

**THE EFFECTS OF SALINE CONDITIONS
ON
GROWTH, PRODUCTIVITY, OIL CONTENT
AND
COMPOSITION OF SUNFLOWER**

BY
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DEPARTMENT OF BOTANY
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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

*In the Name of Allah
The Most Gracious
The Most Merciful
Whose Help We Solicit*



Dedication

I dedicate this humble effort to my
respectable parents, who encouraged me
and supported me financially as well
as spiritually to achieve this target

Mustajab Khan

UNIVERSITY OF PESHAWAR
PESHAWAR

THE EFFECTS OF SALINE CONDITIONS ON GROWTH,
PRODUCTIVITY, OIL CONTENT AND COMPOSITION
OF
SUNFLOWER

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of the requirements for the degree of

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by
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ABSTRACT

Sunflowers (Helianthus annuus L.) were grown in petri plates in laboratory as well as in glazed pots in the open atmosphere which had various degrees of salinity of NaCl, CaCl_2 , MgCl_2 and Na_2SO_4 and their mixture.

Germination was delayed and percent emergence, radicle and plumule length, plant height, capitulum diameter, dry matter yield components of above ground parts and percent moisture in the seeds were significantly decreased by increasing salinity in the soil. However, the effect of NaCl and MgCl_2 on different growth parameters was more pronounced than CaCl_2 , Na_2SO_4 and mixture salts.

Plants transplanted at cotyledonary stage on saline soil were established and grew more vigorously than those transplanted at primary leaf stage or directly germinated plants.

With increasing salinity, plants bloomed and matured earlier resulting in a decrease in oil content of sunflower seed. Nevertheless, the change in uptake and accumulation of various elements was quite different. The concentrations of Na, Ca, N and Cl in the leaf and stem were augmented with increasing salinization regimes in the soil, whereas those of Mg, K, P and S were decreased.

The effect of salinity on refractive index, specific gravity, acid value, iodine and saponification values and fatty acid composition of sunflower seed oil were not significant.

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C O N T E N T S

	Page
LIST OF TABLES.	xii
LIST OF FIGURES	xvi
INTRODUCTION.	1
<u>CHAPTER - I</u> REVIEW OF LITERATURE	5
1.1 Influence of Salinity.	5
1.1.1 Effects of Salinity on Seed Germination. . .	5
1.1.2 Causes of the Reduction of Plant Growth by Salinity.	8
1.1.3 Effects of Internal Osmotic Adjustment . . .	9
1.1.4 Reduction of Water Absorption by Salinity. .	10
1.1.5 Effects of Specific Ions	13
1.1.6 Effects of Saline Conditions on the production, Oil content, and Composition of Sunflower	15
1.1.7 Effects of Salinity on Salts uptake by Sunflower.	18
<u>CHAPTER - II</u> MATERIALS AND METHODS	22
2.1 Germination Studies in the Laboratory	22
2.2 Germination and Plant Growth Studies in Pots .	23
2.3 Growth Studies on Transplanted Plants	25
2.4 Soil Analysis.	26
2.5 Plant Analysis	27
<u>CHAPTER - III</u> RESULTS.	29
3.1 Germination in Petri Plates.	29
3.1.1 Effects of NaCl on the Rate and Germination Percentage of Sunflower.	29

	Page
3.1.2 Effects of CaCl_2 on the Rate and Germination Percentage of Sunflower.	32
3.1.3 Effects of MgCl_2 on the Rate and Germination Percentage of Sunflower.	35
3.1.4 Effects of Na_2SO_4 on the Rate and Germination Percentage of Sunflower.	35
3.1.5 Effects of Mixture Salts on the Rate and Germination Percentage of Sunflower.	36
3.2 Germination in Pots.	43
3.2.1 Effects of NaCl on the Rate and Germination Percentage of Sunflower.	43
3.2.2 Effects of CaCl_2 on the Rate and Percentage Germination of Sunflower.	44
3.2.3 Effects of MgCl_2 on the Rate and Percentage Germination of Sunflower.	49
3.2.4 Effects of Na_2SO_4 on the Rate and Percentage Germination of Sunflower.	52
3.2.5 Effects of Mixture Salts on the Rate and Percentage Germination of Sunflower.	52
3.3 Radicle Length of Germinating Seeds.	57
3.3.1 Effects of NaCl on Radicle Length.	57
3.3.2 Effects of Na_2SO_4 on Radicle Length.	59
3.3.3 Effects of CaCl_2 on Radicle Length	59
3.3.4 Effects of MgCl_2 on Radicle Length	62
3.3.5 Effects of Mixture Salts on Radicle Length	62
3.4 Plumule Length of Germinating Seeds	65
3.4.1 Effects of NaCl on Plumule Length.	65
3.4.2 Effects of Na_2SO_4 on Plumule Length.	65
3.4.3 Effects of MgCl_2 on Plumule Length	68
3.4.4 Effects of CaCl_2 on Plumule Length	68

3.4.5	Effects of Mixture Salts on Plumule Length. . .	71
3.5	Effects of different Salinities on Plant Growth. . .	73
3.5.1	Effects of NaCl on Plant Height.	73
3.5.2	Effects of CaCl_2 on Plant Height.	76
3.5.3	Effects of MgCl_2 on Plant Height.	76
3.5.4	Effects of Na_2SO_4 on Plant Height	81
3.5.5	Effects of Mixture Salts on Plant Height. . .	81
3.6	Effects of Mixture Salts on the Height of Transplanted Plants.	86
3.6.1	Effects of Mixture Salts on the Height of Plants Transplanted at Cotyledonary Stage. . .	86
3.6.2	Effects of Mixture Salts on Plants Trans- planted at the Primary Leaf Stage	87
3.7	Flower Size	87
3.7.1	Effects of NaCl on Flower Size.	87
3.7.2	Effects of CaCl_2 on Flower Size	90
3.7.3	Effects of MgCl_2 on Flower Size	90
3.7.4	Effects of Na_2SO_4 on Flower Size.	93
3.7.5	Effects of Mixture Salts on Flower Size . . .	93
3.7.6	Effects of Salinity on the Flower Size of Plants Transplanted at the Cotyledonary Stage. . .	96
3.7.7	Effects of Salinity on the Flower Size of Plants Transplanted at the Primary Leaf Stage.	96
3.8	Effects of Different Salinities on Blooming and Maturity of Sunflower	99
3.8.1	Effects of NaCl on Blooming and Maturity of Sunflower.	99

3.8.2	Effects of CaCl_2 on Blooming and Maturity of Sunflower.	101
3.8.3	Effects of MgCl_2 on Blooming and Maturity of Sunflower.	101
3.8.4	Effects of Na_2SO_4 on Blooming and Maturity of Sunflower.	104
3.8.5	Effects of Mixture Salts on Blooming and Maturity of Sunflower	104
3.9	Effects of Salinity with Dry matter-yield of Sunflower Plant Parts at the time of Maturity. .	104
3.9.1	Effects of NaCl on the Dry Matter yield of Plant Parts.	107
3.9.2	Effects of CaCl_2 on the Dry Matter yield of Plant Parts.	109
3.9.3	Effects of MgCl_2 on the Dry Matter yield of Plant Parts.	111
3.9.4	Effects of Na_2SO_4 on the Dry Matter yield of Plant Parts.	114
3.9.5	Effects of Mixture Salts on the Dry Matter yield of Plant Parts.	116
3.10	Absorption of Minerals by Sunflower Under Saline Conditions	119
3.10.1	Sodium Concentration.	119
3.10.2	Calcium Concentration	120
3.10.3	Magnesium Concentration	123
3.10.4	Potassium Concentration	125
3.10.5	Nitrogen Concentration.	127
3.10.6	Phosphorus Concentration.	127
3.10.7	Chloride Concentration.	129
3.10.8	Sulphur Concentration	132

3.11 Effects of Mixture Salts on Percentage Moisture of the Seeds of Sunflower.	134
3.12. Effects of Mixture Salts on the Oil of Sunflower.	134
3.12.1 Refractive Index.	137
3.12.2 Specific Gravity and Acid Value	137
3.12.3 Iodine and Saponification Values.	140
3.12.4 Fatty Acid Composition of the Oil of Sunflower Seeds	140
DISCUSSION.	153
SUMMARY AND CONCLUSIONS.	169
LITERATURE CITED.	171

