at the higher levels i.e. at 20, 25 and 30 me/l.

4.9.1.4 Potassium

Leaves: It is evident from the data in Table 47 that there was consistent decrease in K content of leaves with the increase in bicarbonate level. The K content of leaves was significantly decreased from 16 me/l onwards.

Roots: The root-K was also decreased with the increase in salinity. The root-K was high in control, 5 and 10 me/l.

Table 47 : Effect of bicarbonate levels of chlorophyll content(mg/g) of leaves and macro nutrient content (percent) of leaves and roots of Ardhapuri banana

Treat ment	Chlorophyll (mg/g)				Per cent				
	a	b	Total	N	P	K	Ca	Mg	Na
Leaves									
B ₀	11.39	11.48	22.87	2.09	0.50	3.03	0.96	0.50	0.21
B ₁	11.34	22.69	22.09	0.44	3.00	3.00	0.93	0.48	0.26
B ₂	11.06	11.16	22.22	2.01	0.39	2.95	0.84	0.45	0.40
B ₃	10.86	10.96	21.82	1.93	0.33	2.79	0.75	0.40	0.53
B ₄	10.38	10.49	20.87	1.80	0.33	2.60	0.59	0.33	0.61
B ₅	9.89	9.89	19.87	1.69	0.28	2.32	0.49	0.29	0.68
B ₆	9.52	9.63	19.16	1.54	0.26	2.03	0.38	0.26	0.74
S.E†	0.19	0.21	0.37	0.29	0.06	0.08	0.05	0.04	0.02
C.D	0.55	0.63	1.10	0.85	0.19	0.25	0.16	0.11	0.04
Roots									
B ₀				2.63	0.31	2.27	0.62	0.29	0.38
B ₁				2.66	0.30	2.25	0.63	0.28	0.39
B ₂				2.55	0.30	2.20	0.51	0.28	0.46
B ₃				2.46	0.28	2.11	0.43	0.23	0.52
B ₄				2.38	0.27	1.92	0.36	0.21	0.58
B ₅				2.34	0.24	1.80	0.31	0.19	0.66
B ₆				2.30	0.22	1.65	0.26	0.17	0.70
S.E†				0.04	0.01	0.06	0.05	0.02	0.07
C.D				0.11	0.03	0.18	0.14	0.06	0.21

4.9.1.5 Calcium

Leaves: It is seen from the data (Table 47) that the bicarbonate levels 5,10 me/l and control were statistically similar and exhibited higher Ca content than other levels.

Roots: The Ca content of roots was significantly low in all salinity levels over the control. The bicarbonate levels 5,10 me/l and control were statistically similar with each other.

4.9.1.6 Magnesium

Leaves: It is observed from the data (Table 47) that the Mg content of leaves decreased with the increase in bicarbonate level. More Mg content was recorded in control than all bicarbonate levels.

Roots : The control and bicarbonate level 5 and 10 me/l exhibited significantly more Mg content in roots than other levels.

4.7.1.7 Sodium

Leaves: The Na content (Table 47) increased with the increase in bicarbonate levels. The Na content was significantly high at 20,25 and 30 me/l. lowest leaf-N was recorded at control and 5 me/l level.

Roots: The Na content of roots was significantly low in control and 5 me/l bicarbonate level than all bicarbonate levels studied.

4.9.1.8 Zinc

Leaves: The data (Table 48) revealed that the Zn content of leaves was high under control and 5 me/l when compared with higher bicarbonate levels.

Roots: The Zn content of roots was significantly low at higher levels of bicarbonates than at control, 5 and 10 me/l treatment.

4.9.1.9 Iron

Leaves: A decrease in Fe content (Table 48) of leaves with the increase in bicarbonate level was recorded. At higher levels of bicarbonate (at and above 10 me/l) the Fe content of leaves was low as compared to control.

Roots: A decrease in Fe content of roots was recorded from 20 me/l onwards. In general, with the increase in bicarbonate level, decrease in root-Fe was recorded.

4.9.1.10 Manganese

Leaves: The Mn content (Table 48) of leaves under control, 5 and 10 me/l treatment was significantly high than other levels of bicarbonates.

Roots. The Mn content of roots was low at and above 15 me/l as compared to control and other bicarbonate levels.

4.9.1.11 Copper

Leaves: The Cu content of leaves was significantly low at bicarbonate levels 20, 25 and 30 me/l as compared to control (Table 48).

Table 48: Effect of bicarbonate levels on micro nutrient
(ppm) content of leaves and roots of
Ardhapuri banana.

Treatment	PPM			
	Zn	Fe	Mn	Cu
Leaves				
B ₀	45.38	154	404	29.10
B ₁	44.83	154	398	28.80
B ₂	42.10	150	394	27.50
B ₃	39.40	144	383	25.10
B ₄	36.20	136	364	23.50
B ₅	32.36	127	350	21.12
B ₆	30.86	111	330	20.00
S.E.†	2.05	0.027	0.047	1.42
C.D	6.04	0.08	0.14	4.18
Roots				
B ₀	92.10	289	672	29.85
B ₁	92.00	276	659	29.90
B ₂	85.13	261	641	29.90
B ₃	80.08	239	626	26.52
B ₄	70.03	201	611	21.32
B ₅	61.13	180	589	20.13
B ₆	54.13	171	557	18.28
S.E.†	2.65	14.70	11.91	4.93
C.D	7.83	43.37	35.13	N.S.

Roots : The Cu content of leaves was found to be increased with increasing level of bicarbonate upto 10 me/l. However, beyond that limit (i.e. at 15 me/l) the N content was found to be declined. The N content was the lowest at 30 me/l.

4.9.2 Basrai banana

The data pertaining to the chemical composition of leaves and roots as influenced by bicarbonate levels are presented in Table 49 and 50.

4.9.2.1 Chlorophyll

From the data in Table 49 it is seen that total chlorophyll content of leaves decreased with the increase in bicarbonate significantly high chlorophyll content was observed at control, 5 and 10 me/l of bicarbonate levels.

The decline was more sharp at 20 me/l onwards.

4.9.2.2 Nitrogen

Leaves: The N content (Table 49) of leaves decreased with the increase in bicarbonate levels upto 15 me/l, beyond that limit it was reduced.

Roots: The N content of roots at and 30 me/l was significantly low than control, while the bicarbonate levels 5,10,15 and 20 me/l were similar with each other.

4.9.2.3 Phosphorus

Leaves: The P content (Table 49) of leaves decreased with the increase in bicarbonate level, it was high at control and 5 me/l level as compared to other bicarbonate levels.

Table 49: Effect of bicarbonate levels of chlorophyll content (mg/g) of leaves and Macro nutrient content (per cent of leaves and roots of Basrai

Treat ment	Chlorophyll (mg/g)					Per cent			
	a	b	Total	N	P	K	Ca	Mg	Na
Leaves									
B ₀	9.68	9.79	19.47	2.01	0.49	3.04	0.92	0.45	0.20
B ₁	9.68	9.78	19.46	1.97	0.49	3.00	0.91	0.44	0.22
B ₂	9.50	9.61	19.11	1.88	0.46	2.93	0.86	0.41	0.29
B ₃	9.14	9.23	18.37	1.77	0.43	2.71	0.80	0.38	0.40
B ₄	8.71	8.79	17.50	1.63	0.33	2.42	0.69	0.32	0.52
B ₅	8.34	8.45	16.79	1.49	0.30	2.21	0.59	0.29	0.54
B ₆	7.85	7.96	15.81	1.34	0.28	2.12	0.55	0.26	0.60
S.E.†	0.08	0.11	0.21	0.09	0.01	0.12	0.01	0.02	0.05
C.D	0.24	0.31	0.63	0.27	0.03	0.34	0.03	0.07	0.14
Roots									
B ₀				2.71	0.30	2.19	0.61	0.30	0.38
B ₁				2.70	0.30	2.23	0.61	0.28	0.41
B ₂				2.59	0.30	2.11	0.55	0.26	0.49
B ₃				2.44	0.27	2.03	0.48	0.25	0.54
B ₄				2.34	0.24	1.94	0.45	0.22	0.74
B ₅				2.28	0.21	1.77	0.35	0.20	0.75
B ₆				2.14	0.19	1.70	0.31	0.20	0.76
S.E.†				0.13	0.01	0.09	0.02	0.02	0.06
C.D.				0.39	0.03	0.26	0.07	0.06	0.18

Roots: The P content of roots was also significantly low at the higher levels of bicarbonate (i.e. at and above 20 me/l) as compared to rest of the treatments.

4.9.2.4 Potassium

Leaves: There was significant reduction in K content (Table 49) of leaves with each increase in bicarbonate level except 5,10,15 me/l and control.

Roots: Root-K decreased with the increase in bicarbonate level. A significant decline was observed from 20 me/l onwards.

4.9.2.5 Calcium

Leaves: The data presented in Table 49 showed that the Ca content of leaves was high under control and 5 me/l as compared to all bicarbonate levels.

Roots: The Ca content of roots was significantly low at bicarbonate level 15,20,25 and 30 as compared to 5, 10 me/l and control

4.9.2.6 Magnesium

Leaves: The Mg content of leaves (Table 49) decreased with the increase in bicarbonate level. It was significantly low at 20 me/l and above. There was no significant difference between the treatment 25 and 30 me/l.

Roots: There was significant reduction in root-Mg with each increment in bicarbonate level (at and above 20 me/l except 5,10,15 me/l and control.

4.9.2.7 Sodium

Leaves: The N content (Table 49) of leaves increased with the increase in bicarbonate levels. A significantly more Na content was recorded at all bicarbonate levels over control.

Roots: Root-Na increased with the increase in bicarbonate levels. A significant increase in Na content of roots was observed at bicarbonate level 15 me/l onwards.

4.9.2.8 Zinc

Leaves: From the data (Table 50) it is seen that Zn content of leaves was high under control plants than all bicarbonate levels. The plants of bicarbonate levels 5,10 me/l and control were statistically similar.

Roots: The zinc content of roots at bicarbonate levels 20,25 and 30 me/l was significantly low as compared to control and other levels.

4.9.2.9 Iron

Leaves: It is evident from the data (Table 50) that there was decline in leaf-Fe content as the bicarbonate level was increased.

Roots: Root-Fe decreased with the increase in bicarbonate levels. It was significantly low at and above 20 me/l of chloride level as compared with control and previous levels.

4.9.2.10 Manganese

Leaves: The Mn content of leaves (Table 50) was

Table 50 : Effect of bicarbonate levels on micro nutrient content (ppm) of leaves and roots of Basrai banana

Treatment	PPM			
	Zn	Fe	Mn	Cu
Leaves				
B ₀	42.44	149	398	25.01
B ₁	42.44	148	395	24.11
B ₂	38.34	138	389	23.10
B ₃	35.10	119	370	22.08
B ₄	31.04	107	359	20.00
B ₅	28.18	98	334	17.38
B ₆	27.13	95	316	14.21
S.E.	1.71	0.047	0.91	0.72
C.D.	5.04	0.14	0.31	2.13
Roots				
B ₀	93.01	280	672	30.25
B ₁	92.25	280	670	30.10
B ₂	81.13	267	661	28.21
B ₃	77.00	248	623	25.25
B ₄	66.00	223	589	22.11
B ₅	60.00	198	546	20.08
B ₆	50.18	181	503	18.00
S.E.	5.47	11.64	4.44	1.99
C.D.	16.13	34.35	13.11	5.88

significantly high at control. In general, with the increase in bicarbonate level there was decrease in Manganese content.

Roots: A significant decrease in Mn content of roots was recorded from bicarbonate level 16 me/l and above. The effect was more pronounced at bicarbonate level 30 me/l

4.9.2.11 Copper

Leaves: There was a significant decrease in Cu content (Table 50) of leaves with the increase in bicarbonate level. The decreasing effect was more sharp at 5 and 10 me/l.

Roots: The Cu content of roots was significantly decline with every incremental level from bicarbonate level of 20 me/l onwards over previous lower level.

4.10 Effect of sulphate levels on physiological and chemical composition of banana plants.

4.10.1 Ardhapuri banana

The data pertaining to the chemical composition of leaves and roots as influenced by various sulphate levels are presented in Table 51 and 52. The chemical composition was registered after 240 days of planting for the chloride level of 42 me/l as plants were died.

4.10.1.1. Chlorophyll

From the data (Table 51) it is seen that total chlorophyll content of leaves decrease with the increase

in sulphate level. Significantly high chlorophyll content was observed at sulphate level 7,14 me/l and control than other levels. The decline was more sharp at 35 me/l.

4.10.1.2 Nitrogen.

Leaves: The N content (Table 51) of leaves increased with the increase in sulphate level upto 35 me/l, beyond that limit it was reduced.

Roots: The N content of roots of 7,14,21 me/l were statistically similar with each other, while the sulphate level 28,35 and 42 me/l was significantly low than control and pervious levels.

4.10.1.3 Phosphorus

Leaves: The P content (table 51) of leaves was decreased with the increase in sulphate level. It was high at sulphate level of 7,14 me/l and control as compared to other levels.

Roots: The P content of roots was also significantly low at the higher levels of 28,35 and 42 me/l as compared to rest of the treatments.