LIST OF TABLES

Table	Page
1. Physio-Chemical analysis of the soil sampled for the experiment.	24
2a. Effects of NaCl on rate and percent germination of various cultivars of sunflower grown in petri dishes.	30
2b. Effects of NaCl on percent germination of various cultivars of sunflower grown in petri dishes.	31
3a. Effects of CaCl_2 on rate and percent germination of various cultivars of sunflower grown in petri dishes.	33
3b. Effects of CaCl_2 on percent germination of various cultivars of sunflower grown in petri dishes.	34
4a. Effects of MgCl_2 on rate and percent germination of various cultivars of sunflower grown in petri dishes.	37
4b. Effects of MgCl_2 on percent germination of various cultivars of sunflower grown in petri dishes.	38
5a. Effects of Na_2SO_4 on rate and percent germination of various cultivars of sunflower grown in petri dishes.	39
5b. Effects of Na_2SO_4 on percent germination of various cultivars of sunflower grown in petri dishes.	40
6a. Effects of mixture salts on rate and percent germination of sunflower cultivars grown in petri dishes.	41
6b. Effects of mixture salts on percent germination of sunflower cultivars grown in petri dishes.	42
7a. Effects of NaCl on rate and percent germination of various cultivars of sunflower grown in pots.	45

Table	Page
7b. Effects of NaCl on percent germination of various cultivars of sunflower grown in pots.	46
8a. Effects of CaCl_2 on rate and percent germination of various cultivars of sunflower grown in pots . .	47
8b. Effects of CaCl_2 on percent germination of various cultivars of sunflower grown in pots.	48
9a. Effects of MgCl_2 on rate and percent germination of various cultivars of sunflower grown in pots . .	50
9b. Effects of MgCl_2 on percent germination of various cultivars of sunflower grown in pots.	51
10a. Effects of Na_2SO_4 on the rate and percent germination of various cultivars of sunflower grown in pots.	53
10b. Effects of Na_2SO_4 on percent germination of various cultivars of sunflower grown in pots . .	54
11a. Effects of mixture salts on rate and percent germination of various cultivars of sunflower grown in pots.	55
11b. Effects of mixture salts on percent germination of various cultivars of sunflower grown in pots . .	56
12. Effects of NaCl on plant height of various cultivars of sunflower	74
13. Effects of CaCl_2 on plant height of various cultivars of sunflower.	77
14. Effects of MgCl_2 on plant height of various cultivars of sunflower.	79
15. Effects of Na_2SO_4 on plant height of various cultivars of sunflower.	82
16. Effects of mixture salts on plant height of various cultivars of sunflower.	84

Table	Page
17. Effects of NaCl on blooming and maturity of sunflower.	100
18. Effects of CaCl_2 on blooming and maturity of sunflower.	102
19. Effects of MgCl_2 on blooming and maturity of sunflower.	103
20. Effects of Na_2SO_4 on blooming and maturity of sunflower.	105
21. Effects of mixture salts on blooming and maturity of sunflower	106
22. Effects of NaCl on the dry matter yield of sunflower plant parts.	108
23. Effects of CaCl_2 on the dry matter yield of sunflower plant parts.	110
24. Effects of MgCl_2 on the dry matter yield of sunflower plant parts.	112
25. Effects of Na_2SO_4 on the dry matter yield of sunflower plant parts.	115
26. Effects of mixture salts on the dry matter yield of sunflower plant parts	118
27. Effects of salinity levels on sodium concentration of sunflower plant parts	121
28. Effects of salinity levels on calcium concentrations of sunflower plant parts	122
29. Effects of salinity levels on magnesium concentrations of sunflower plant parts	124
30. Effects of salinity levels on potassium concentrations of sunflower plant parts	126

Table	Page
31. Effects of salinity levels on nitrogen concentrations of sunflower plant parts.	128
32. Effects of salinity levels on phosphorus concentrations of sunflower plant parts	130
33. Effects of salinity levels on chloride concentrations of sunflower plant parts	131
34. Effects of salinity levels on sulphur concentrations of sunflower plant parts.	133
35. Effects of mixture salts on the moisture percentage of sunflower seeds	135
36. Effects of mixture salts on the oil content of sunflower seeds.	136
37a. Effects of mixture salts on the refractive index of the oil of sunflower seeds	138
37b. Effects of mixture salts on the specific gravity of the oil of sunflower seeds	138
38. Effects of mixture salts on the acid value of the oil of sunflower seeds.	139
39. Effects of mixture salts on the iodine value of the oil of sunflower seeds	141
40. Effects of mixture salts on the saponification value of the oil of sunflower seeds	142

LIST OF FIGURES

Figure	Page
1. Effects of sodium chloride on the radicle length of germinating seeds of sunflower.	58
2. Effects of sodium sulfate on the radicle length of germinating seeds of sunflower	60
3. Effects of calcium chloride on the radicle length of germinating seeds of sunflower.	61
4. Effects of magnesium chloride on the radicle length of germinating seeds of sunflower	63
5. Effects of mixture salts on the radicle length of germinating seeds of sunflower.	64
6. Effects of sodium chloride on the plumule length of germinating seeds of sunflower.	66
7. Effects of sodium sulfate on the plumule length of germinating seeds of sunflower.	67
8. Effects of magnesium chloride on the plumule length of germinating seeds of sunflower.	69
9. Effects of calcium chloride on the plumule length of germinating seeds of sunflower	70
10. Effects of mixture salts on the plumule length of germinating seeds of sunflower.	72
11. Effects of sodium chloride on plant height	75
12. Effects of calcium chloride on plant height.	78
13. Effects of magnesium chloride on plant height.	80
14. Effects of sodium sulfate on plant height	83
15. Effects of mixture salts on plant height	85
16a. Effects of salinity on the height of plants transplanted at the cotyledonary stage	88

16b.	Effects of salinity on the height of plants transplanted at the primary leaf stage.	88
17.	The effect of sodium chloride on flower size.	89
18.	The effect of calcium chloride on flower size.	91
19.	The effect of magnesium chloride on flower size.	92
20.	The effect of sodium sulfate on flower size	94
21.	Effects of mixture salts on flower size.	95
22.	Effects of salinity on the flower size of plants transplanted at the cotyledonary stage	97
23.	Effects of salinity on the flower size of plants transplanted at the primary leaf stage	98
24.	Fatty acid composition of the oil of Cv. Shams at 2.5 mmhos/cm EC value of the soil	144
25.	Fatty acid composition of the oil of Cv. Shams at 7.5 mmhos/cm salinity of the soil	145
26.	Fatty acid composition of the oil of Cv. Shams at 15.0 mmhos/cm salinity of the soil.	146
27.	Fatty acid composition of the oil Cv. H01 at 2.5 mmhos/cm EC value of the soil.	147
28.	Fatty acid composition of the oil of Cv. H01 at 7.5 mmhos/cm salinity of the soil	148
29.	Fatty acid composition of the oil of Cv. H01 at 15.0 mmhos/cm salinity of the soil	149
30.	Fatty acid composition of the oil of Cv. Noor at 2.5 mmhos/cm EC value of the soil	150
31.	Fatty acid composition of the oil of Cv. Noor at 7.5 mmhos/cm salinity of the soil	151
32.	Fatty acid composition of the oil of Cv. Noor at 15.0 mmhos/cm salinity of the soil.	152

INTRODUCTION

Soil salinity has long been on the list of global catastrophies. It rapidly and dramatically alters both physical and biological environment, especially in irrigated arid and semi arid regions where precipitation is low enough to carry excess soluble salts from the plant's root zone. In response to environmental stimuli, physiological events occur within the plant body which affect its normal growth. Pakistan being situated in such a zone is in the severe grip of salinity. According to a report (Ahmad, 1982) out of the total acreage of 4,29,3843, the slightly saline soil is 11%, moderately saline 6% and strongly saline 8%.

In some cases complete reclamation of such problem soils may not be economically feasible due to high cost of chemicals, impermeable nature of the soil and seepage from canals. While in others, saline water may be the only water available for irrigation. Growing of salt tolerant crops, therefore, may be one of the approaches under such conditions to utilize such lands for crop production.

Pakistan, being an agricultural country, is losing nearly 1,00,000 acres of land to salinity annually (Hasnain and Sheikh, 1976) on the one hand, while on the other, it faces the acute shortage of vegetable oil and spends huge amount of foreign exchange on the import of edible oil.

Vegetable oils are Pakistan's largest single food import, with consumer demand steadily increasing at seven percent a year.

Henceforth with domestic production stagnant, the vegetable oil problem has reached crisis proportions. Consumption of vegetable ghee and liquid cooking oil has risen from about 400,000 tons in 1973 to about 900,000 tons in 1984. (Office of International Cooperation and Development, U.S. Department of Agriculture, 1985).

To overcome the growing gap between production and consumption, during the last decade, edible vegetable oil imports increased almost two-fold to 500,000 tons in 1982. Foreign exchange costs increased from \$ 31 millions in 1973 to \$ 224 millions in 1982. During the past decade Pakistan's imported edible oils cost about \$ 1.5 billion (Office of International Cooperation and Development, U.S. Department of Agriculture, 1985). The world edible oil market has become increasingly unstable during the last decade and Pakistan's balance of payment problem has been further aggravated by this trend.

The indigenous production has kept pace with the growing national demand of the oil. It is likely that in future the spectre of oil shortage will be more severe due to imbalance between production of the oil and the rapid population growth coupled with increased per capita consumption (per capita consumption of vegetable oil in Pakistan is only 6.97 Kg which is quite low as compared to developed countries where it ranges between 10-11 Kg).