4.10.1.4 Potassium

Leaves: There was significant increase in the K content (Table 51) of leaves with each increase in sulphate level except 7,14 me/l and control.

Roots: Roots K increase with the increase in sulphate level. A significant decline was registered at 7,14,21 me/l and control.

Table 51 : Effect of sulphate levels on chlorophyll content (Mg/g) of leaves and macro nutrient content (per cent) of leaves and roots of Ardhapuri banana plant

Treat ment	Chlorophyll (mg/g)			Per cent					
	a	b	Total	N	P	K	Ca	Mg	Na
SL ₀	11.39	11.48	22.87	2.09	0.49	3.04	0.97	0.48	0.20
SL ₁	11.33	11.45	22.78	2.09	0.49	3.11	0.90	0.48	0.23
SL ₂	11.05	11.15	22.20	2.01	0.46	3.23	0.85	0.50	0.28
SL ₃	10.89	10.98	21.87	1.96	0.42	3.30	0.77	0.53	0.34
SL ₄	10.48	10.58	21.06	2.14	0.40	3.41	0.68	0.57	0.41
SL ₅	9.98	10.09	20.07	2.19	0.37	3.52	0.54	0.52	0.50
SL ₆	9.68	9.79	19.47	2.09	0.35	3.56	0.46	0.48	0.55
S.E	0.11	0.14	0.28	0.24	0.03	0.10	0.08	0.03	0.02
C.D	0.33	0.41	0.83	N.S	0.09	0.30	0.23	0.09	0.07

Roots

SL ₀	2.63	0.31	2.27	0.62	0.30	0.38
SL ₁	2.69	0.29	2.20	0.57	0.32	0.44
SL ₂	2.59	0.28	2.22	0.49	0.33	0.53
SL ₃	2.41	0.28	2.34	0.33	0.30	0.62
SL ₄	2.30	0.25	2.47	0.30	0.27	0.66
SL ₅	2.26	0.23	2.43	0.26	0.24	0.68
SL ₆	2.20	0.21	2.39	0.22	0.20	0.71
S.E	0.08	0.02	0.06	0.05	0.01	0.03
C.D.	0.24	0.04	0.19	0.14	0.03	0.09

4.10.1.5 Calcium

Leaves: The data presented in Table 51 showed that Ca content of leaves was high under control as compared to all sulphate levels.

Roots: The Ca content of roots was significantly low at sulphate level 21, 28, 35 and 42 me/l as compared to sulphate level 7, 14 me/l and control.

4.10.1.6 Magnesium

Leaves: The Mg content of leaves (Table 51) increased with the increase in sulphate level upto 28 me/l while again it was reduced for higher levels.

Roots: There was significant reduction in root Mg with the increment in sulphate level except 7 and 14 me/l. Lowest root Mg was recorded at 42 me/l of sulphate level.

4.10.1.7 Sodium

Leaves: The Na content (Table 51) of leaves increased with the increase in sulphate levels. A significantly more Na content was recorded at all sulphate level over control and 7 me/l.

Roots: Root Na increased with the increase in sulphate level. A significant increase in Na content of roots was observed at sulphate level 7 me/l and control.

4.10.1.8 Zinc

Leaves: From the data (Table 52) it is seen that Zn content of leaves was high under control and 7 me/l sulphate level. A general decrease in zinc content was

recorded with the increase in sulphate level.

Roots: The Zn content of roots of sulphate level 28 me/l onwards was significantly lower as compared to control and other sulphate levels.

4.10.1.9 Iron.

Leaves: It is evident from the data (Table 52) that there was decline in Fe content of leaves as the sulphate level was increased. The difference between control and all sulphate levels was non-significant.

Roots: Root-Fe decreased with the increase in sulphate levels. It was significantly low at sulphate level 21 me/l and onwards as compared to control and other levels.

4.10.1.10 Manganese

Leaves: The Mn content of leaves (Table 52) was significantly higher at sulphate level 7, 14 and 21 me/l and control as compared to higher sulphate levels.

Roots: A significant decrease in Mn content of roots was recorded from sulphate level of 28 me/l and above. The effect was more pronounced at sulphate level 42 me/l

4.10.1.11 Copper:

Leaves: There was a decrease in Cu content (Table 52) of leaves with the increase in sulphate level. The effect was more sharp at 35 and 42 me/l.

Roots: The Cu content of roots was significantly declined with every incremental level of sulphate from 35 me/l onwards over previous level.

Table 52 : Effect of sulphate levels on micro nutrient content (ppm) of leaves and roots of Ardhapuri plant.

Treatments	PPM			
	Zn	Fe	Mn	Cu
Leaves				
SL ₀	46.12	156	403	29.00
SL ₁	46.10	150	403	28.00
SL ₂	45.32	150	400	26.12
SL ₃	42.13	147	394	23.37
SL ₄	39.10	142	388	21.00
SL ₅	36.18	138	380	19.48
SL ₆	34.31	134	374	18.12
S.E.	2.08	8.94	4.25	2.04
C.D.	6.14	N.S.	12.53	6.03
Roots				
SL ₀	92.28	290	671	32.00
SL ₁	91.25	286	665	30.19
SL ₂	85.30	280	653	27.32
SL ₃	80.14	263	651	25.14
SL ₄	76.19	243	639	22.88
SL ₅	68.13	222	614	20.34
SL ₆	54.37	213	593	20.18
S.E.	4.52	7.46	8.25	2.41
C.D.	13.34	22.00	24.34	7.11

4.10.2 Basrai banana

The data pertaining to the physiological and chemical composition of leaves and roots as influenced by sulphate levels are presented in Table 53 and 54.

4.10.2.1 Chlorophyll.

It is evident from the data (Table 53) that total chlorophyll content decreased with increasing sulphate levels. The total chlorophyll content was significantly high at sulphate level of 7,14 me/l and control as compared to other levels.

4.10.2.2 Nitrogen

Leaves: The N content (Table 53) of the leaves decreased with the increase in sulphate levels but non significant difference was found among the sulphate levels studied.

Roots: The root-N decreased with the increase in sulphate levels. The sulphate level 7 me/l and control recorded higher N than other levels.

4.10.2.3 Phosphorus

Leaves: The P content of leaves (Table 53) showed a decreasing trend with increasing sulphate levels. The P content under control, sulphate level 7 and 14 me/l was similar. While significant difference was observed at other levels.

Roots: The P content of roots was significantly declined at and above 21 me/l as compared to control, 7 and 14 me/l sulphate level.

Table 53 : Effect of sulphate on chlorophyll content
(Mg/g) of leaves and macro nutrient content
(per cent) of leaves and roots of
Gasrai banana plant

Treat ment	Chlorophyll (Mg/g)			Per cent					
	a	b	Total	N	P	K	Ca	Mg	Na
Leaves									
SL ₀	9.71	9.81	19.59	2.02	0.49	3.00	0.88	0.46	0.21
SL ₁	9.70	9.79	19.49	2.02	0.46	3.00	0.87	0.45	0.20
SL ₂	9.48	9.58	19.06	1.97	0.41	3.09	0.82	0.48	0.29
SL ₃	9.09	9.19	18.28	1.88	0.35	3.18	0.79	0.50	0.41
SL ₄	8.68	8.79	17.47	1.77	0.32	3.29	0.73	0.47	0.50
SL ₅	8.30	8.41	16.71	1.72	0.30	3.40	0.62	0.44	0.57
SL ₆	7.76	7.85	15.61	1.69	0.30	3.49	0.54	0.39	0.66
S.E	0.08	0.11	0.21	0.14	0.03	0.10	0.03	0.02	0.03
C.D	0.23	0.33	0.64	N.S.	0.10	0.31	0.09	0.06	0.10
Roots									
SL ₀				2.68	0.31	2.20	0.60	0.29	0.36
SL ₁				2.64	0.31	2.19	0.56	0.29	0.40
SL ₂				2.53	0.26	2.23	0.46	0.30	0.46
SL ₃				2.38	0.24	2.29	0.32	0.27	0.60
SL ₄				2.34	0.22	2.39	0.28	0.25	0.71
SL ₅				2.30	0.20	2.22	0.23	0.22	0.75
SL ₆				2.21	0.19	2.18	0.21	0.21	0.71
S.E				0.14	0.02	0.08	0.02	0.01	0.08
C.D				0.43	0.05	0.25	0.05	0.02	0.23

4.10.2.4 Potassium

Leaves: There was direct relationship between leaf-K and sulphate levels. In general, with the increase in sulphate level increase in leaf-K was found. Highest leaf-K was recorded at sulphate level of 42 me/l.

Roots: The root-K increased with the increase in sulphate level upto 28 me/l. Lowest root-K was registered at 42 me/l.

4.10.2.5 Calcium

Leaves: The perusal of the data (Table 53) revealed that Ca content of leaves decreased as sulphate level was increased. The Ca content of leaves was significantly decreased beyond, 28 me/l with every increase in sulphate level over previous lower level.

Roots: The Ca content of roots was low in all sulphate levels from 14 me/l as compared to 7 me/l and control.

4.10.2.6 Magnesium.

Leaves: The Mg content of leaves (Table 53) increased with the increase in sulphate levels upto 28 me/l onwards it was reduced. Highest leaf-Mg was registered at 21 me/l of sulphate level as compared to all sulphate levels and control.

Roots: Root-Mg declined significantly from 21 me/l onwards over control, 7 and 14 me/l.

4.10.2.7 Sodium.

Leaves: The sodium content of leaves (Table 53) showed a reverse pattern which exhibited an increase in Na with increase in sulphate level. The sodium content of leaves at all sulphate levels was significantly higher as compared to control.

Roots : An increase in the Na content of roots with successive increase in sulphate levels was observed . lowest root-Na was registered at control followed by 7 me/l.

4.10.2.8 Zinc

Leaves : The Zn content of leaves (Table 54) under control plants was high than all sulphate levels. The sulphate levels 28,35 and 42 me/l significantly recorded lower Zn content as compared to control and previous levels.

Roots: The Zn content of roots was significantly declined from sulphate level of 28 me/l onwards. However Zn content at sulphate level 28,35 and 42 me/l levels was found similar with each other.

4.10.2.9 Iron

Leaves: It is evident from the data (Table 54) that there was a consistent fall in Fe content of leaves with the increase in sulphate level. The decline was non significant.

Table 54 : Effect of sulphate levels on micro nutrient content (ppm) of leaves and roots of Basrai banana

Treatment	ppm			
	Zn	Fe	mn	Cu
SL ₀	41.93	148	396	24.84
SL ₁	40.00	145	391	23.00
SL ₂	38.17	141	382	21.52
SL ₃	35.16	121	969	19.10
SL ₄	33.00	103	355	18.05
SL ₅	30.03	99	336	17.13
SL ₆	28.03	93	311	16.13
S.E	1.67	9.49	5.19	0.37
C.D	4.94	28.00	15.30	1.08

ROOTS

SL ₀	91.79	281	671	30.00
SL ₁	89.30	273	660	28.10
SL ₂	82.24	262	644	27.52
SL ₃	75.10	250	618	27.00
SL ₄	69.14	221	579	24.13
SL ₅	60.11	203	556	21.33
SL ₆	51.13	194	545	18.38
S.E.	3.41	11.53	4.44	0.85
C.D	10.08	34.00	13.11	2.52

Roots: There was decrease in Fe content of roots with the increase in sulphate levels. The decline was significantly high from sulphate level 21 me/l and onwards as compared to all sulphate levels studied.