Edible oil in our country is usually extracted from established crops like cotton, rapeseed, mustard, sesame and groundnut. The oil from the rape and mustard cannot be used in the manufacture of vegetable ghee as it contains high level of erucic acid and sulphur compounds which are injurious to human health. Further sulphur content in the oil interferes with the catalyst nickel and is also corrosive for the machinery. Groundnut can be a good source of vegetable oil but most of it is consumed as roasted nuts with the result that it is not available in sufficient quantity for oil extraction. Sesame is produced in small quantity and is mostly used in confectionary. Locally produced edible oil particularly for ghee manufacture, is restricted to cotton seed. Since cotton seed is a by-product, the amount available depends on demand for cotton. The world hard currency price of cotton is lower than the internal rupee price and Pakistan is subsidizing exports to gain foreign exchange. Given world market conditions, therefore, cotton will not produce an appreciable increase of seed oil for extraction. Under the stringent situation sunflower, a relatively salt resistant crop (Piunovski, 1952), seems to be the only oilseed which can bridge the gap of national oil requirement. It is the fourth important source of vegetable oil in the world after soybean, cottonseed and pea-nut. Russia is the world leading producer followed by Argentina, Eastern Europe, U.S.A. and China. It is cultivated on an area of 14,00,000 hectares with a total production of 183.84 metric tons in the world (U.S. Deptt. Agri. FAS, Washington DC. 1985/).

Sunflower (Helianthus annuus L.), belonging to the family Asteraceae, is a newly introduced crop to Pakistan. It was first sown on our soil in 1978 and by 1981-82 the total acreage reached 44,000 with yields of less than 227 Kg /acre. At present there is little information regarding the effects of salinity upon the productivity of this crop. In order to attain self sufficiency in edible oil and make the best use of land which may be somewhat saline or subjected to the hazards of salinity, systematic study is needed on some aspects of this important crop. The objectives of this research were to evaluate the effects of the degree of six salinity regimes created by salts of NaCl, CaCl_2 , MgCl_2 and Na_2SO_4 used single as well as in mixture on germination, plant growth and development, oil content and composition and the uptake of different minerals by tissues of sunflower plant.

REVIEW OF LITERATURE

1.1. Influence of Salinity

A large number of investigators have studied the effect of soil salts on the physiological phenomena of plants; However, only the presence of excessive concentrations of soluble salts as defined by U.S. Salinity Laboratory Staff (1954), cause decreases in germination, growth, yield, and quality of the crops. Under natural conditions, plants growing on saline soils usually suffer from lack of water (physiological drought), and nutrient salts (salt hunger), as well as an excess of non-nutrient salts, which penetrate into their cells. Therefore, the direct investigation of the various responses of plants to salinity are very complicated. It differs to a large extent with plant species, the stages of growth, soil fertility, water regime, and climatic variables (Maas and Hoffman, 1977). Consequently it is difficult to extend results from species to species or from one set of conditions to another.

At the present time, there is a paucity of literature on the subject of salinity and sunflower production. Nevertheless, the available literature in foreign journals on this subject is reviewed below under various headings.

1.1.1 Effects of Salinity on Seed Germination.

A large number of reviewers on salinity have revealed great differences in reactions of some crop species to salinity during germination as against their reaction during subsequent

growth (Bernstein, 1964; Kapp, 1947; Khan and Patel, 1972; Meiri and Shalhevet, 1973; Pasternak et al., 1976; Francois et al., 1984 and Allen et al., 1985).

The amount of soil moisture and the salt concentration adjacent to the seed are continually changing through the influence of evaporation, capillary transmission, rainfall or irrigation. Therefore, it is necessary first to ascertain the effect of varying levels of salinity on germination when all other factors are held constant or as uniform as possible (Ayers and Haywards, 1948).

Accumulation of salts in irrigated soils of arid and semiarid regions of the world results in reduction of seed germination and plant growth (Abel and Mackenzie, 1964; Chavan and Karadge, 1980; Arunsiri Kumlung, 1983; Patricio, 1984 and Nand Kishore et al., 1985). Therefore, the ability of any given species or variety of a plant to germinate and establish the seedling is an important factor in crop production and under saline conditions this phase of life may be the critical one (Hayward, 1954).

It has been shown that induction of water stress by increasing salt concentration reduced seed germination of a number of plants (Younis and Hatata, 1971; Rauf and Mian, 1966; Wahhab, 1961; Ota and Oga, 1953; Malik, 1975; Mehta and Desai, 1958; Stroganov, 1964; Nadeem, 1973; Zahid, 1976; Arunsiri Kumlung, 1983 and Jadhav, 1985).

Kaddah (1963) reported that salinity in irrigation water upto 2000 ppm resulted in delayed germination of rice.

Chaudhery (1933) observed that jute seeds can germinate on soils containing salts upto 0.5%. Redmann (1974) found that alfalfa seed germination was inhibited the most by Na_2SO_4 , K_2SO_4 and NaCl . In contrast, KCl , MgCl_2 and MgSO_4 were the least inhibitory. The decrease in percent emergence of soybean was due to the combined effects of solute suction and toxicity of salts (Uhrvit s, 1946). Similarly, NaCl was more detrimental to the germination of wheat and berseem seeds than KCl (Malik, 1975).

Ayers et al. (1952), Millington et al. (1951) and Bernal et al. (1974) concluded that wheat can grow on soils containing salts upto 0.3%. Ogasa (1939), Ahmad and Muhammad (1969) observed that increasing soil salinity decreased not only percent emergence but also reduced the rate of emergence of soybean.

Sunflower can germinate on soils having salt concentration upto 0.5% (Rabochev and Kravchuk, 1974). Makhdom and Muhammad (1971) stated that percent germination and seedling dry matter yield in sunflower decreased with increase in the soil salinity levels. Loughridge (1901) found it to endure 3740 ppm of total salt* content in saline soils. This was also confirmed by the work of piunovski (1952) who considered it moderately salt tolerant when grown in different irrigated areas of Central Asia. Kabaev (1954) suggested that in several areas of Central Asia, sunflower is satisfactory for use on strongly saline soils as a

first crop. Kathiresan and Ramasway (1968) concluded that seed germination of sunflower was maximum in September sown crop (97%). Germination was positively correlated with 1000 seed weight as well as with Kernal/Hull ratio ($r=0.40$). Oertili and Richardson (1968) found no varietal response in sunflower on saline soils. Ghorashy and Kheradnam (1972) and Chabra et al. (1978) have reported that an ESP higher than 16 delayed the germination and decreased the plant height and stem to leaves ratio in sunflower.

1.1.2 Causes of the Reduction of Plant Growth by Salinity.

Decreases in yields due to salinity in different crops have been investigated by a number of scientists (Aceves et al., 1975; Bole and Wells, 1978; Strogonov, 1964; Strogonov and Lapina, 1964; Grillot, 1954; Ahmad and Muhammad 1969; Muhammad and Makhdam, 1971; Strack et al., 1975; Heikal, 1978; Holm, 1978; Pakroo and Kashirad, 1981. Selassie and Wagnet, 1981; Pessoa de Costa and Smucker, 1981). The salt stress survival depends upon the crop type (Maianu et al., 1965); crop type and irrigation managements (Childs and Hanks, 1975); environmental conditions, irrigation methods and the length of time plants are exposed to the salt (Lunin et al. 1961; Meiri and Poljakoff Mayber, 1970; Levitt, 1980). Moreover, not all plant parts and growth stages are affected equally (Maas and Hoffman, 1977).

In majority of the cases, the aerial organs may be affected more than the underground parts of the plant (Ayers and Eberhard, 1960; Jodhav et al., 1976; Haqqani, 1976; Zahid, 1976; Bernstein and Pearson, 1954; Eaton, 1942; Ahmad et al., 1979; Charsalli and Cherif, 1979).

Grain yields of corn (Zea mays L.) (Kaddah and Ghowail, 1964), rice (Oryza sativa L.) (Korkar and Abel, 1976; Pearson, 1959; Hayward and Bernstein, 1958; Kaddah et al., 1975) and sorghum (Sorghum bicolor L.) (Francois et al., 1984) may be relatively depressed more than the vegetative growth with increasing soil salinity. Delayed emergence in flowers of almost all the tested rice cultivars as well as in peach were observed by Mercado et al. (1974) and Patricio, (1984). The salt affected plants are normally stunted with small dark green leaves, which in extreme cases may show necrosis or marginal burn (Ehlig and Bernstein, 1958). Such leaves usually fall off earlier (Kovalskaya, 1958; Prisco and O'Leary, 1972).