4.10.2.10. Manganese.

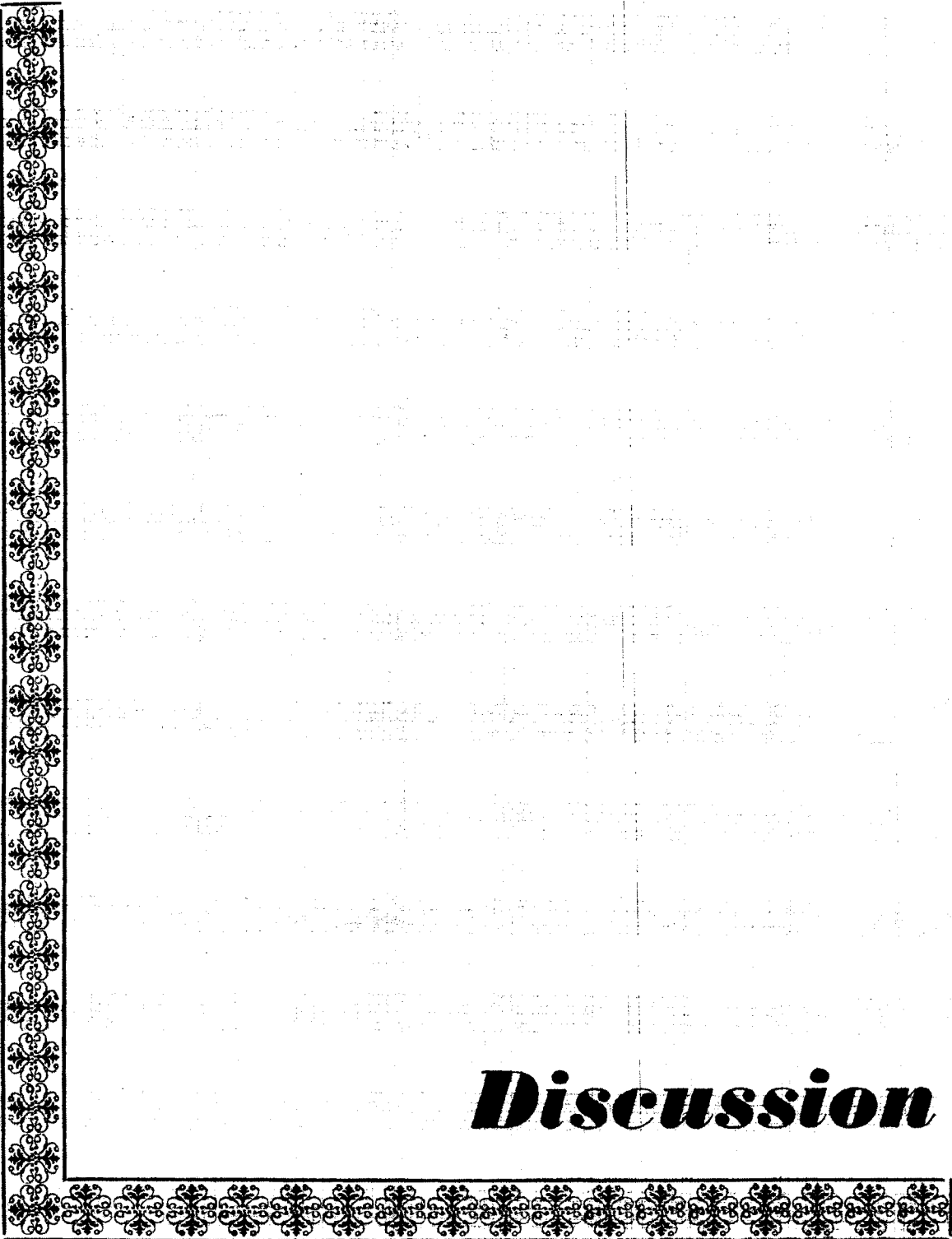
Leaves: The Mn content (Table 54) of leaves was higher at sulphate level 7 me/l and control than other sulphate levels. The sulphate levels 7,14,21 me/l and control were statistically similar with each other.

Roots : The Mn content of roots was significantly low at and above 28 me/l of sulphate level as compared to control and previous sulphate levels. The effect was more pronounced at 42 me/l.

4.10.2.11 Copper.

Leaves : In general, increasing sulphate level decreased copper content of leaves. The sulphate levels 7,14,21 me/l and control were statistically similar with each other as compared to rest of the treatments.

Roots: Significantly lower Cu content of roots was observed at 28 me/l onwards and onwards as compared to control and previous treatments. The effect was more sharp at 35 and 42 me/l.



Discussion

Chapter 5

DISCUSSION

The present investigation was conducted to study the effect of various levels of exchangeable sodium percentage and salinity in soil on the growth and Chemical composition of two cultivars of banana. The results are discussed in this chapter.

5.1 Effect of exchangeable Sodium percentage

5.1.1 Effect on the growth

The results of the experiment indicated pronounced decrease in various growth parameters with successive increase in ESP level in soil.

The Ardhapuri and Basrai cultivars of banana were severely affected at and above ESP 24 in respect of height and number of leaves. The pseudostem diameter was also affected at the same ESP level. In the present investigation Basrai was more tolerant followed by Ardhapuri. Ardhapuri showed more growth and suffered from less mortality under higher ESP as compared to Basrai.

The growth suppression in sodic soils may 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 checked the root growth. Different views i.e. structural deterioration of physical

properties of soil, direct toxic effects, production of toxic substances within plants and nutritional imbalance 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, 1962). Similar ill effects of sodium on growth were also reported in various fruit crops viz., grapevines (Khanduja et al., 1980), citrus root stocks (Patil and Bhambota, 1977; Rajput, 1990), pomegranate (Patil and Patil, 1982). Detrimental effects on growth were also observed in aonla (Tewari, 1983 and Sharma ^{et al.}, 1987), ber (Pandey, 1984), Bael (Pandey et al., 1985 and Tewari, 1985), tree species (Sadaria, 1989 and Valia, 1989).

Mortality

Injury or mortality symptoms appeared at ESP 24 in Ardhapuri, while in Basrai the mortality appeared at ESP 32 onwards. In both species, dull green colour of leaves was observed under higher ESP. Burning was first noticed on older leaves. Leaf scorching and signs of chlorosis were observed which extended towards the base of the leaf. In higher ESP, death of apical portion and drying of shoot tip were observed. Injury may be attributed to the accumulation of abnormally high Na in the leaf tissues. Toxicity symptoms were reported in mango rootstocks (Thakur et al., 1982), Pomegranate (patil

and Patil, 1982), aonla (Tewari, 1983) and bael seedlings (Pandey, et al., 1985) in similar situation.

In both the cultivars the fresh weight of whole plant, fresh weight of top and roots with rhizome, dry weight of top and roots with rhizome, root length, leaf area per plant decrease with the increase in ESP level in the soil. Degree of depression was different at the same ESP level in two cultivars. Relationship between relative growth (Fresh weight of whole plant) per cent of each cultivars and levels of ESP was therefore worked out and shown in Fig.1. The theoretical growth values were obtained from the regression equation given below which were derived from the observed value

$Y = 3439.25$	$- 38.899$	$x + 0.0713 x^2$	Ardharpuri
$= \text{S.E.}$	26.860	0.538	$R^2 = 0.850$
$= 3225.34$	$- 24.571$	$x - 0.370 x^2$	Basrai
$= \text{S.E.}$	15.071	0.301	$R^2 = 0.939$

Where Y = growth values and X = ESP level.

The relative growth was plotted against ESP levels for each plant species. The detailed information regarding ESP tolerance indices for different cultivars is given in Table 55.

It is evident from the growth depression data the Basrai was most tolerant than Ardharpuri.

Table 55: Sodium tolerance indices of banana cultivars.

Cultivars/ levels ESP	Growth depression(%)	
	20	50
Ardhapuri	18.00	35.00
Basrai	27.50	40.00

It is evident that 20 per cent growth depression in ESP range of 18.00 and 27.50 was noticed in Ardhapuri and Basrai, respectively.(Table 55)

5.1.2 Correlation coefficients among different characters in presence of ESP.

The results on character association Table 56 indicated that all the characters exhibited positive and highly significant correlation with dry matter in both the cultivars of banana (Table 56).

5.2 Effect of soil salinity

5.2.1 Effect on the growth of plants.

In saline soils, all growth attributes were decreased significantly with increasing salinity level in both the cultivars . Different reasons could be assigned to explain the detrimental effects of salts on plant growth viz., osmotic inhibition of water absorption, nutritional imbalance, toxic effects of ions, production of toxic substances in plants and ill effects on plant

Table 56 : Correlation coefficients among different characters in presence of exchangeable sodium percentage (ESP)

Characters	Cultivar	Plant height (cm)	Number of leaves	Pseudo stem diameter (mm)	Fresh weight of whole plant (g)	Root length (cm)	Total leaf area (sq.m)	Plant spread (cm)	Dry matter (r)
Characters height (cm)	Ardhapuri Basrai	1.000 1.000	0.915** 0.931**	0.990** 0.962**	0.951** 0.816*	0.654** 0.783*	0.943** 0.989*	0.932** 0.958*	0.924** 0.916*
Number of leaves	Ardhapuri Basrai		1.000 1.000	0.916** 0.968**	0.901** 0.877*	0.647** 0.903*	0.850** 0.922*	0.849** 0.963*	0.827** 0.956*
Pseudostem diameter (mm)	Ardhapuri Basrai			1.000 1.000	0.977** 0.833*	0.690** 0.864*	0.944** 0.960*	0.949** 0.982*	0.938** 0.971*
Fresh weight of whole plant (g)	Ardhapauri Basrai				1.000 1.000	0.779** 0.797*	0.886** 0.766*	0.927** 0.874*	0.926** 0.876*
Root length (cm)	Ardhapuri Basrai					1.000 1.000	0.544** 0.788*	0.648** 0.847*	0.680** 0.827*
Total leaf area (sq.m)	Ardhapuri Basrai						1.000 1.000	0.927** 0.945*	0.909** 0.906*
Plant spread(cm)	Ardhapuri Basrai							1.000 1.000	0.930** 0.974*

*, ** Significant at 5 and 1 per cent level, respectively.

metabolism. Under saline conditions, the greater osmotic pressure produces a kind of physiological drought (stress) within plants which results in the depression of growth. The findings of Hayward and Wadleigh (1949), Bernstein (1968) and Allison (1964) also supported this view.

In the present studies suppression in plant growth due to salinity have been noticed. As the conductivity increased the adverse effects on plant height, pseudostem diameter and number of leaves were also accentuated.

The significant adverse effects in Ardhapuri and Basrai cultivars started from conductivity of 12 dsm^{-1} and 9 dsm^{-1} of the saturation extract, respectively.

Remarkable decrease in various growth attribute like root length, leaf area/plant, plant spread, fresh weight of whole plant, fresh and dry weight of top and roots with rhizome was observed with the increase in salinity level. Suppression of growth due to high salinity has been also reported in citrus species (Pearson, et al., 1957; Joolka^{and Singh}, 1977; Patil and Bhambota, 1978 a and b; Rajput, 1990), in grapes (Nauriyal and Gupta, 1967; Pandey and Divate, 1976; Joolka et al., 1977 and Hooda et al., 1990), in Guava (Makhija et al., 1980; Kaul, 1981; Patil et al., 1984), in ber (Dhankar and

Dahiya, 1980), in Shishum (Singh and Yadav, 1985), in eucalyptus and acacia (Gupta et al., 1986), in neem persian lilac (Ahmed et al., 1985), Sadaria (1989) and Valia (1989) in different tree species.

Mortality

Mortality symptoms in Ardhapuri and Basrai were noted at salinity level 9 dsm^{-1} . Mortality symptoms appeared in the form of general yellowing, marginal and tip burning which progressed inwards and towards the base of leaves. Inward curling of the leaves and wilting of young leaves was also observed. Subsequently the plants started drying from top to downwards. These are practically the same salt injury symptoms as recorded by Pandey et al. (1985) in bael, Desai and Singh (1980) in guava, Dahiya and Dhankar (1982) in ber, Patil (1980) in pomogranate, Sadaria (1989) in bael, mulberry and eucalyptus.

Relationship between relative growth (fresh weight of whole plant) per cent and levels of salinity was worked out. The theoretical growth values were obtained from the regression equation given below which were derived from the observed values.

Y	=	3287.824	-59.277X	-1.746 X ²	Ardhapuri
	=	S.E.	30.438	1.625	R ² = 0.967
	=	2933.854	-111.091X	-14.058 X ²	Basrai
	=	S.E.	88.913	4.746	R ² = 0.913

Where Y = growth values and X = Salinity level.

The relative per cent growth was plotted against salinity levels for each cultivar. The detailed information regarding salinity tolerance indices in two cultivars of banana is given in Table 57.

Table 57 : Salinity tolerance indices of banana plants.

Cultivars/levels ECe	Growth depression (%)	
	20	50
Ardhapuri	9.5	14.0
Basrai	6.5	12.5

It is evident from the above growth depression data that Ardhapuri cultivar was tolerant as compared with Basrai. On the other hand, Ardhapuri and Basrai showed 50 per cent growth depression in the salinity range of 9.5 to 6.5 dsm^{-1} , respectively.

5.2.2 Correlation coefficients among different Characters in presence of salinity (ECe).

The dry matter of both the cultivars was found to be significantly high correlated with all the characters except root length with fresh weight of whole plant and dry matter in Ardhapuri cultivar of banana (Table 58).

Table 58 : Correlation coefficients among different characters in presence of salinity (Ece)

Character	Cultivar	Plant height (cm)	Number of leaves	Pseudo stem diameter (mm)	Fresh weight of whole plant (g)	Root length (cm)	Total leaf area (sq.m)	Plant spread (cm)	Dry matter (r)
Plant height (cm)	Ardhapuri Basrai	1.000	0.947** 0.946**	0.981** 0.997**	0.871** 0.806	0.502* 0.979**	0.905** 0.954	0.911** 0.987	0.869** 0.938
Number of leaves	Ardhapuri Basrai		1.000 1.000	0.961** 0.939**	0.906** 0.748	0.513* 0.893	0.872** 0.908	0.886** 0.909	0.905** 0.892
Pseudostem diameter (mm)	Ardhapuri Basrai			1.000 1.000	0.923** 0.789	0.486** 0.978	0.901** 0.957	0.935** 0.986	0.904** 0.964
Fresh weight of whole plant (g)	Ardhapuri Basrai				1.000 1.000	0.350 0.809**	0.881** 0.811	0.903** 0.800	0.924** 0.820
Root length (cm)	Ardhapuri Basrai					1.000 1.000	0.454** 0.959	0.433* 0.996	0.406** 0.774
Total leaf area (sq.m)	Ardhapuri Basrai						1.000 1.000	0.851** 0.965	0.858** 0.735
Plant spread (cm)	Ardhapuri Basrai							1.000 1.000	0.902** 0.972

*, ** Significant at 5 and 1 per cent level, respectively

5.3. Effect of chlorides

5.3.1 Effect on the growth

The results of the experiment indicated pronounced decrease in height of the plant, number of leaves, pseudostem diameter, plant spread and leaf area per plant with increasing chloride levels in soil. Both the cultivars ceased to grow at varied levels of chloride. However, in general, plants under higher chloride levels (above 12 me/l) ceased growing earlier.

Chloride, sodium, sulphate and bicarbonate are the ionic species in soil, which adversely affect the plant growth. Among these, chloride sodium and sulphate are commonly seen causing injury. In the present investigation Basrai ceased growing earlier compared to Ardhapuri. Basrai showed low values of chloride (above 24 me/l). Thus, the results in the present investigation are confirmatory with the Chapman (1960), Haas (1950), Salerno (1955), Ehlig and Bernstein (1958), Ehlig (1960), Saglio (1969), Goell (1968), Alexander and Wooham (1968), Wadleigh et al. (1951) and Kadam (1984).

Mortality

Injury symptoms appeared at chloride level 18 me/l in Ardhapuri, while in Basrai it was noticed at 12 me/l onwards. Marginal burning of mature leaves and signs of chlorosis was observed which was extended towards the base of the leaf. In higher chloride level

death of apical portion and drying of shoot tip were observed.

et al.

Bingham (1968) opined that chloride injury may result from excessive accumulation of chloride in leaves, which promotes dehydration and permanent injury to the leaf cells. Kleinhof et al. (1975) reported that the chloride decreased chlorophyll, soluble protein and nitrate in plant and the nitrate reductase activity was lost. Similarly Shabuny and Kashiwad (1979) investigated that chloride salinity reduced chlorophyll content, photosynthesis and respiration. Toxicity symptoms were also reported in grape (Ehlig, 1960), Citrus (Singh, 1966; Chapman, 1969; Nilangekar and Patil, 1978; Kadam, 1984; Zekri and Pearson, 1990), apricot (Ivanova, 1971).

In both the cultivars of banana the fresh weight of whole plant, fresh weight of top and root with rhizome, dry weight of top and root with rhizome, root length, leaf area per plant decreased with the increase in chloride level in the soil. Degree of depression was different at the same level in two cultivars. Relationship between relative growth (fresh weight of whole plant) per cent of each cultivars and levels of chloride was therefore worked out. The theoretical growth values were obtained from the regression equation given below which were derived from the observed value.

$$\begin{array}{llll}
 Y = & 3241.390 & - 32.087X & - 3.688 X^2 & \text{Ardhapuri} \\
 = & \text{S.E.} & 61.000 & 1.620 & R^2 = 0.910 \\
 = & 3093.410 & -27.031X & - 8.364 X^2 & \text{Basrai} \\
 = & \text{S.E.} & 52.03 & 2.497 & R^2 = 0.873
 \end{array}$$

Where Y = growth values and X = salinity level.

The relative per cent growth was plotted against chloride levels for each cultivar. The detailed information regarding chloride tolerance indices in two cultivars of banana is given in Table 59.

Table 59: Chloride tolerance indices of banana cultivars.

Cultivars/levels	Growth depression (%)	
	20	50
Ardhapuri	11.00	20.50
Basrai	9.25	17.25

It is evident from the above growth depression data that Ardhapuri cultivar was tolerant than Basrai.

5.3.2 Correlation coefficients among different characters in presence of soil chloride level

In Ardhapuri and Basrai cultivar (Table 60), the dry matter was significantly correlated with all characters in presence of different soil chloride levels.

The inter relationship was positive.

Table 60 : Correlation coefficients among different characters in presence of soil chloride levels.

Characters	Cultivar	Plant height (cm)	Number of leaves	Pseudo-stem diameter (mm)	fresh of whole plant (g)	Root length (cm)	Total leaf area (sq.m)	Plant spread (cm)	Dry matter (r)
Plant height (cm)	Ardhapuri	1.000	0.977**	0.996**	0.911**	0.992**	0.987**	0.995**	0.951**
	Basrai	1.000	0.991	0.996**	0.999	0.895**	0.991**	0.997**	0.998**
Number of leaves	Ardhapuri		1.000	0.980**	0.919**	0.961**	0.956**	0.963**	0.910**
	Basrai		1.000	0.982**	0.987**	0.982**	0.880**	0.984**	0.986**
Pseudostem diameter (cm)	Ardhapuri			1.000	0.918**	0.993**	0.985**	0.991**	0.956**
	Basrai			1.000	0.996**	0.998**	0.995**	0.997**	0.996**
Fresh weight of whole plant (g)	Ardhapuri				1.000	0.901**	0.898**	0.897**	0.890**
	Basrai				1.000	0.923**	0.990**	0.997**	0.996**
Root length (cm)	Ardhapur					1.000	0.989**	0.912**	0.952**
	Basrai					1.000	0.994**	0.947**	0.993**
Total leaf area (sq.m)	Ardhapuri						1.000	0.980**	0.952**
	Basrai						1.000	0.991**	0.963**
plant (cm)	Ardhapuri							1.000	0.964**
	Basrai							1.000	0.971

*, ** Significant at 5 and 1 per cent level, respectively.

5.4 Effect of bicarbonates

5.4.1 Effect on the growth

The results of the experiment indicated decreasing values of growth parameters with increasing bicarbonate level in soil. Although the rate of growth was slower at the higher level of bicarbonate. Basrai cultivar continued till the termination of the experiment. This indicated that adverse effects of bicarbonate were not as pronounced as those of chloride. C-hapman (1960) had rightly pointed out that among ionic species, chloride, sodium, sulphate and bicarbonate are commonly causing injuries to plant in the decending order. According to Harding and Chapman (1960) and USDA Salinity lab. Staff (1954) the range of bicarbonate in the soil is from 0.1 to 20 me/l of extract and the satisfactory range in soil is 0.1 to 5 me/l. Chapman (1960) opined that owing to modifying influences of soil, climate, rootstock, scion and characters of accompanying anions, it is difficult give precisely the critical limit of bicarbonate.

Paliwal and Maliwal (1971) observed that the specific effect of bicarbonate ions seems to inhibit the metabolic processes in the plant, which may be responsible for the reduction of crop growth and absorption of nutrients. In the present investigation most adverse effects of bicarbonates were observed at 20 and 15 me/l level in

Ardhapuri and Basrai, respectively. Kadam (1984) notice similar type of effects in different citrus rootstocks.

Mortality.

Symptoms of mortality in Ardhapuri and Basrai were noticed at bicarbonate level of 20 me/l. Mortality symptoms appeared in the form of general yellowing, marginal and tip burning which progressed inwards and towards the base of the leaves. Inward curling of the leaves was also observed. These type of results were also observed in Kichilli, Cleopatra tangerin and to some extent in Troyer citrange and Trifoliate orange (Kadam, 1984).

Relationship between relative growth (fresh weight of whole plant) per cent and levels of bicarbonate was worked out and is graphically showing Fig. . The theoretical growth values were obtained from the regression equation given below which were derived from the observed values.

$$\begin{array}{llll}
 Y & = & 3183.22 & - 16.134X - 0.903X^2 & \text{Ardhapuri} \\
 & = & \text{S.E.} & 9.273 & 0.313 & R^2 = 0.923 \\
 & = & 3114.85 & - 13.474X - 0.888X^2 & \text{Basrai} \\
 & = & \text{S.E.} & 8.494 & 0.272 & R^2 = 0.986
 \end{array}$$

Where Y = growth values and X = bicarbonate level

The relative per cent growth was plotted against bicarbonate levels for each cultivar. The detailed

information regarding bicarbonate tolerance indices in two banana cultivars is given in Table 61.

Table 61 : Bicarbonate tolerance of banana cultivars.

Cultivar/levels Bicarbonate (me/l)	Growth depression (%)	
	20	50
Ardhapuri	20.5	26.5
Basrai	24.5	34.5

The data showed that Ardhapuri is tolerant than Basrai cultivar when growth depression was taken into consideration.

5.4.2 Correlation coefficients among different characters in presence of soil bicarbonate levels

Highly significant and positive correlation were observed among 8 characters in presence of soil bicarbonate levels in both cultivars except plant spread with pseudostem diameter, number of leaves, fresh weight of whole plant, root length, total leaf area and dry matter content in Ardhapuri (Table 62).

5.5 Effect of sulphates

5.5.1 Effect on the growth

On consideration of cultivars, adverse effects on growth were noticed above 28 and 21 me/l of sulphate

Table 62: Corrdation coefficients among different characters in presence of soil bicarbonate levels.

Character	Cultivar	Plant height (cm)	Number of leaves	Pseudo stem diameter (mm)	Fresh weight of whole plant (g)	Root length (cm)	Total leaf area (sq.m)	Plant spread (cm)	Dry matter (r)
Plant height (cm)	Ardhapuri	1.000	0.969**	0.996**	0.797**	0.992**	0.979**	0.417*	0.989**
	Basrai	1.000	0.888**	0.992**	0.962**	0.989**	0.917**	0.980**	0.940**
Number of leaves	Ardhapuri		1.000	0.968**	0.766**	0.950**	0.935**	0.387*	0.947**
	Basrai		1.000	0.877**	0.896**	0.880**	0.823**	0.923**	0.884**
Pseudostem diameter(mm)	Ardhapuri			1.000	0.800**	0.991**	0.973**	0.403*	0.986**
	Basrai			1.000	0.964**	0.986**	0.926**	0.982**	0.939**
Fresh weight of whole plant (g)	Ardhapuri				1.000	0.824**	0.740**	0.418*	0.786**
	Basrai				1.000	0.959**	0.921**	0.957**	0.945**
Root length (cm)	Ardhapuri					1.000	0.970**	0.398*	0.988**
	Basrai					1.000	0.927**	0.984**	0.924**
Total leaf area (sq.m)	Ardhapuri						1.000	0.391*	0.975**
	Basrai						1.000	0.914**	0.922**
Plant spread(cm)	Ardhapuri							1.000	0.354*
	Basrai							1.000	0.942**

*, ** Significant at 5 and 1 per cent level, respectively.

level in Ardhapuri and Basrai cultivars, respectively. After 180 days of planting effect was pronounced on plant height, number of leaves and pseudostem diameter and plant spread. In general, good growth was observed under control than rest of the levels.

The specific effects of sulphate ions is to inhibit the metabolic process in the plants, which may be responsible for reduction of crop growth and absorption of nutrients. Suppression of growth due to high sulphate has been reported in citrus species (Zusman, 1956; Kadam, 1984 and Rajput, 1990), Cherry (Dilley et al., 1958 and Porups, 1958), in Siberian larch (Cartir, 1980), pea nut (Chavan and Koradge, 1980) and bush bean (Mohmed and Abethadi, 1985).

Mortality

Injury symptoms appeared at sulphate level 21 me/l in both the cultivars. Marginal burning which progresses inward and towards the base of the leaf. General yellowing, leaf scorching and inward curling was also observed. These are practically the same injury symptoms as recorded by Joolka et al. (1976) in grape and Rajput (1990) in citrus rootstocks.

Various growth attributes like root length, leaf area per plant, fresh weight of whole plant, fresh and dry weight of top and root with rhizome were observed

remarkably reduced with the increase in sulphate salinity. Similar type of results were recorded by Zusman (1956) , Dilley et al. (1958), Porups (1958) Cartir (1980), Kadam (1984) and Rajput (1990) in different fruit crops.

Relationship between relative growth (fresh weight of whole plant) per cent and levels of sulphate was worked out and is graphically shown in Fig. . The theoretical growth values were obtained from the regression equation given below which were derived from the observed values.

$$\begin{array}{llll}
 Y & = & 3306.00 & - 20.507 X - 0.560 X^2 & \text{Ardhapuri} \\
 & = & \text{S.E.} & 15.557 & 0.355 & R^2 = 0.963 \\
 & = & 3118.05 & - 6.861 X - 0.691 X^2 & \text{Basrai} \\
 & = & \text{S.E.} & 10.145 & 0.232 & R^2 = 0.977
 \end{array}$$

The relative per cent growth was plotted against levels for each cultivar. The detailed information regarding sulphate tolerance indices in two cultivars of banana is given in Table 63.

Table 63: Sulphate tolerance of banana cultivars.

Cultivar/levels (me/l)	Growth depression (%)	
	20	50
Ardhapuri	21.5	31.5
Basrai	21.5	36.5

Table 64: Correlation coefficients among different characters in presence of soil sulphate levels.