1.1.3 Effects of Internal Osmotic Adjustment.

In order to adapt to low water potential of saline root medium, plants have to maintain lower internal osmotic potential. This process of osmotic adjustment or osmoregulation results in accumulation of inorganic or organic solutes in the plant sap. The mechanism of osmoregulation due to uptake of salt or salt ions was examined by Arnold (1955), Wallace and Kleinkopf (1974): Abd-El-Rehman et al. (1972) and Flowers et al. (1977), while the second process, the synthesis of organic solutes for osmotic adjustment has been studied by Muller and Wegmann, (1978); Gimmler et al. (1977), Borowitzka and Brown (1974), Rabinowitch et al. (1951); Lerner and Avron (1977); Kaplan and Sreiber (1977); Gimmler and Schirling (1978); Acker-Son and Youngner (1975), and Liu and Hellebust (1976).

Uptake of excess ions by a plant may or may not be toxic (Bernstein and Hayward, 1958; Greenway, 1973; Greenway and Munns, 1980) and the relative contribution of various ions to osmotic adjustment depends upon the mechanism regulating membrane transport (Maas and Nieman, 1978). The organic solutes which are synthesized and accumulated in plant cells and are responsible for osmoregulation have been identified as Glycerol (Heimer, 1973; Ben Amotz and Avron, 1973; Ben Amotz, 1975; Borowitzka et al., 1977), Sucrose (Muller and Wegmann, 1978; Bernstein and Ayers, 1953; Gauch and Eaton, 1942; Nightingale and Farham, 1936), free amino acids (Gilles and Pequenx, 1977), mannitol (Kirst, 1975), glucose and inositol (Wignarajah et al., 1975), Ascorbic acid (Kim, 1958), Proline (Moore, 1975; Storey and Jones, 1977; Soltani and Bernard, 1977; Bar-Nun and Poljakoff Mayber, 1977) and betaine (Storey and Jones, 1977; Hall et al., 1978).

Such organic compounds operate not only as osmoregulators but also protect enzymes from damage by low internal water stress (Pollard and Jones, 1979). Because plants divert energy from synthesis of organic matter to uptake of extra ions and that a larger proportion of photosynthates is used as osmotic solute; therefore, the process of osmoregulation occurs at the expense of growth.

1.1.4 Reduction of Water Absorption by Salinity

The change in the water balance of cultivated plants

under saline conditions was determined by many factors. Soluble salts in soils decreased the free energy of soil water and therefore supply of water to the plants is limited (Bernstein and Hayward, 1958; Eaton, 1941; Hayward and Spurr, 1944). The reduction in plant growth due to osmotic effects was studied by a number of workers (Ayers et al., 1943; Hayward, 1943; Rosen, 1941; Eaton, 1941; Hayward and Spurr, 1943; Long, 1943; Magistad, 1945; Wadleigh and Ayers, 1945; Weatherly, 1963; Shalhevet and Bernstein, 1968; Elvsawaby, 1980). They concluded that the reduction in crop yield was directly related to the decrease in average water potential. The low water potential may be due to low soil water content, high concentration of salts or a combination of the two.

According to some investigators (Kolosov et al., 1936; Alekseev and Suleimanov, 1949), the amount of the adsorbed potassium and calcium in plants increased and the ratio between sodium and calcium changed in favour of sodium (Suleimanov, 1951). The decrease in permeability of the root cells to water may be regarded as a specific response of the plant to the water regime on saline soils (Fedorov-skii, 1950; Kurgultseva, 1935; Kramer, 1969; Kirkham et al., 1969).

The direct relations between the salt stress and the water stress can be noticed in Cowpea (Imbamba, 1973) and bean (Kirkham et al., 1974) where salinity increased the water stress resistance of plants by increasing their water content.

The growth of the plant may be simultaneously suppressed, for instance in the sensitive wheat seedling (Fogle and Munns, 1973). In more salt resistant sugarbeet, on the other hand, growth was enhanced (Lawlor and Milford, 1973), leading to a 20-30% increase in yield (Sergeev and Japparov, 1970). The water content of the leaves of safflower and sunflower, however, significantly decreased at the high salinity level (600 ppm only) (Heikel, 1977).

The increased water content is due to the high osmotic effectiveness of the absorbed salt, and the salt induced decrease in transpiration (Gorev, 1954; Tal and Gavish, 1973). In some cases this effect was observed only at high temperature (Kleinkopf et al., 1975). In all cases the decrease in transpiration was due to stomatal closure (Imbamba, 1973; Kaplan, 1972; Kirkham et al., 1974; Tal and Gavish, 1973), though mesophyll resistance was also involved in one case (Kaplan, 1972). Root hydraulic conductance of tomato and sunflower, on the other hand, was not affected by salinity within the range of fluxes tested (Shalhvet et al., 1976).

Salts reduce root elongation (Arunsiri Kumlung, 1983) and enhanced root suberization (Hayward and Blair, 1942). Smaller root system with higher resistance to water movement could be another reason causing water stress. Moreover, Certili (1968) and Borodulina and Kulaeva (1958) concluded that the capacity of leaf cells to accumulate salts was limited and as the water

evaporated the concentration of salts in the outer space may become sufficiently high to cause the turgor of the leaf cells to drop. Hence, Epstein (1972) is of the opinion that physiological drought could not be ruled out as a factor when plants were exposed to saline conditions, even though plants have been shown to generate a sufficiently high internal solute concentration to bring about an osmotic adjustment.

1.1.5 Effects of Specific Ions

Ions that are frequently found in excess in saline soils include, chloride, sulfate, sodium, calcium and magnesium (Johnsgard, 1974). Ion excess is a condition where high internal ion concentrations reduce growth of the plant (Greenway and Munns, 1980). However, there is no clear-cut idea how the ions exert their adverse effect. This could be on membrane permeability or enzyme activity. Alternatively, high ion concentrations in the water of the cell walls could decrease cell turgor or volume (Levitt, 1980).

Excess ions in the root medium may exert detrimental effects on plant growth by causing nutritional imbalance and by specific ion toxicity (Fenn et al., 1970; U.S. Salinity Laboratory Staff, 1954; Lagerwerff, 1969; Lahaye and Epstein, 1969; Ayoub and Ishaq, 1974; Matar et al., 1975). Thus high Cl^- concentrations in expanded leaves of certain species are associated with chlorosis and death e.g. in avocado (Bingham et al., 1968), grapevines (Bernstein et al., 1969), raspberries (Ehlig, 1964),

rice (Tagawa and Ishizaka, 1963), maize (Lapina, 1966), and in the wheat seedlings (Bhardwaj, 1962).

Effects of specific ions on increases in succulence with increasing external osmotic pressure have also been interpreted in terms of ion transport (Jennings, 1976; Handley and Jennings, 1977). Large differences in ion accumulation occur among different species (Collander, 1941; Greenway et al., 1981; Jeschke, 1979; Jeschke and Stelter, 1976).

There are large differences in ion concentration between different parts of the same plant. Older leaves of non-halophytes grown at high salinity usually have higher Cl^- concentrations than the younger leaves, e.g. beans (Greenway et al., 1966), soybean (Wieneke and Lauchli, 1979), Pepper (Bernstein, 1961), barley (Greenway et al., 1965), and soybean species (Wilson et al., 1970). Ion concentrations are related to cellular differentiation at least in certain species. For beans and maize at 50 mM NaCl external solution, the Na^+ and Cl^- concentrations were usually two to three fold higher in proximal than in apical regions (Kramer et al., 1977; Lauchli et al., 1974; Lauchli and Wieneke, 1978; Yeo et al., 1977).

According to Gauch and Wadleigh (1944), MgCl_2 and MgSO_4 had more pronounced injuring effect on kidney beans than NaCl, CaCl_2 and Na_2SO_4 . Excessive Mg decreases absorption of Ca and K, and the SO_4 ion restricts Ca uptake, while promoting the uptake of Na (Hayward and Wadleigh, 1949). The effects of Ca salts

on plants have been studied by a number of workers (Cordukes and Meclean, 1973; Kinzel, 1963; Ingested, 1973; Levitt, 1980). CaCl_2 has more inhibitory effect on wheat than NaCl (Aceves et al., 1975). High CaCl_2 concentration in the root medium also increases Ca content and depresses K and Mg in plants (Bernstein, 1964).

NaCl depressed the growth of Phaseolus vulgaris, Pisum sativum and Citrus aurantium, but this inhibition was overcome by K (Georgi et al., 1967; Greenway, 1963; Solovev, 1969; Kurian, 1976). NaCl salinity increased the Cl content more than Na in the shoots of sunflower. The same salt decreased the K content much less than the Ca (Lessani and Marshner, 1978). Such differences can only be explained by a greater injurious effects of the Mg than Na and of the Cl than the SO_4 , CO_3 or NO_3 (Yaron et al., 1969). Others have concluded that Cl and Na injure leaf and cause dieback in a number of fruit trees (Bernstein, 1964; Bernstein and Hayward, 1958) and produce specific injury in crop plants, e.g. cotton (Strogonov et al., 1963). But most herbaceous plants do not exhibit leaf injury symptoms (Maas and Hoffman, 1977).