Character	Cultivar	Plant height (cm)	Number of leaves	Pseudo stem diameter (mm)	Fresh weight of whole plant (g)	Root length (cm)	Total leaf area (sq.m)	Plant spread (cm)	Dry matter (r)
Plant height (cm)	Ardhapuri	1.000	0.976**	0.996**	0.993**	0.967**	0.969**	0.993**	0.992**
	Basrai	1.000	0.906	0.966	0.969	0.940	0.916	0.975	0.955
Number of leaves	Ardhapuri		1.000	0.964**	0.979**	0.935**	0.937**	0.962**	0.975**
	Basri		1.000	0.826	0.858	0.963	0.833	0.875	0.897
Pseudostem diameter (mm)	Ardhapuri			1.000	0.987**	0.972**	0.972**	0.996**	0.987**
	Basri			1.000	0.945	0.889	0.909	0.983	0.904
Fresh weight of whole plant	Ardhapuri				1.000	0.946**	0.956**	0.981**	0.994**
	Basrai				1.000	0.915	0.878	0.961	0.932
Root length (g)	Ardhapuri					1.000	0.974**	0.986**	0.946**
	Basrai					1.000	0.863	0.937	0.030
Total leaf area (sq.m)	Ardhapuri						1.000	0.976**	0.963**
	Basrai						1.000	0.893	0.897
Plant spread (cm)	Ardhapuri							1.000	0.980**
	Basrai							1.000	0.920

*, ** Significant at 5 and 1 per cent respectively.

The data showed that Basrai is tolerant than Ardhapuri cultivar when growth depression is taken into account.

5.5.2 Correlation coefficients among different

Characters in presence of soil sulphate levels.

The all characters in presence of sulphate levels were highly significant, positively correlated with dry matter in both Ardhapuri and Basrai (Table 64).

5.6 Effect of ESP on the physiological parameters of banana cultivars.

5.6.1 Chlorophyll

The total chlorophyll content in the leaves of both cultivars viz., Ardhapuri and Basrai decreased significantly with increasing levels of soil ESP. The reduction in chlorophyll content may be due to the reduced uptake of Ca, Mg and P and increased uptake of sodium. Some of the micronutrients viz., Zn, Fe, Mn are also responsible for the synthesis of chlorophyll, but in sodic soils, availability of these micro nutrients is reduced, which tends to decrease the Chlorophyll content in the leaves . Such type of results were also reported in citrus rootstocks (Patil 1976; Patil and Bhambota, 1978 c; Kadam, 1984), ber (Patil et al., 1981 and Pandey, 1984), pomogranate (Patil and Patil, 1982), bael seedlings (Pandey et al., 1985; Tewari, 1985), and in tree species (Sadaria, 1989; Valia, 1989). These investigators supported the findings of present investigation.

5.6.2 Effect of ESP on the chemical composition of banana cultivars

Nitrogen

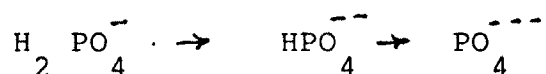
The N content in leaves of Ardhapuri and Basrai increased with the increase in ESP upto certain level, but it was not consistent. The same, however, decreased at the highest ESP level. In the experiment of Patil (1980) the N content was also increased in leaves with the increase in ESP in pomegranate, ber, chiku and fig but it was not consistent. It again decreased at high level of ESP. In the present investigation the N content of the roots of both the cultivars was decreased under high ESP. It seems that sodium interferes in the N metabolism of plants. Divate (1974) and Pandey and Divate (1976) also putforth similar observations and reported that under high salt concentration, the level of protein decreased due to its breakdown in grapes. Similar type of results were reported in guava(Desai and Singh 1979), tamarind, eucalyptus (Sadaria, 1989), Cashew, coconut, markingnut, soapnut, karonda and drumstick (Valia, 1989).

Phosphorus

The reduction in P content of leaves and roots due to increasing ESP level was observed in both the cultivars. Similar results of reduced P availability under increased ESP have been observed in citrus

rootstocks (Patil, 1976; Kadam, 1984), Mango (Thakur, et al., 1982), Pomegranate (Patil and Patil, 1982), jamun (Patil and Patil, 1983a) and tree species (Sadaria, 1989 and Valia, 1989).

Phosphorus is not available in sodic soils, though it may be present in plenty. 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 phosphate equilibria get shifted significantly with the change in pH. As the pH increased the P form in the soil also get shifted in the following way (Singh, 1973).



He further explained that H_2PO_4^- is most readily available, while more energy is required for the absorption HPO_4^{--} and PO_4^{---} is the least 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.

Potassium

In the leaves and roots, K content decreased with successive increase in ESP LEVELS. Similar results have been reported by Patil and Bhambota (1977) in citrus rootstocks, Thakur et al. (1982) in mango, Patil and

Patil (1982) in pomegranate, Patil and Patil (1983a) in jamun, Mehta (1982) in ber, in citrus rootstocks, (Kadam, 1984; Rajput, 1990), tamarind, woodapple, bael, khirni, eucalyptus and persian lilac by Sadaria (1989).

Reduction in absorption of K under high ESP levels by plants shows that Na + K are antagonistic in the absorption. According to Heiman (1966) absorption of K in presence of high Na requires more energy. This energy can be deprived from oxygen resulting in the reduced uptake of K.

Calcium and magnesium

Calcium and magnesium contents in the leaves and roots declined by the increasing ESP levels. A sharp decline in calcium and magnesium contents in leaves was observed at and above ESP 24. Similar results of decreased accumulation of Ca and Mg have been reported by Jones et al. (1957) in young lemon plants buded on different rootstocks, in citrus (Patil, 1976; Kadam 1984; Rajput, 1990), Thakur et al. (1982) in mango Patil and Patil (1982) in pomegranate, Patil and patil (1983a) in jamun, Patil et al. (1980) and Mehta (1982) in ber, Sadaria (1989) in tamarind, woodapple, mulberry khirni eucalypts and Valia (1989) in cashew, coconut, markingnut, soapnut and Karonda.

Sodic soils are deficit in Ca because it is precipitated in the soil in the presence of bicarbonate ions. Since the soil with high ESP contains more sodium on the exchange complex, absorption of Na increases and those of Ca and Mg decreases. This is as per the complementary ion effects as explained by Jenny and Ayers (1939). Sodium is relatively loosely held on the exchange complex than other cations and hence the replaceability of other cations 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 Ca 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.

Sodium

Manifold increase in Na due to higher ESP was seen in both the cultivars. Increased sodium was reported in citrus rootstocks (Patil, 1976; Kadam, 1984; Rajput, 1990), in mango (Thakur et al. 1982), in pomogrenate (Patil and Patil, 1982; Dor-ing and Ludders, 1986), and Jamun (Patil and Patil. 1983 a) with increase in soil ESP levels. Similar results were also observed in

aonla (Tewari, 1983), in jujube (Singh et al., 1983) in bael (Pandey et al., 1985) in palms (Prema^{et al.}, 1987) in tamarind, woodapple, neem, mulberry, bael (Sadaria, 1989) and in cashew, markingnut, passion fruit (Valia, 1989). The two cultivars viz., Ardhapuri and Basrai have accumulated different concentrations of Na at the same level. The toxic limits of sodium in leaves on dry weight basis for Ardhapuri and Basrai were 0.81 and 0.68 per cent, respectively

Ca: Na and Ca + Mg + K : Na

With the increase in soil ESP the Ca : Na and Ca + Mg + K: Na reduced considerably in both the cultivars. These results are in agreement with those reported by Patil (1980) in guava, pomegranate, custard apple, jamun, ber, chiku and fig and in citrus rootstocks (patil, 1976). Also Sadaria (1989) in tamarind, mulberry, khirini, bael, eucalyptus, persian lilac and Valia (1989) in cashew, markingnut and passion fruit reported similar type of results. In the present investigation Ca:Na and Ca+Mg + K : Na was the lowest in Ardhapuri followed by Basrai when the ESP level was 48. This may be one of the important reason that why these cultivars have the lowest sodium tolerance. Root composition ratio has also shown that these two cultivars are inferior to the alkaline media.

The harmful effects of higher ESP may 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 need to be considered. Bajwa et al. (1975) also emphasized the need of taking into account the absorption of Ca, Mg and K along with sodium by the plant species while studying the sodium tolerance of plants.

Zinc

Increasing levels of ESP caused the significant decrease in the concentration of Zn, in the leaves and roots of both the cultivars. Similar results were found in citrus rootstock (Patil 1976), pomogranate, custard apple, jamun and fig (Patil, 1980), ber (Patil et al., 1981; Mehta, 1982 and Nirlepkmargda, 1990) and in tree species (Sadaria, 1989 and Valia , 1989). However, Present investigation differ from Singh et al. (1983) they found 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) solubility diagram also showed a negative correlation between available Zn and pH of the soil.

Iron

With the increase in ESP the Fe content of

leaves decreased. A significant decrease in iron content in leaves and roots of both the cultivars was observed. From this, it is clear that under high ESP the Fe absorption was adversely affected. These results are in agreement with those reported in citrus rootstocks (Patil 1976), pomogranate (Patil and Patil 1982), ber (Patil et al. 1981 and Nirlepkumar ^{et.al.} 1990). Sadaria (1989) in tamarind woodapple, mulberry eucalyptus, neem, bael, khirni and persian lilac. However Singh et al. (1983) found that increase in Fe under high ESP in jujube and guava. As per the solubility diagram presented by Lindsay (1972) ferric ion mostly contribute to the total soluble Fe in well aerated soils. The Fe ⁺⁺⁺ activity in the 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

Decrease in Mn content in the leaves and roots of both cultivars was observed with successive increase in the levels of ESP except in leaves of Basrai. In conformity to this, decreased Mn content was reported in citrus rootstocks (Patil, 1976), pomegranate (Patil and Patil, 1982), ber (Mehta, 1982 and Nirlepkumar ^{et.al.} 1990) , Jujube and guava (Singh et al., 1983), tamarind,

woodapple, khirni, neem, bael, eucalyptus (Sadaria 1989), and coconut, phalsa, markingnut, cashew and drumstick (Valia, 1989) with increase in soil ESP level. 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. (1953 and 1959) have also reported that high ESP adversely affected Mn absorption by citrus seedlings.

Copper

The Cu content varied with the cultivars and ESP levels. The Cu content of leaves and roots of both the cultivars decreased at higher levels of ESP. Similar results were also reported by Patil (1976) in citrus rootstocks, Patil et al. (1981) and Nirlep Kumar ^{et al.} (1990) in ber, Patil (1980) in guava, pomegranate, jamun, Sadaria (1989) in tamarind, woodapple, bael, khirni, eucalyptus, neem and persian lilac. The decline in Cu content may be due to the decreased solubility of Cu in the soil under alkali conditions as shown by Lindsay (1972).

It may be tempting to conclude that low sodium tolerance indices of Ardhapuri and Basrai appears to be mainly due to basic physiological nutritional disorder. Under the high ESP levels, these two cultivars failed to absorb essential elements in enough quantity. These

cultivars also absorbed relatively high amount of Na resulting in the spectacular decrease in the ratios of Ca and Na and $Ca + Mg + K : Na$. However, the fundamental physiological causes of plant in tolerance to high ESP rather than secondary effects like nutritional deficiency of nutrients due to interactive effects of Na with other cations. Ardhapuri cultivar showed slightly better tolerance than Basrai.

5.7 Effect of salinity on physiological parameters

5.7.1 Chlorophyll

In saline soil, total chlorophyll content in the leaves of both the cultivars decreased with the increasing levels of soil salinity. 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 and Rajput, 1990), grapes (Divate and Pandey, 1981), guava (Kaul, 1981), neem and persian lilac (Ahmed et al., 1985) and Sadaria (1989) in tree species. The decrease in chlorophyll content may be attributed with the reduction in the uptake of Ca, Mg, Zn, Fe, Mn and increased uptake of Na.

5.7.2 Effect of salinity on the chemical composition of banana plant

Nitrogen

The results showed that the N content decreased

as the salinity levels increased in Ardhapuri but it was not consistent while in Basrai banana N content increased upto certain level (i.e. upto 15 dsm^{-1}) and it again decreased at highest salinity level. The N content gradually decreased in the roots of both the varieties with increase in salinity level. It was significantly low at higher levels of salinity. The nitrogen metabolism in plants in saline substrate get disturbed due to protein breakdown (Strongonov, 1962). Increase in N content was reported by Divate and Pandey (1981) in grape leaves, in guava (Desai and Singh, 1979) and Patil et al., 1984), Sadaria (1989) in tamarind, mulberry and khirni. Patil (1976) however, reported decrease in N content at higher soil salinity in Kharna Khatta and Carrizo rootstocks of citrus. Joolka and Singh (1977) and Rajput (1990) in citrus rootstock and Makhija et al. (1980) in guava also found decrease in N content in the leaves under higher salinity.

Phosphorus

Phosphorus content in the leaves and roots showed decreasing trend with increasing Salinity level in soil in both the cultivars. This suggest that the uptake of P under high salinity was reduced. Numerous evidences are available corroborating these findings, Ivanova (1972) in stone fruits, Desai and Singh (1979) in guava, Jindal et al. (1979) in mango, Joolka and Singh (1977), Patil and Bhambota (1980) and Rajput (1990) in citrus

rootstocks, and Sadaria (1989) in tamarind woodapple, mulberry, bael, eucalptus, neem and persian lilac tree species.

Potassium

Potassium content showed decreasing pattern with increasing salinity levels in the leaves and roots of both cultivars. A sharp decline was noticed at and above 6 dsm^{-1} . The decrease in K content in various fruit crops was also reported by Bernstein (1965a), Pearson et al. (1957), Kanwar and Bhambota (1968), Joolka and Singh (1977), Patil and Bhambota (1980), Rajput (1990) in citrus species; Desai and Singh (1979), Patil (1980), Makhija et al. (1980) in guava; Pandey et al. (1985) in bael; Divate and Pandey (1981) in grape and Sadaria (1989) in tamarid woodapple, mulberry, bael, khirni and equalptus under higher salinity treatments, thus supporting the findigs of the present investigation.