1.1.6 Effects of Saline Conditions on the Production, Oil Content and Composition of Sunflower

The production of sunflower like other crops in irrigated and semi-irrigated areas is greatly influenced by the soil salinity. According to Chabra et al. (1978), Holm (1978), Elvswaby (1980) and Haikal (1977), the average sunflower seed yields were

significantly decreased by salinity. Pakroo and Kashirad (1981) concluded that dry matter yield, shoot/root ratio, leaf area, plant height and transpiration of sunflower decreased as salinity increased. These results were also confirmed by Pessoa da Costa and Smucker (1981). The influence of salinity on the physiology of sunflower was assayed by Ahmad et al. (1979) and Heikal (1978). They found that increasing salinity caused a decrease in leaf area, dry matter weight, pigment content, and photosynthetic activity. Similar yield reductions in other crops due to salinity have been reviewed by a number of authors (Francois and Bernstein, 1964; Brown and Hayward, 1956; Gauch and Wadleigh, 1944; Ahmad and Muhammad, 1969; Hayward and Wadleigh, 1949; Nouri et al., 1970; Shuang Fu Cheng, 1983 and Patricio, 1984).

Salinity may cause nutritional imbalance and depress the plant yield (Bernstein, 1964; Bernstein and Hayward, 1958). In most of the cases the aerial parts are affected more than the underground parts of the plant e.g. sunflower (Ahmed et al., 1979; Charsalli and Cherif, 1979). Similar studies on sunflower production were also conducted by other workers (Laughridge, 1901; Oertili, 1968; Oertili and Richardson, 1968).

The decrease in oil formation of sunflower seed under saline conditions was found by Asaliev (1976), Raju and Ranganayakulu (1978) and Chabra et al. (1978). Variable climatic conditions during the seed formation period have been known to

produce rather wide differences in oil content in sunflower, safflower, flax and other oilseeds (Painter et al., 1944; Sims et al., 1961; Weiss et al., 1952; Barker, 1932; Eyre, 1932; Kathiresan and Ramasway, 1978).

The fatty acid composition of the leaves and the roots of sunflower were differently modified by salinity. Thus linolenic acid of the leaves decreased with increasing salinity, whereas linoleic acid increased in the roots (Charsalli and Cherif, 1979).

The effects of planting, location and temperature on the oil content and fatty acid composition of sunflower seeds were examined by Robertson et al. (1978), and Canvin (1965). Location and different dates of sowing affected the oil content significantly. Temperature and latitude had no significant effects on the total oil content. Nevertheless, temperature and latitude affected fatty acid composition significantly. Oleic acid was positively correlated with minimum temperature, whereas palmitic, stearic and linoleic acids were negatively correlated with minimum temperature. The linoleic acid content varied inversely with the Oleic acid content (Robertson and Green, 1981).

Soil salinity depressed Oil content, seed weight and protein content, but had no effect on the fatty acid composition of safflower (Yermanos et al., 1964; Werkhoven et al., 1966; Makhdum, 1970). Salinity accelerated flowering and hastened final maturation in Safflower (Francois and Bernstein, 1964).

According to Chabra et al. (1978), however, flowering in the same plant was delayed due to increased salinity. Several investigators have reported that the degree of unsaturation increased as oil seeds approached maturity (Howell and Collins, 1957; Painter, 1944; Simmons and Quackenbush, 1954; Simms et al., 1961).

Sunflower is comparatively a salt tolerant plant (Cobia and Zimmer, 1978; Robinson, 1973). However, its reduced production due to saline conditions in the soil may be remedied in part by supplementing with appropriate quantity of water (Sipos and Paltineanu, 1974; Ortiz, 1972; Robelin, 1967; Robinson, 1973; Alessi et al., 1977; Boyer and Bowen, 1970; Unger et al., 1976; Cheng and Zubriski, 1978).

1.1.7 Effects of Salinity on Salts Uptake by Sunflower

Information about the salts removed by crops and the uptake mechanism of nutrients during the life cycle of a plant are important for the proper utilization of a certain saline soil and for maximum crop production.

Salinity may affect the uptake of certain ions, thereby changing the ionic concentrations in the plant body. This subject has been reviewed by a number of authors (Shere et al., 1974; Luken, 1962; Khalil et al., 1967; Bernstein, 1964; Kurian, 1976). Lunin and Gallatin (1965) indicated that the cation composition of a plant was directly affected by the cation composition of the saline soil. The uptake of essential anions, on the other hand, was rarely affected to a critical degree by salinity.

Different ions are absorbed differently by the plant. Thus K^+ and Cl^- are taken up very rapidly and accumulate to high concentrations in plants growing in saline soils (Mengel and Kirby, 1979). Chloride contributes much more to osmoregulation than sulfate (Maas and Nieman, 1978). A high external Cl^- concentration may exert antagonistic effect on the uptake of other anions, e.g. NO_3^- (Torres and Bingham, 1973). Increases in Na^+ and Cl^- concentration in plant tissue were highly correlated with increasing ambient concentration, but in most cases accumulated Cl^- greatly exceeded accumulated Na^+ (Maas et al., 1972; Pakroo and Kashirad, 1981). In saline media, the ratio of Na^+ to K^+ is typically high. The concept of dual mechanism of ion transport developed by Epstein et al. (1963) in plants has provided a working model for investigations on this process (Rains, 1972).

The effect of Na^+ on K^+ uptake is two fold. At low concentrations, Na^+ may actually increase K^+ uptake, though decreasing it at higher concentrations, for instance in sugarcane (Nimbalkar and Joshi, 1975), and rice (Paricha et al., 1975). Ca^{2+} uptake and growth were also decreased at high Na^+ concentrations in both of these plants as well as in wheat (Poonia et al., 1972). Even in a relatively tolerant Brassica campestris, increasing soil concentrations of Na^+ salts were accompanied by decreases in Mg^{2+} and K^+ , although N, P, Ca^{2+} , as well as Na^+ concentrations increased in the plant (Ansari, 1972). Similarly in lettuce and Paspalum (turfgrass) Na salts decreased dry matter

production and K^+ , Mg^{2+} and Ca^{2+} contents of the leaf (Mater et al., 1975; Dedek and Peacock, 1985).

Chlorides and sulfates also caused decrease in content of total and inorganic P in tomatoes (Zhukovskaya, 1962). Resistance, however, was shown by Glycine falcata (Wilson et al., 1970). More S as well as K^+ was required by cotton when salinized with Na Cl (Shevyakova, 1973). Reduced uptake of nutrients will occur as a result of the salt induced decrease in growth e.g. in wheat roots (Patel et al., 1975; Fogle and Munns, 1973). In barley, P accumulation was higher in the roots and lower in the leaves of the salinized plants (Zhukovskaya, 1973) indicating more of a transport than an absorption problem. Long distance transport was also impeded in Zea mays (Drier and Goering, 1974). In rice, P absorption was suppressed more than N uptake (Amirova et al., 1975). In grapes, guava, and olive plants, the accumulation of both P and K decreased as salinity levels increased, but N was unaffected (Taha et al., 1972). In millet (Ravikovitch, 1973), P uptake is usually stimulated by Na^+ . In young barley plants, salinization impaired both growth and N uptake (Helal et al., 1975). Both yield of wheat and uptake of N, P and K^+ decreased with an increase in salinity (Sharma and Lal, 1975).

Salinity due to NaCl and $CaCl_2$ in the nutrient solution generally increased Na^+ and Ca^{2+} content of Sunflower and Safflower. The total N content of the leaves of these plants was also increased. Salinity had not significant effect on

P content, while K and Mg contents were significantly decreased by salinity (Heikal, 1978). According to Chabra et al. (1978) Na^+ increased and Ca^{2+} decreased with increased ESP, and there was no effect on the Mg^{2+} and P content of the plant parts. K^+ content of the leaves at maturity increased with increased ESP.

Low and moderate salinity increased dry weight and contents of Na^+ , Ca^{2+} , Mg^{2+} , P, and N in different organs of the sunflower plant. However, at higher salinities these parameters were reduced in many cases (Heikal et al., 1980). Pakroo and Kashirad (1981) showed that increased salinity levels significantly reduced P, K, Ca^{2+} and Mg^{2+} uptake by sunflower roots, as well as that of N, P, K^+ , Ca^{2+} and Mg^{2+} by shoots, but Cl^- and Na^+ uptake increased with increasing salinity.