Calcium

The leaf and root Ca decreased with the increase in salinity levels but the extent of reduction differed with the cultivars. The reduction of Ca in leaves and roots may be attributed to the relatively higher ratio of Na:Ca and relatively more common ion effect of Na in the soil solution. The results in the present investigations are in agreement with Pearson et al. (1957), Patil and Bhambota (1978a and 1980), Patil, (1980), Dasai and Singh

(1979), Sadaria (1989) and Rajput (1990). They reported decreased concentration of Ca in the leaves of various fruit crops under higher salinity. But contrary to these results 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 and roots decreased with successive increase in salinity levels in both the species. Reduction in Mg content with increasing salinity may be due to high proportion of Na as compared to Mg. In conformity of these results, Patil (1980) recorded lower Mg content in the leaves and roots under higher salinity in guava, pomegranate, fig, chiku, custard apple, jamun and ber. Similar results were also noticed in citrus rootstock (Patil and Bhambota, 1978 a and 1980) and in guava leaves (Desai and Singh 1979). In contrary to these results increasing trends of magnesium was reported in ber (Dahiya and Dhankar, 1982; Hooda et al., 1990), Divate and Pandey (1981) in grapes, Makhija et al., 1980), in guava and Rajput (1990) in citrus rootstocks. This may be due to fact that Na salts were not applied to built up salinity level.

Sodium

With the increase in salinity, the successive increase in sodium content in the leaves and roots of both the species was observed. In general, this increase was highest in Basrai followed by Ardhapuri. Pearson et al. (1957) found a direct relationship between conductivity of saturation extract and the concentration of Na in the leaves of citrus.

These results are in line with Lilleland et al. (1945) and Brown et al. (1953) in stone fruits, Desai and Singh (1979) for guava. Jindal et al. (1979) for mango, Patil and Bhambota (1980) and Rajput (1990) for citrus rootstocks, Dhankar et al. (1978) for phalsa, Patil (1980) for guava, pomegranate, ber, jamun, chiku and fig.

Zinc

The Zn content of leaves in both cultivars decreased significantly with the increase in salinity. This decrease was highest in Ardhapuri cultivar. The salinity resulted in decrease in availability of Zn due to higher pH and precipitation and formation of insoluble complex. These results are supported by Patil (1976), Patil (1980), Patil et al. (1984) and Sadaria (1989) in different fruit crops.

Iron

Under high salinity, the leaf and root-Fe decreased significantly in both the cultivars. This

reveals that absorption of Fe was also adversely affected under saline conditions. In general, more Fe content accumulated in roots than leaves. The salinity resulted in decreased availability of Fe content may be due to higher pH in soil where it is difficult to keep Fe in soluble forms to be available to plants. Similar results were recorded by Abdel Messih et al. (1979) in citrus rootstocks, Patil (1980) also recorded similar results in guava, pomegranate, custard apple, ber, jamun and fig under high salinity. However Fe content of orange leaves increased under higher levels of salinity as per the findings of Bhambota (1965) and Patil et al. (1984) in citrus rootstocks.

Manganese

Under high salinity the Mn content of leaves and roots decreased significantly in both the cultivars. But Basrai was affected at relatively lower levels of salinity as compared to Ardhapuri. The Mn content significantly decreased at 9 dsm^{-1} onwards. Decrease in the Mn content under saline conditions may be due to the increase in pH as demonstrated by Lindsay (1972). Similar findings are also reported by Patil (1980) in seven fruit crops and Sadaria (1989) in eight tree species.

Copper

The Cu content in the leaves and roots of both the cultivars decreased with the increase in salinity but

Basrai cultivar showed significant decrease. It was significantly reduced from 9 dsm^{-1} onwards. The salinity resulted in a decreased availability of copper due to higher pH and precipitation and formation of insoluble complex. Significant decrease in Cu content was reported in guava and pomegranate (Patil 1980) and Sadaria (1989) in different tree species while in other crops namely custard apple, ber jamun, fig and chiku decrease in Cu content was not very conspicuous (Patil, 1980). Bhambota (1965) also reported that Cu content was depressed by the higher levels of salinity in orange leaves.

5.8. Effect of chloride on the physio-logical parameters of banana cultivars

5.8.1 Chlorophyll

With an increasing chloride level, the total chlorophyll content in the leaves decreased significantly in both the cultivars of banana. The reduction in chlorophyll content may be due to the reduced uptake of Ca and P and increased uptake of Na. Decrease in micro nutrient (Zn, Fe and Mn) affected synthesis of chlorophyll. Similar type of results were recorded by Shaybuny and Kashiwad (1979) in Acacia saligna and in citrus rootstocks (Kadam, 1984)

5.8.2 Effect of chloride on the chemical composition

Nitrogen

With the increase in chloride level, the leaf N

content of both the cultivars increased upto middle level of chloride (18 me/l). The same however, decreased at higher level of chloride. The N content of roots of both Ardhapuri and Basrai decreased with the increase in chloride concentration. Kadam (1984) working on citrus rootstocks reported similar type of findings.

Phosphorus

The phosphorus content in leaves and roots of both Ardhapuri and Basrai cultivars decreased with successive increase in chloride level. Numerous evidences are available corroborating these findings, Ivanova (1971) in stone fruit, Joolka et al. (1979) in grape and Kadam (1984) in citrus rootstock.

Potassium

Potassium content showed decreasing pattern with the increasing chloride levels in the leaves and roots of both Ardhapuri and Basrai. A sharp decline was noticed at and above 6 me/l. Similar type of decrease in K content was noticed in grape fruit (Pearson et al., 1957), citrus rootstocks (Cooper et al., 1958 and Kadam, 1984), pecan seedlings (Frauque, 1968), cherry and peach (Dilley et al., 1958), stone fruit (Ivanov, 1971), grapes (Joolka, 1972), Mango (Jindal, et al., 1975) sweet cherry, pear and apricot (Ivanov and Ivanova, 1976) with increasing chloride concentration.

Calcium

Calcium content in the leaves and roots except in leaves of Ardhapuri and Basrai banana, a sharp decline was observed at 12 me/l. Similar type of results of decreased accumulation of Ca have been reported by Pearson et al. (1957), Zid and Boukharis (1977) in citrus rootstocks (Kadam, 1984) while increase in chloride level increased Ca content in sour orange rootstock (Cooper et al., 1958) and in grapes (Joolka et al., 1978).

Magnesium.

The Mg content in the leaves and roots increase with successive increase in chloride levels in Ardhapuri cultivar while reverse trend was noticed in Basrai. Increase in Mg content with the increased level of chloride was noticed by Joolka et al. (1977) in grape and in citrus rootstocks (Kadam, 1984). While decrease in Mg content was reported in grapefruit (Pearson et al. 1957). and Peynado, 1962).

Sodium

Increase in the Na content of leaves and roots with the successive increase in chloride level was noticed in both the cultivars of banana. The rate of sodium accumulation was more in Basrai as compared to Ardhapuri. Similar type of results were noticed in different citrus species (Pearson et al., 1957; Bernstein 1968; Hyder, 1969; Wutcher and Shull, 1972 and Kadam 1984).

Zinc

The Zn content of leaves and roots of both the cultivars decreased significantly with the increase in chloride level except in the leaves of Ardhapuri in which the decrease was consistent. However, Dilley et al., 1958) noticed no marked effect were observed in Zn content in apple, cherry, peach and grape when chloride supply was increased.

Iron

Under high chloride levels, the leaf and root Fe decreased significantly in both the cultivars this shows that the absorption of Fe was adversely affected under saline conditions. Wordlaw (1938) and Marchel and Martin Preval (1971) noticed that lack of P availability in soil may lead to the unavailability of iron in soils, Dilley et al. (1958) found no marked effect on Fe content when supply of chloride was increased in apple, cherry, peach and grapes.

Manganese

An increase in chloride level significantly decreased Mn contents of leaves and roots of both the cultivars. Significant decrease in Mn content was recorded above 12 me/l of chloride level. Highest Mn content was reported in control plants as compared to rest of the levels. Dilley et al. (1958) also reported similar results in apple, cherry and peach.

Copper.

A significant decrease in copper content of both Ardhapuri and Basrai was recorded with the increase in chloride levels. The decrease was more pronounced at 12 me/l in Basrai as compared to Ardhapuri. No marked effect on copper content was noticed in apple, cherry, peach and grape when supply of chloride was increased (Dilley et al 1958).

5.9 Effect of bicarbonate on physiological parameters.

5.9.1 Chlorophyll

Decreasing trend of total chlorophyll content in the leaves with the increase in bicarbonate level was recorded in both the cultivars of banana. In saline soils availability of Ca, Mg K, Zn, Fe, Mn get reduced leading to the imbalance of nutrients which indirectly affects chlorophyll synthesis in the plants. Bhamboṭa and Kanwar (1970) and Kadam (1984) reported similar type of decline of chlorophyll content in different rootstocks with increase in bicarbonate level.

5.9.2 Effect of bicarbonate on chemical composition of banana

Nitrogen

A significant decrease in N content of both the cultivars was noticed when bicarbonate level in soil was increased. In general, N content in roots was more as

compared to leaves. In the experiment conducted by Desai and Singh (1979) the leaf - N content was decreased in guava cultivar Allahabad safeda with the successive increase in bicarbonate level. Kadam (1984) also found similar type of results in citrus rootstock.

Phosphorus

With the increase in bicarbonate salinity, a significant decrease in P content of Ardhapuri and Basrai cultivars was noticed. Similar type of results of reduced P availability under increased bicarbonate level have been observed in guava (Desai and Singh, 1979) and in citrus rootstock (Kadam, 1984).

Potassium

In the leaves and roots of both the cultivars, K content decrease significantly with the increase in bicarbonate level. The accumulation of K content was in general, more in roots as compared to leaves. The decrease was more pronounced after 15 me/l of bicarbonate level. Desai and Singh (1979) in guava and Kadam (1984) in citrus rootstock reported similar type of decline under higher bicarbonate salinity.

Calcium

There was reduction in the Ca content in the leaves and roots of both the cultivars with each

increment of bicarbonate level. In general, accumulation of calcium was more in leaves as compared to roots. Similar finding were reported by Desai and Singh (1979) in guava and Kadam (1984) in citrus rootstocks. Richard (1954) revealed that there is tendency for bicarbonate to cause precipitation of Ca in soil thereby increasing exchangeable sodium. An inverse relationship between concentration of HCO_3 and uptake of Ca in fruit trees was reported by Kessler (1958).

Magnesium

Magnesium content in the leaves and roots declined by the increasing bicarbonate level. A sharp decline was observed at and above 15 me/l. Similar results of decrease accumulation of Mg have been reported by Desai and Singh (1979) in guava furthermore, they reported that the increase and decrease was proportional to the concentration of salts. Kadam (1984) in his studies noticed that there was decrease in Mg content with successive increase in bicarbonate level.

In alkaline soils, availability of Na increases which adversely affect the absorption of Mg (Thorne, 1944). This is as per the complementary ion effects as explained by Jenny and Ayers (1939). Sodium is relatively loosely held on the exchange complex, hence the replaceability of other cations is low. These leads to the less availability.

Sodium

With the increase in bicarbonate salinity, the Na accumulation tend to be increased generally. In Ardhapuri cultivar Na accumulation was more in leaf while it was more in roots of Basrai.

Sodium is relatively loosely held on the exchange complex than other cations thus leads to the unavailability of Ca and Mg cations. In alkali soils sodium is abundantly available in the soil complex (Thorne, 1944).

Zinc

A significant decline in the zinc content in leaves and roots was noticed in both Ardhapuri and Basrai cultivars. A sharp decline in Zn content was found above 15 me/l of bicarbonate level. Lindsay's (1972) solubility diagram showed a negative correlation between Zn and pH of soil, thus agreeing with the findings of the present investigation.

Iron

In general, Fe content was found more in roots as compared to leaves of banana. A general decrease in iron content in leaves and roots of both the cultivars of banana was noticed. Maximum content of Fe was recorded in control as compared to the bicarbonate levels studied.

The availability of Fe is reduced due to solubility of Fe ⁺⁺⁺ ions in the soil (Lindsay, 1972).

Manganese

Decrease in Mn content in the leaves and roots of Ardhapuri and Basrai was recorded. The decrease was more sharp above 15 me/l of bicarbonate level. The unavailability of Mn may be due to increase pH of soil (Lindsay, 1972).

Copper

Highest amount of copper was recorded in the control plants in both the cultivars of banana. In general, with the increase in bicarbonate level, copper content in leaves and roots of Ardhapuri and Basrai decreased significantly, Salinity decreased availability of copper due to higher pH and precipitation and formation of insoluble complex in the soil (Allison, 1964)

5.10 Effect of sulphate on the physiological parameters.

5.10.1 Chlorophyll.

Considering only the effect, chlorophyll content was highest in Ardhapuri followed by Basrai. In general, decrease in chlorophyll was observed due to successive increase in sulphate level. The ill effects may be attributed to the accumulation of sulphate ions in toxic amounts in the medium. Similar results were also

reported by Pandey (1981) in guava, Mohamed and Abetihadi (1985) in bush bean, Rajput (1990) in ten different root stocks of citrus while the contradictory results were reported by Bhambota and Kanwar (1970) in sweet orange.

5.10.2 Effect of sulphate on the chemical composition Nitrogen

On considering only the effect of cultivar highest leaf N was recorded in Basrai. There was decrease in N content of leaves and roots of both the cultivars with each increase in sulphate level but the decrease was not consistent in Basrai. The findings of Ivanov and Ivanova (1976) in peach, apricot, sweet cherry, pear trees and Rajput (1990) in citrus rootstocks are in line with the results of the present studies.

Phosphorus

Without considering the sulphate levels, Ardhapuri cultivar noted highest leaf P followed by Basrai. A significant decrease in P content with the successive increase in bicarbonate level was noticed from 21 me/l of bicarbonate level. Walter and Ballinger (1962) in blue berry, Jindal et al (1979) in mango and Rajput (1990) in citrus rootstocks reported similar type of results while no effect in apple, cherry, peach and grape was noticed by Dilley et al. (1958) with increase in bicarbonate level.

Potassium

There was significant increase in leaf and root K content with each increment of sulphate level. Maximum leaf - K content was noticed at highest level of sulphate salinity (42 me/l) while lowest root-K was observed in control in both the cultivars of banana. Similar results of increased accumulation of K have been reported by Ivanov and Ivanova (1976) in peach, apricot, sweet cherry, pear and Rajput (1990) in citrus rootstock while Porups (1958) in cherry recorded very little effect in contrary to these results. Edelburger (1978) in grape noticed that K content decreased with increase in sulphate levels of the media.

Calcium

Leaf and root Ca decreased with an increase in level of sulphate in both the cultivars. In general, maximum Ca content was reported in control while minimum in highest sulphate level. The present results are in agreement with those of Zusman (1956) in sour orange, Dilley et al. (1958) in cherry and peach, Porups (1958) in cherry, Edelburger (1978) in grape and Rajput (1990) in citrus rootstocks.

Magnesium

While considering only the effect of cultivar, Ardhapuri showed highest leaf and root Mg as compared to Basrai.

Significantly more leaf Mg was noted under 28 and 21 me/l of sulphate level in Ardhapuri and Basrai cultivar, respectively. In general, Mg content was increased upto some level and again it was decreased. In conformity to this, decreased Mg content was reported in cherry (Porups, 1958), in grape (Ehlig, 1960 and Edelburger, (1978) in mango (Jindal, 1979) and in citrus species (Bhambota and Kanwar, 1970 and Rajput 1990).

Sodium

With the increase in sulphate salinity, leaf and root-Na content was decreased significantly. Accumulation of Na in leaf and root of Basrai was highest as compared to Ardhapuri. Lowest content of Na was noticed in control plants of both the cultivars. Similar type of results were reported by Bhambota and Kanwar (1970) in citrus and Doring and Luddres (1980) in pomogranate while in contrast to these results Chavan and Koradge (1980) in peanut and Zekri and Pearson (1990) in citrus recorded decrease in Na content with the increase in supply of sulphate.

Zinc

A significant decrease in Zn content in leaves and roots of both the cultivars of banana was noticed. Zinc content was declined at and above 21 me/l and 14 me/l in Ardhapuri and Basrai cultivars, respectively.

In general, Zn accumulation was more in roots as compared to leaves. Similar type of findings were reported by Porups (1958) in cherry and Edelburger (1978) in grape while Dilley et al. (1958) found no marked effect on Zn content with the increase in sulphate level.

Iron

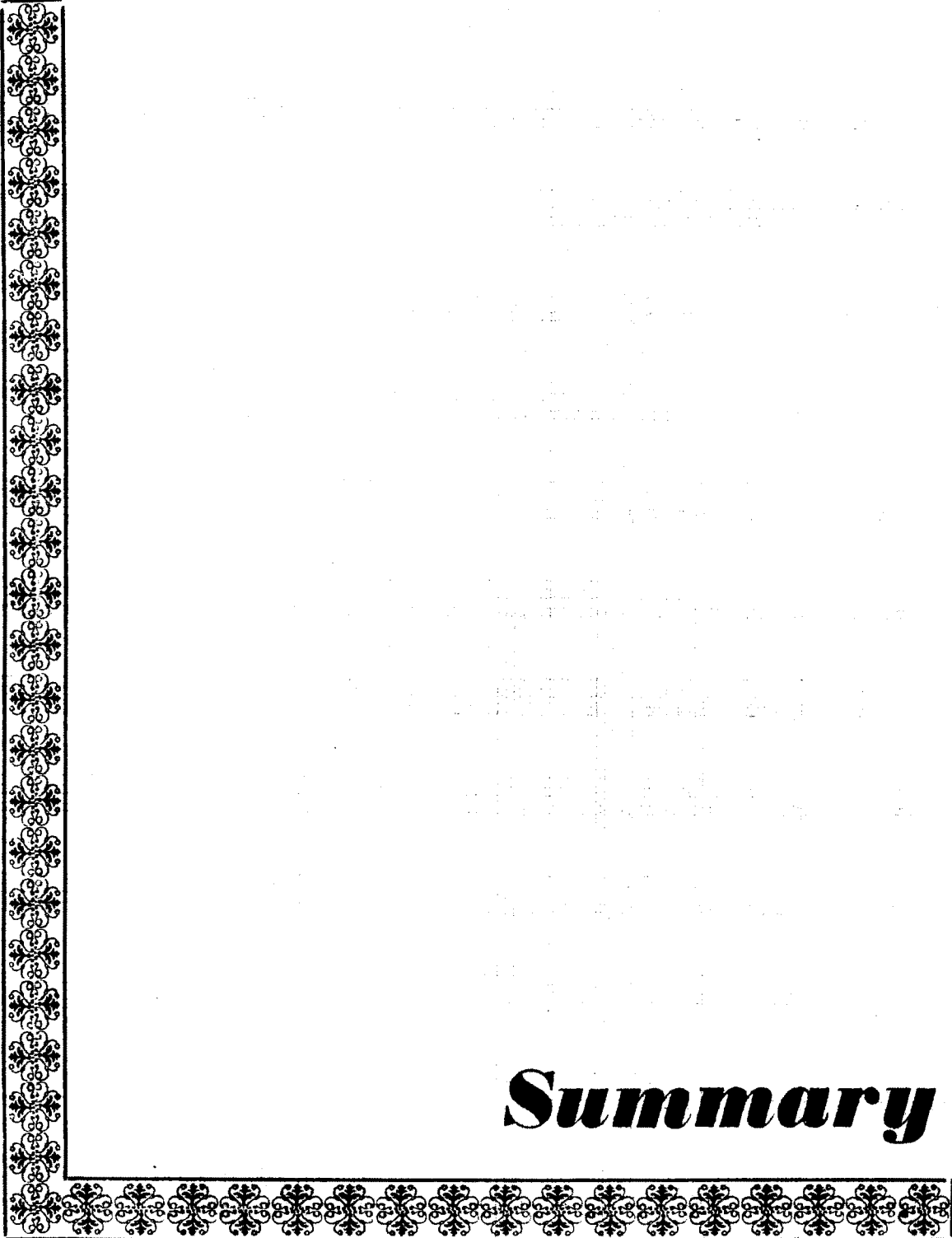
A significant decrease in leaf and root Fe content was noticed with the increase in sulphate level, except in leaves of Ardhapuri cultivar. Iron accumulation was more in roots when compared to leaves in both the cultivars. These findings are in line with Edelburger (1978) in grape and Chavan and Koradge (1980) in peanut. However, no effect on Fe was noticed by Dilley et al., (1958) in apple, pear, peach and grape and Bhamkota and Kanwar (1970) in citrus with increasing levels of sulphate in soil.

Manganese

Maximum Mn content was recorded in control plants when compared with the sulphate levels. In general, with the increase in sulphate level Mn content decreased significantly. Mn accumulation in the leaves and roots of Ardhapuri was more than Basrai, this may be due to the genetic make up of the plant. Edelburger (1978) in grape and Chavan and Koradge (1980) reported similar type of results.

Copper

Increasing sulphate level decreased Zn content in both leaves and roots of Ardhapuri and Basrai cultivar. A significant decline in Cu accumulation was noticed at 21 me/l onwards in Ardhapuri while in Basrai it was 14 me/l. The decreased absorption of Cu may be due to the increase in salinity of the media. These results corroborate with the findings of Edelburger (1978) in grape. However, Dilley et al. (1958) in apple cherry, peach and grape reported no marked effect on reduction of Cu content with increased supply of sulphate.



Summary

Chapter 6

SUMMARY

The present investigation 'studies on soil exchangeable sodium percentage and salinity on banana' were conducted at the Department of Horticulture, Marathwada Agricultural University, Parbhani during 1990 and 1991. Experiments were conducted in greenhouse in the pots containing medium black cotton soil classified as inceptisol. Separate experiments on two cultivars of banana viz., Ardhapuri and Basrai were laid out to study the effect of soil ESP, Salinity, chlorides, bicarbonates and sulphates.

6.1 Effect of ESP on the Growth and correlation coefficients:

The soil was treated with the solution of sodium bicarbonate for building the ESP 8,16,24,32, 40 and 48 by following the procedure described by Bains and Fireman (1964).

Progressive decrease in growth parameters with the increase in ESP was observed. Ardhapuri and Basrai were affected at an above ESP 24 in growth parameters viz., plant height, number of leaves and pseudostem diameter. The fresh weight of whole plant, fresh and dry weight of top and root, plant spread, leaf area per plant, root length decreased with the increase in ESP in

both the cultivars.

The tolerance limits of ESP (ESP level representing 50 per cent growth depression) were calculated to be 35.0 and 40.0 for Ardhapuri and Basrai, respectively.

With the increase in ESP, sodium content and mortality of two cultivars were also increased. The highest mortality was recorded in Ardhapuri followed by Basrai at ESP 48. The toxic limits of sodium in the leaves on dry weight basis for Ardhapuri and Basrai were 0.81 and 0.68 per cent respectively. In general, Ardhapuri accumulated more Na content in the leaves as compared to Basrai.

Significant positive correlatios were observed with dry matter in respect of plant height, number of leaves, pseudostem dimeter, fresh weight of whole plant, root length, total leaf area per plant and plant spread in both the cultivars of banana.

6.2. Effect of Salinity on growth and correlation coefficients

Besides Control (0.42 ECe), six soil salinity levels i.e. electrical conductivity of saturation extract viz., 3,6,12,15 and 18 dsm^{-1} were fixed. The salinity levels were develoed by addition of requisite amount of salts (NaCl_2 , NaHCO_3 , Na_2SO_4 , CaCl_2 , MgCl_2) to soil in pot.

The adverse effects of salinity were seen right from conductivity level of 12 dsm^{-1} of saturation extract in Ardhapuri while in Basrai the adverse effects were noted at and above 9 dsm^{-1} .

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

Mortality Symptoms in Ardharipuri and Basrai were noted at and above 9 dsm^{-1} , Highest mortality symptoms were observed in Basrai and least in Ardhapuri at $\text{ECe } 15 \text{ dsm}^{-1}$.

The salinity tolerance indices (salinity level representing 50 per cent growth depression) were calculated to be 14.0 and 12.5 for Ardhapuri and Basrai, respectively.

Significant positive correlations were observed with dry matter in respect of plant height, number of leaves, stem diameter, fresh weight of whole plant and plant spread in both the cultivars except root length with fresh weight of whole plant and dry matter in Ardhapuri cultivar.

6.3. Effect of Chlorides on the growth and correlation coefficients

Besides control (3 me chlorides/l of saturation extract), six chloride levels (6,12,18,24,30 and 36 me chloride/l of extract) were developed by addition of requisite amount of calcium chloride ($\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$) to the 30 kg of soil in pot. A false bottom was also provided to each pot with the help of gravels to facilitate drainage.

With the successive increase in chloride levels progressive decrease in growth parameters viz., plant height, number of leaves, pseudostem diameter, leaf area per plant and plant spread was noticed. Adverse effects were observed in Ardhapuri and Basrai at and above 18 me/l.

/ The tolerance limits to chloride (Chloride level representing 50 per cent growth depression) were calculated to be 20.5 and 17.25 for Ardhapuri and Basrai, respectively.

Mortality ~~symptoms~~ in Ardhapuri and Basrai were noted at 18 and 12 me/l of chloride level respectively

Significant positive correlations were observed with dry matter in respect of plant height, number of leaves, pseudostem diameter, fresh weight of whole plant, root length, plant spread and leaf area per plant in both the cultivars in soil chloride experiment.

6.4 Effect of bicarbonate on growth and correlation coefficients.

Besides control (2 me bicarbonate/l), six bicarbonate levels namely 5,10,15,20,25 and 30 me/l were developed by addition of requisite amount of KHCO_3 to 30 kg soil in pot. With the help of gravels a false bottom was provided to each pot.

The adverse effects of bicarbonate salinity were seen right from conductivity level of 20 and 15 me/l in Ardhapuri and Basrai, respectively.