MATERIALS AND METHODS

The studies reported in this manuscript were carried out in the Department of Botany, University of Peshawar during the years 1982-86. The objective was to investigate the effects of salinity on the germination, growth, minerals uptake, productivity and oil composition of sunflower cultivars. The problem soil analyses revealed that among cations, Na^+ , Ca^{++} , and Mg^{++} and anions Cl^- and SO_4 were the most responsible for salinity in Peshawar valley. Thus NaCl , CaCl_2 , MgCl_2 and Na_2SO_4 salts were used to induce artificial salinity for germination studies in petri dishes in the laboratory and plant growth studies in pots. The salts were used either single or in mixture to produce salinity levels viz. 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0 mmhos/cm. The certified seeds of sunflower cultivars viz. Shams, Noor and Hol were obtained from Agril. Research Instt. Tarnab, Peshawar and National Agril. Res. Centre, Islamabad. The research was undertaken in the following phases:

2.1 Germination Studies in the Laboratory

Petri plates containing double filter paper were first dry sterilised in the oven at 120°C for 4 hours. Then fifteen healthy seeds of each cultivar were placed in each petri dish and flooded with 5 ml distilled water that served as the control. Other plates were poured in with salt solution of NaCl , CaCl_2 , MgCl_2 and Na_2SO_4 either single or in mixture that had electrical conductivity of 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0 mmhos/cm. Each treatment was replicated four times and incubated in the oven at $25 \pm 1^\circ\text{C}$. Rate of germination was recorded on

alternate days and total germination was calculated after 15 days of sowing. Plumule length and radicle length was also measured in each level of salinity of every test solution at the end of experiment.

2.2 Germination and Plant Growth Studies in Pots.

A non-saline sandy loam soil was air dried, ground and passed through 2 mm sieve. It was mixed thoroughly and a representative sample was analyzed for physical and chemical properties in the Soil Testing Laboratory of Agril. Research Institute Tarnab, Peshawar. The analyzed data are given in Table 1. Electrical conductivity of the saturation extract ($EC \times 10^3$) of the non-saline soil was 2.5 mmhos/cm. It was used as check. Then calculated amounts of each salt i.e. NaCl, $CaCl_2$, $MgCl_2$ and Na_2SO_4 were thoroughly mixed with the soil and salinity levels of 5.0, 7.5, 10.0, 12.5, and 15.0 mmhos/cm were maintained. However, in the case of mixture salts NaCl, $CaCl_2$, $MgCl_2$ and Na_2SO_4 were mixed in the ratio of 4:10:5:1 to give Na:Ca:Mg ratio of 14:5:1 and that of SO_4 and Cl of 1:1. According to Makhdam (1973) these salts were found in the above ratio in most saline soils of Pakistan. Each pot was filled in with 12 Kg of air dried, non saline sandy loam soil which was then incorporated with calculated amount of the mixture salts in order to produce the salinization regimes of 5.0, 7.5, 10.0, 12.5, and 15.0, mmhos/cm. The conductivity of the soil, however, was verified and adjusted to the desired values with the help of conductivity bridge. A basal dose of N.P.K @ 150 kg N, 50 kg

Table 1. Physio-Chemical analyses of the soil sampled for the experiment.

S.No.	Properties	Units	Values
1.	Moisture	%	2.3
2.	pH (Saturated paste)		8.0
3.	Elect. Conductivity	mmhos/cm (ECx10 ³)	2.5
4.	HCO ₃ ["]	meq/L	2.0
5.	Cl ⁻	"	5.0
6.	SO ₄ ["]	"	9.0
7.	Ca ⁺⁺ Mg ⁺⁺	"	10.0
8.	Na ⁺	"	5.5
9.	Cation Exchange capacity.	meq/100gm soil	7.5
10.	Organic Matter	%	0.52
11.	Available P ₂ O ₅	ppm	13.0
12.	Available K ₂ O	"	280
13.	Eq. CaCO ₃	%	13.5
14.	Clay	"	20.2
15.	Silt	"	28.0
16.	Sand	"	51.8
17.	Textural Class	"	sandy loam

P_2O_5 and 50 kg K_2O per two million kg of soil was mixed thoroughly in each pot at the time of planting seeds. The sunflower seeds were sown in early March of 1983 and thinned to 3 plants per pot one week after emergence. Data on rate of emergence were recorded and plant height was measured with two weeks interval until harvest of the crop. Days to blooming, final maturity and ~~capitulum~~ diameter were also recorded.

2.3 Growth Studies on Transplanted Plants.

Seedlings of the same cultivars of sunflower were grown in small plastic bags which had sandy loam soil of 2.5 mmhos/cm. After emerging the plants to cotyledonary and primary leaf stages, these were transplanted into glazed pots having the same salinization regimes as were produced with mixture salts in the previous direct sowing experiment. This practice was put to test in order to see their establishment behaviour and evaluate some of the yield components of sunflower under different sets of circumstances.

The harvested plant materials were separated into leaves, stems and receptacles and were dried at $70^{\circ}C$ in the oven for 48 hours. After drying, the dry weight of the individual yield components per plant was computed, ground in Wiley mill to pass a 20-mesh sieve and stored in small bottles for the determinations of Na, Ca, Mg, K, N, P, Cl and S.

Moisture in the seeds was found by placing 2.00 gm sample in an oven at 130°C for two hours. The following formula was applied for the calculation of percent moisture.

$$\text{Moisture \%} = \frac{\text{Loss in weight of seeds} \times 100}{\text{weight of (oven dried) seeds}}$$

Seeds collected from plants treated in different salinization regimes were crushed in a mortar and feeded to the soxhlet apparatus in 3.0 gm sample each repeatedly for 6 hours. Then the bulk oil samples of each treatment were stored in bottles for the determination of Iodine value, specific gravity, refractive index saponification value and fatty acid composition. All the analytical work was done at Agril. Research Instt. Tarnab, Peshawar except fatty acid composition of the oil which was carried out in the Postgraduate Institute of Chemistry, Karachi University.

2.4 Soil Analyses

The soil used in the glazed pots for growing sunflower was analysed for the following values:

Texture of the test soil was determined by Bouyoucos Hydrometer as given by Moodie et al. (1954) in Laboratory Manual for Soil Fertility.

Electrical conductivity ($\text{EC} \times 10^3$) of the saturation extract was measured with solubridge conductivity meter.

pH of the saturated paste was determined by Bechman pH meter as recommended by Jackson (1964).

The determinations of soluble cations and anions were made by EDTA method as given by Richard et al. (1954). For this purpose extract of soil water ratio of 1:5 was used.

Cation exchange capacity was found with flame photometer as suggested by U.S. Salinity Laboratory Staff (1954).

Analysis of soil for organic matter was performed by wet Combustion method of Walkley and Black as recommended by Jackson (1958).

Equivalent CaCO_3 was determined by acid neutralization method as given by Allison and Moodie (1954).

Available phosphorus was tested by spectrophotometer as suggested by Olson and Dean (Black, 1965), while available potassium (K_2O) was determined by flame photometer method as described by Chapman and Prett (1961).

2.5 Plant Analyses

For mineral composition of the leaves and stems sodium and potassium were determined with flame photometer, phosphorus with spectrophotometer and calcium and magnesium were analysed with titration method (U.S. Sal. Lab. Staff., 1954). Total nitrogen was estimated by kjeldahl modified method, sulfur by barium sulfate method and chloride was analysed by dry ashing followed by titration with Silver nitrate as described by Chapman and Prett (1961).

Iodine value of the oil was computed by the method 28.19-20, specific gravity by pycnometer method 28.003, refractive

index by Abe's refractometer method 28.007 of AOAC (1970). Composition of the oil for palmitic, stearic, Oleic, linolic and linolenic acids was determined by Gas liquid chromatography in the Postgraduate Institute of Chemistry, Karachi University.

The climatic data of the experimental period is shown in Annex-1 a-d.

RESULTS

The relative tolerance of the three cultivars of sunflower, Shams, Noor, and H01 to salinity concentrations, 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0 mmhos/cm was studied at different stages of the plant growth. The different regimes of salinity were maintained in the petri plates in the laboratory as well as in the glazed pots containing soil in the open atmosphere. Observations were recorded on the plant from germination till the harvest phase.

3.1 Germination in Petri Plates

3.1.1 Effects of NaCl on the Rate and Germination Percentage of Sunflower.

Addition of the salt to the culture medium affected the emergence of nearly all the cultivars under investigation, but some were affected more than others. There were significant differences in seed emergence due to difference in concentrations of NaCl (Table 2b). The three cultivars subjected to zero salt concentration did not differ in their emergence; it was 100% after one week of sowing. Germination at 2.5 mmhos/cm took the same time of all the cultivars for 100% germination. Salinity level at 5.0 mmhos/cm although delayed the final seed germination until 10th day, it was not very toxic because the final emergence was 95% in Shams and Noor and 98% in H01. Increase in salinity to 7.5 and 10.0 mmhos/cm decreased the rate of germination but the final germination was above 50% in all the tested cultivars. Further increase in the conductivity of the salt solution to 12.5 mmhos/cm

Table 2a. Effects of NaCl on rate and percent germination of various cultivars of Sunflower grown in Petri dishes.