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

Mortality symptoms in Ardhapuri and Basrai were noted at and above 20 me/l of bicarbonate level.

The tolerance limits of bicarbonate (bicarbonate level representing 50 per cent growth depression) were calculated to be 24.5 and 34.5 for Ardhapuri and Basrai, respectively.

Significant positive correlations were observed with dry matter in respect of plant height, number of leaves, pseudostem diameter, fresh weight of whole plant, root length, plant spread, leaf area per plant in both the cultivars except plantspread with pseudostem

diameter, number of leaves, root length, total leaf area and fresh weight of whole plant in Ardhapuri.

6.5 Effect of sulphate on the growth and correlation coefficients.

Besides control (1.25 me sulphate/l) six sulphate levels namely 7, 14, 21, 28, 35 and 42 me/l were developed by addition of requisite amount of sodium sulphate (Na_2SO_4) to 30 kg soil in the pot. With the help of gravels a false bottom was provided to each pot.

The adverse effects of sulphate salinity were seen right from conductivity level of 21 me/l in Ardhapuri and Basrai cultivars.

As the sulphate salinity increased, the adverse effect on different growth characters i.e. plant height, number of leaves, pseudostem diameter, leaf area per plant and plant spread were also accentuated.

Mortality symptoms in Ardhapuri and Basrai were noted at and above 21 me/l of sulphate level.

The tolerance limits of sulphate (Sulphate level representing 50 per cent growth depression) were calculated to be 31.5 and 36.5 for Ardhapuri and Basrai, respectively.

Significant positive correlations were observed with dry matter in respect of plant height, number of leaves, pseudostem diameter, fresh weight of whole plant, root length, plant spread and leaf area per plant in both the cultivars of banana.

6.6 Effect of ESP on the physico-chemical Composition of banana plant

The total chlorophyll content in leaves of both the cultivars decreased with the increase in soil ESP. In general, cultivar showing more tolerance indices had greater chlorophyll content in leaves.

The N content in leaves of Ardhapuri and Basrai increased with the increase in ESP upto certain level, but it was not consistent. The same, however, decreased at highest ESP level. Root N of both the cultivars decreased with the increase in ESP.

The P content in leaves and roots of both the cultivars decreased with the increase in ESP.

In general, decrease in K, Ca and Mg content in leaves and roots due to high ESP was recorded in both the cultivars. Under increasing ESP the Ca: Na and Ca + Mg + K: Na of leaves and roots decreased. It was lowest at ESP 48. Increase in sodium content in leaves and roots was noticed with the increase in ESP in both the cultivars.

Increasing levels of ESP significantly decreased the Zn, Fe, Mn and Cu contents in leaves and roots of both the cultivars of banana.

6.7 Effect of salinity on the physico-chemical composition of banana plants

The total chlorophyll content in leaves

decreased with the increase in salinity levels in both Ardhapuri and Basrai plants.

The N content in leaves and roots of two cultivars decrease gradually with the increase in salinity level. But decrease was not consistent in Ardhapuri.

The P, K, Ca and Mg content in leaves and roots of both the cultivars decreased significantly with the increase in salinity status of the media.

Increase in sodium content in leaves and roots due to higher salinity was observed in both the cultivars while sodium accumulation was found comparatively more in Basrai.

Successive increase in salinity level decreased the leaf and root Zn, Fe, Mn and Cu in Ardhapuri and Basrai.

6.8. Effect of chlorides on the physico-chemical composition of banana plants

The total chlorophyll content in leaves decreased with the increase in chloride levels in Ardhapuri and Basrai.

As the chloride level increased, the leaf-N content increased to some extent. The same, however, decreased at highest chloride level. Root -N in both the cultivars decreased with the increase in chloride concentration.

In general, increase in chloride concentration of the substrate decreased significantly P, K, Ca and Mg content of both leaves and roots of Ardhapuri and Basrai.

With the increase in chloride levels the leaf Zn, Fe, Cu and Mn content decreased in both Ardhapuri and Basrai while the decrease in leaf- Zn of Ardhapuri was not consistent.

Increase in levels of chlorides significantly increased sodium concentration in the leaves and roots.

6.9 Effect of bicarbonate on the physico-chemical composition of banana plant

With the successive increase in bicarbonate levels the total chlorophyll content decreased in both the cultivars of banana.

The N, P, K, Ca and Mg content of leaves and roots of both the cultivars decreased consistently with the increase in bicarbonate salinity.

Increase in bicarbonate levels significantly increased Na content in both leaves and roots of both the cultivars of banana.

Increase in bicarbonate concentration of the medium significantly decreased Zn, Fe and Mn content in both leaves and roots of Ardhapuri and Basrai.

The Cu content in leaves and roots decreased with the increase in bicarbonate levels but the decrease was not consistent in Ardhapuri.

6.10 Effect of sulphate on the physico-chemical composition of banana plants

The total chlorophyll content in leaves of both the cultivars of banana decreased with successive increase in sulphate level.

The leaf N content in Ardhapuri increased upto certain limit however, it again decreased at highest sulphate level but it was not consistent. While leaf and root-N in Basrai and root-N in Ardhapuri decreased with successive increase in sulphate concentration .

The P, Ca and Mg content in leaves and roots of both Ardhapuri and Basrai cultivar decreased with the increase in sulphate level.

With the advancement of sulphate level K and Na content of leaves and roots of both the cultivars increased significantly.

Decrease in leaf and root Zn, Fe, Mn and Cu with the increase in sulphate salinity was recorded but the decrease of leaf - Fe was not consistent in Ardhapuri.

CONCLUSION

Among the cultivars studied Basrai was tolerant to ESP and sulphates while Ardhapuri was susceptible. On the other hand, Ardhapuri was tolerant to salinity, chlorides and bicarbonates.



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xviii

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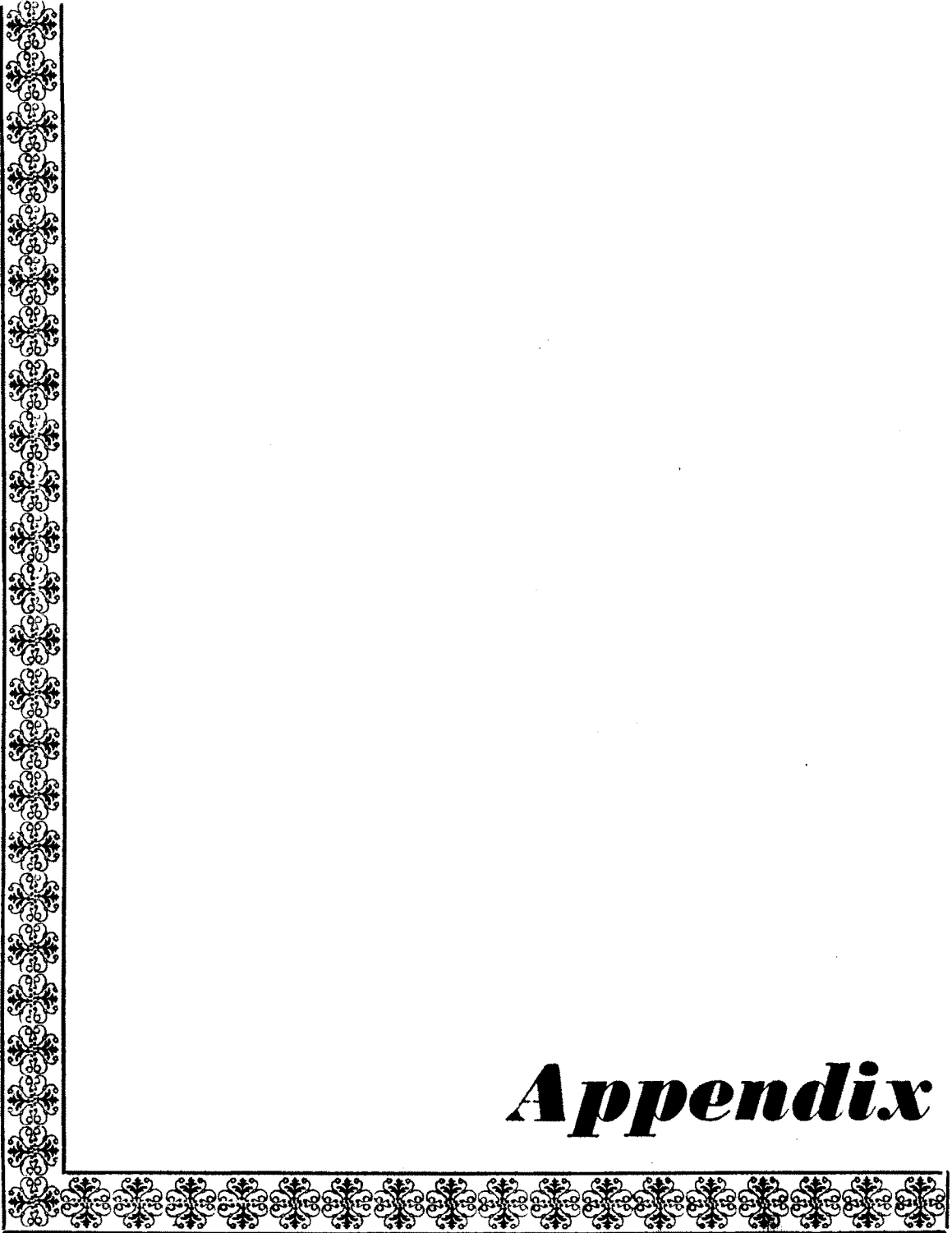
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Appendix

APPENDIX

Meteorological data during the course of investigation
(September, 1990 to October, 1991)

Month	Meteo. week	Tempera- ture°C		Humidity%		Rain- fall (mm)	No.of rainy days	Sunshine hr/day
		Max.	Min.	a.m.	p.m.			
1	2	3	4	5	6	7	8	9
Sept,90	39	30.7	22.1	91	69	127.5	5	6.0
Oct,90	40	32.0	21.5	86	58	36.8	3	7.9
	41	39.8	21.5	92	64	124.8	5	4.3
	42	31.8	17.0	85	32	-	-	10.2
	43	29.1	19.7	87	62	125.3	4	5.5
Nov,90	44	29.9	18.2	78	47	1.6	1	9.0
	45	31.4	15.7	81	35	-	-	9.9
	46	31.1	18.2	75	43	-	-	8.8
	47	30.4	15.9	80	36	-	-	8.2
Dec,90	48	31.7	17.4	82	41	-	-	9.0
	49	30.3	16.7	86	41	-	-	7.9
	50	29.1	12.9	77	34	-	-	9.0
	51	28.3	11.6	80	28	-	-	9.3
Jan,91	52	28.8	10.2	81	30	-	-	9.7
	1	26.4	8.9	74	34	-	-	8.6
	2	30.3	12.6	79	35	-	-	9.4
	3	30.1	15.2	81	41	-	-	9.2
	4	32.0	14.7	76	32	-	-	9.7

1	2	3	4	5	6	7	8	9
Feb,91	5	32.6	10.4	68	21	-	-	10.2
	6	33.4	15.3	72	27	-	-	9.5
	7	34.2	13.4	60	17	-	-	10.0
	8	34.0	13.9	63	18	-	-	9.8
March,91	9	35.0	16.7	60	19	-	-	10.3
	10	36.3	17.3	49	19	-	-	10.5
	11	37.8	18.2	41	15	-	-	10.5
	12	38.1	18.5	41	14	-	-	9.5
	13	39.2	20.7	46	18	-	-	10.0
April,91	14	36.7	21.1	74	30	9.4	1	8.4
	15	38.6	19.9	49	16	-	-	10.5
	16	41.5	22.8	35	17	-	-	11.0
	17	41.6	23.0	43	17	-	-	10.3
May,91	18	41.9	24.5	48	18	-	-	10.9
	19	41.9	26.7	45	17	-	-	10.5
	20	43.1	26.1	36	12	-	-	9.8
	21	42.9	25.7	52	22	10.8	1	10.1
June,91	22	33.4	23.6	72.9	60.1	59.4	4	4.4
	23	34.7	24.6	75.6	66.4	166.6	5	4.5
	24	33.1	23.9	83	50	37.8	2	7.0
	25	34.2	24.0	79	51	75.0	2	7.5
	26	34.4	23.8	85	48	9.4	2	6.5

1	2	3	4	5	6	7	8	9
July, 91	27	32.9	22.8	85	12	101.6	6	4.1
	28	29.7	22.7	90	84	164.2	6	1.0
	29	30.6	22.6	85	59	37.0	2	2.9
	30	31.0	22.0	82	62	12.8	4	4.0
Aug, 91	31	32.0	22.7	80	48	2.6	1	6.4
	32	31.2	22.2	82	55	1.8	1	4.5
	33	29.8	22.2	84	66	45.1	4	5.9
	34	31.5	22.6	80	54	-	-	5.1
	35	32.5	21.7	81	46	-	-	6.1
Sept, 91	36	33.3	22.5	81	46	6.0	1	7.5
	37	34.5	21.3	75	35	-	-	10.2
	38	34.2	23.2	77	45	-	-	6.2
	39	35.1	22.1	77	35	2.8	1	5.2
Oct, 91	40	35.5	21.4	66	30	1.0	1	9.5