(i) Cv. SHAMS

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	30	74	100	-	-	-
2.5	-	15	62	100	-	-	-
5.0	-	5	74	82	95	-	-
7.5	-	-	30	60	90	-	-
10.0	-	-	7	30	60	70	-
12.5	-	-	-	6	30	37	40
15.0	-	-	-	8	20	28	31

(ii) Cv. NOOR.

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	22	68	100	-	-	-
2.5	-	10	57	100	-	-	-
5.0	-	-	40	70	95	-	-
7.5	-	-	30	60	90	-	-
10.0	-	-	-	40	50	70	-
12.5	-	-	-	10	30	37	40
15.0	-	-	-	5	15	25	30

Table 2a continued.

(iii) Cv. H01 ✓

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	20	70	100	-	-	-
2.5	-	25	60	100	-	-	-
4.0	-	10	60	80	98	-	-
7.5	-	-	30	60	85	90	-
10.5	-	-	10	40	65	70	-
12.5	-	-	-	8	20	26	30
15.0	-	-	-	10	10	18	20

Table 2b. Effects of NaCl on percent germination of various cultivars of sunflower grown in Petri dishes.

Cultivars	Salinity levels in mmhos/cm							Ave
	(0.0)	2.5	5.0	7.5	10.0	12.5	15.0	
Shams	100	100	95	90	70	39	30	87.37a
Noor	100	100	94	90	70	40	30	87.33a
H01	100	100	98	90	69	29	20	84.25b ^{1/}
Ave	100a	100a	96b	90c	69d	36e	27f	

^{1/} Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

caused drastic reduction in the rate of germination. It could not start germination until 8th day. Moreover, final germination of only 40% could occur in Shams and Noor and 30% in Hol until 14th day. Almost the same trend of delay in the rate of germination and percent emergence was revealed by all the cultivars at 15.0 mmhos/cm, where the total seed germination was 31% in Shams, 30% in Noor and 20% in Hol (Table 2a).

3.1.2 Effects of CaCl_2 on the Rate and Germination percentage of ²Sunflower.

Germination of the seeds of the three test cultivars at zero and 2.5 mmhos/cm salt concentration was 100% after one week of sowing (Table 3a). Increase in concentration of the ambient solution to 5.0 mmhos/cm did not affect the rate and % germination of the seeds. Salinities at 7.5 and 10.0 mmhos/cm caused some delay in the rate of germination, but the final emergence was not inhibited below 60% in the three cultivars. Further increase to 12.5 and 15.00 mmhos/cm salinity impeded the rate and percent germination of all the seeds. The final observation on 14th day of the experiment revealed that germination was significantly reduced (Table 3b). At 12.5 mmhos/cm the final emergence was 40% in Shams, 45% in Noor and about 35% in Hol. The last regime of salinization, 15.0 mmhos/cm had almost the same inhibitory effect on seed germination of all the cultivars. The final emergence was 30% in Shams and Noor and only 25% in Hol. At the highest salinity of this salt there was also a concurrent decrease in plumule and radicle length of all the cultivars.

Table 3a. Effects of CaCl_2 on rate and percent germination
of various cultivars of Sunflower grown in Petri plates.

(i) Cv. SHAMS

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	15	80	100	-	-	-
2.5	-	10	85	100	-	-	-
5.0	-	-	65	95	-	-	-
7.5	-	-	40	70	80	-	-
10.0	-	-	-	45	60	70	-
12.5	-	-	-	15	30	30	40
15.0	-	-	-	10	20	25	30

(ii) Cv. NOOR

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	20	75	100	-	-	-
2.5	-	15	65	100	-	-	-
5.0	-	-	55	70	95	-	-
7.5	-	-	35	55	80	90	-
10.0	-	-	-	45	65	75	-
12.5	-	-	-	20	40	40	45
15.0	-	-	-	-	15	15	30

Table 3a. continued

(iii) Cv. H01

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	30	75	100	-	-	-
2.5	-	20	60	100	-	-	-
5.0	-	15	60	90	-	-	-
7.5	-	-	35	60	80	-	-
10.0	-	-	10	40	60	-	-
12.5	-	-	-	15	-	35	-
15.0	-	-	-	10	20	-	25

Table 3b. Effects of CaCl_2 on percent germination of various cultivars of sunflower grown in petri dishes.

Cultivars	Salinity levels in mmhos/cm							Ave
	(0.0)	2.5	5.0	7.5	10.0	12.5	15.0	
Shams	100	100	94	80	70	40	29	29a
Noor	100	100	95	90	74	45	30	30a
H01	100	100	90	80	60	34	25	25b ₁ /
Ave	100a	100a	93b	83c	68d	39e	28f	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

3.1.3 Effects of $MgCl_2$ on the Rate and Germination percentage of Sunflower.

The salt affected the rate of germination (Table 4a) and the final emergence (Table 4b) significantly. In zero salt concentration, all the seeds germinated to 100% within a week time. It is evident from Table 4a that addition of the salt to the ambient solution had an immediate effect on germinating seeds at such low salinity as 2.5 mmhos/cm. The germination was delayed by one day in Cv. Noor and Hol and there was a reduction of 5% in germination in Cv. Shams. Addition of the salt to the culture medium at 5.0 and 7.5 mmhos/cm impeded the rate of germination and final emergence of the seeds. Appreciable reduction in seed germination was noticed at 10.0 mmhos/cm salinity level. With prolongation of the time until 14th day, there was only 55% total emergence in Shams and Noor and 60% in Hol. Higher salinization regimes had very drastic effect on the seed germination. At 12.5 mmhos/cm, in addition to delay, the final emergence was 30% in Shams and Hol and 20% in Noor. At the last salinity level i.e. 15.0 mmhos/cm all the cultivars were affected severely. The final germination was 20% in Shams and Hol and 15% in Noor.

3.1.4 Effects of Na_2SO_4 on the Rate and Germination percentage of Sunflower.

The salt effect on the rate of germination and the final emergence are presented in table 5a and Table 5b respectively. Almost 100% germination of all the seeds occurred at salinity

levels zero, 2.5, and 5.0 mmhos/cm. However, with increase in the salt solution the rate of germination was affected, but the response of all the cultivars in final germination was not as significant as in other salts viz. NaCl, CaCl_2 . It can be deduced from the data in Table 5a though, apparently there was some delay in the rate of germination, final emergence at 15.0 mmhos/cm still averaged 43% in all the seeds.

3.1.5 Effects of Mixture Salts on the Rate and Germination Percentage of Sunflower.

The rate of germination and final germination percentage were significantly reduced with the application of mixture salts (Table 6a and Table 6b). Salinities at zero, 2.5 and 5.0 mmhos/cm did not have significant effects on germinating seeds; all the three cultivars germinated to almost 100% after a week of sowing. With increase in salinity there was a gradual decrease in final emergence until salinity level of 10.0 mmhos/cm where 73% germination was exhibited in Cv. Shams, 71% in Noor and 62% in H01. Further increase in salinity severely hampered the germination efficiency of all the cultivars. At 12.5 mmhos/cm salinity level 40% germination was recorded in Shams and H01 and 30% in Noor. At the EC value of 15.0 mmhos/cm the germination was affected as severely as in the individual salts, NaCl and MgCl_2 because only 30% germination was observed in Cv. Shams and Noor and 20% in H01 which showed the highest susceptibility at this level of salinity.

Table 4a. Effects of $MgCl_2$ on rate and percentage germination of various cultivars of sunflower grown in petri plates.

(i) Cv. SHAMS

Salinity levels in mmhos/cm.	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	20	75	100	-	-	-
2.5	-	5	60	95	-	-	-
5.0	-	-	25	75	90	-	-
7.0	-	-	20	40	60	70	-
10.0	-	-	10	30	40	40	55
12.5	-	-	-	5	5	25	30
15.0	-	-	-	-	10	15	20

(ii) Cv. NOOR

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	30	85	100	-	-	-
2.5	-	20	70	90	100	-	-
5.0	-	10	60	85	90	-	-
7.5	-	-	30	55	65	70	-
10.0	-	-	10	30	35	50	55
12.5	-	-	-	2	15	15	20
15.0	-	-	-	2	10	10	15

(iii) Cv. H01

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	15	80	100	-	-	-
2.5	-	10	75	90	100	-	-
5.0	-	5	45	75	80	-	-
7.5	-	2	35	60	-	-	-
10.0	-	-	15	40	45	50	60
12.5	-	-	2	10	10	25	30
15.0	-	-	-	5	15	15	20

Table 4b. Effects of $MgCl_2$ on percent germination of various cultivars of sunflower grown in petri dishes.

Cultivars	Salinity levels in mmhos/cm							
	Control (0.0)	2.5	5.0	7.5	10.0	12.5	15.0	Ave
Shams	100	90	90	70	54	30	20	65.50a
Noor	100	100	89	71	55	20	15	64.35b
H01	100	100	80	69	59	30	20	65.43a _{1/}
Ave	100a	98b	86c	70d	56e	26f	18g	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at rp 1%.

Table 5a. Effects of Na_2SO_4 on rate and percent germination of various cultivars of sunflower grown in petri dishes.

(i) Cv. Shams

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	30	85	100	-	-	-
2.5	-	20	70	100	-	-	-
5.0	-	10	60	100	-	-	-
7.5	-	8	70	90	95	-	-
10.0	-	-	55	80	90	-	-
12.5	-	-	15	40	55	60	-
15.0	-	-	-	30	42	-	45

(ii) Cv. Noor

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	35	80	100	-	-	-
2.5	-	15	75	100	-	-	-
5.0	-	-	70	100	-	-	-
7.5	-	-	60	80	90	-	-
10.0	-	-	45	60	75	80	-
12.5	-	-	-	10	50	60	-
15.0	-	-	-	20	30	40	41

Table 5a. continued

(iii) Cv. H01

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	30	70	100	-	-	-
2.5	-	25	65	100	-	-	-
5.0	-	28	70	95	-	-	-
7.5	-	12	50	80	90	-	-
10.0	-	-	40	70	80	-	-
12.5	-	-	40	50	55	60	-
15.0	-	-	14	20	30	45	45

Table 5b. Effect of Na_2SO_4 on percent germination of various cultivars of sunflower grown in petri dishes.

Cultivars	Salinity levels in mmhos/cm							Ave
	Control (0.0)	2.5	5.0	7.5	10.0	12.5	15.0	
Shams	100	100	100	95	90	59	45	84.17a
Noor	100	100	100	90	80	60	41	81.57b
H01	100	100	94	90	80	60	50	82.00b _{1/}
Ave	100a	100a	98b	92c	83d	59c	45f	

_{1/} Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

Table 6a. Effects of mixture salts on rate and percent germination of sunflower cultivars grown in petri plates.

(i) Cv. Shams

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.00 (Control)	-	30	80	100	-	-	-
2.5	-	30	75	100	-	-	-
5.0	-	18	60	100	-	-	-
7.5	-	-	50	80	90	-	-
10.0	-	-	48	60	70	73	-
12.5	-	-	10	20	20	40	-
15.0	-	-	-	10	15	25	30

(ii) Cv. Noor

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	40	80	100	-	-	-
2.5	-	30	80	100	-	-	-
5.0	-	15	50	90	-	-	-
7.5	-	10	40	80	80	85	-
10.0	-	-	30	60	70	71	-
12.5	-	-	-	10	20	30	-
15.0	-	-	-	-	18	28	30

Table 6a. continued.

(ii) Cv. H01

Salinity levels in mmhos/cm	Days after sowing						
	2	4	6	8	10	12	14
0.0 (Control)	-	20	75	100	-	-	-
2.5	-	15	70	100	-	-	-
5.0	-	-	50	90	92	-	-
7.5	-	-	60	70	90	-	-
10.0	-	-	40	50	60	-	62
12.5	-	-	20	-	30	40	-
15.0	-	-	-	-	10	18	20

Table 6b. Effect of mixture salts on percent germination of sunflower cultivars grown in petri dishes.

Cultivars	Salinity in mmhos/cm							
	Control (0.0)	2.5	5.0	7.5	10.0	12.5	15.0	Ave
Shams	100	100	100	90	73	40	30	76a
Noor	100	100	100	85	71	30	29	73b ✓
H01	100	100	91	89	61	39	20	72c1/
Ave	100a	100a	97b	88c	68d	36e	26f	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

3.2

GERMINATION IN POTS

Sandy loam soil was filled in glazed pots having capacity of 12 kg each. The soil had an electrical conductivity of 2.5 mmhos/cm which served as the control. Six salinization regimes were maintained in the soil with the addition of NaCl, CaCl_2 , MgCl_2 , and N_2SO_4 either in single or in mixture doses. The conductivity of the saturation paste was determined with the help of a conductivity bridge. Each treatment was replicated four times. Fifteen seeds were sown in each pot in early March of the year. After emergence, the plants were thinned to three in each pot. Data on different aspects of the plant in relation to different salinization regimes were recorded right from germination.

3.2.1 Effects of NaCl on the Rate and Germination Percentage of Sunflower.

The germination pattern may be followed from table 7a & table 7b. Germination started in the control pots having electrical conductivity 2.5 mmhos/cm on 6th day of sowing. About 97% seeds germination in Cv. Shams, followed by 96% in Noor and 94% in H01 after 8 days of the sowing. Increase in salinity to 5.0 mmhos/cm delayed germination by 3 days and the final emergence was reduced to 94% in Cv. Shams, 86% in Noor and 83% in H01. Further increase in salinity decreased the rate of germination and increased the emergence time. Drastic change in germination was noticed at salinity level 10.0 mmhos/cm. Emergence of all the seeds could be noticed only after 8 days of sowing. It started with only 20% in Noor & H01 and 27% in Shams.

Final emergence was also badly affected at this level, particularly in Hol (39%) and Noor (46%). Shams however, resisted and showed about 60% stand. It is evident from Table 7a that none of the cultivar could resist the toxic effects of the salt above 10.0 mmhos/cm. Hol was the most vulnerable at 12.5 mmhos/cm and revealed total germination of only 27% on 18th day of sowing. Total emergence of Noor and Shams was also below 50%. The three cultivars subjected to the highest salinity level 15.0 mmhos/cm: differed significantly in ultimate emergence. The final emergence was 34% in Shams, 25% in Hol and 19% in Noor. The germination of all the seeds started after a delay of 11 days but prolongation beyond the 18 days limit could not improve.

3.2.2 Effects of CaCl_2 on the Rate and Germination Percentage of Sunflower.

The significant effect of this salt on the rate of final emergence can be noticed from Table 8a & Table 8b. Addition of the salt to soil solution to the level of 5.0 mmhos/cm did not induce any adverse effect on the seed germination. Germination of Shams and Noor was almost 100% within 8 days of sowing as compared to the control treatment. Cv. Hol, however, showed 5% reduction in final germination at this level. Increase in salinity to 7.5 and 10.0 mmhos/cm delayed germination, but the final emergence was above 50% in all the cases. Noticeable change in % germination occurred only when the salt concentration was raised to 12.5 mmhos/cm. At this level the initial germination was delayed until 8th day of sowing and completed on 15th day with about 45% germination in Hol, 42%

Table 7a. Effects of NaCl on rate and Percent germination
of various cultivars of sunflower grown in pots.

(A) Cv. Shams

Salinity levels in mmhos/cm	Days after sowing					
		6	9	12	15	18
2.5 (Control)	-	65	97.5	-	-	-
5.2	-	25	63	94.5	-	-
7.5	-	47	67	85.5	-	-
10.0	-	-	27	40.0	59.75	-
12.5	-	-	34	40	46.5	-
15.0	-	-	-	20	27	34.25

(B) Cv. Noor

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (Control)	-	54	96.25	-	-	-
5.0	-	45	74.0	86.0	-	-
7.5	-	40	60	69.5	-	-
10.0	-	-	20	34	46.0	-
12.5	-	-	-	27	38.0	40.50
15.0	-	-	-	14	-	19.25

Table 7a continued.

(14) Cv. H01

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (Control)	-	60.0	94.25	-	-	-
5.0	-	40.0	60.00	83.50	-	-
7.5	-	27.0	54.00	66.25	-	-
10.0	-	-	20.0	27.00	39.0	-
12.5	-	-	-	20.0	25.0	27.5
15.0	-	-	-	14.0	24.0	25.5

Table 7b. Effect of NaCl on percent germination of various
cultivars of sunflower grown in pots.

Cultivars	Salinity in mmhos/cm						
	Control (2.5)	5.0	7.5	10.0	12.5	15.0	Ave
Shams	97.50	94.50	85.50	59.75	46.50	34.25	69.66a
Noor	96.25	86.00	69.50	46.00	40.50	19.25	59.58b
H01	94.25	83.25	66.25	39.00	27.50	25.50	56.00c ^{1/}
Ave	96.0a	88.0b	73.75c	48.25d	38.17e	26.33f	

^{1/} Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

Table 8a. Effects of CaCl_2 on rate and percent germination
of various cultivars of sunflower sown in pots.

(I) Cv. Shams

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (Control)	-	65	100	-	-	-
5.0	-	62	99	-	-	-
7.5	-	57	78	84.25	84.25	-
10.0	-	32	58	70	79.25	-
12.5	-	-	20	38	42.25	-
15.0	-	-	12	27	27	33

(II) Cv. Noor

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (Control)	-	72	100	-	-	-
5.0	-	61	98	-	-	-
7.5	-	40	80	90	-	-
10.0	-	28	52	75.25	-	-
12.5	-	-	15	32	39.5	-
15.0	-	-	5	25	25	29.75

Table 8a continued

(48) Cv. H01

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (Control)	-	75	100	-	-	-
5.0	-	52	95	-	-	-
7.5	-	45	70	91	-	-
10.0	-	15	50	70	81	-
12.5	-	-	12	30	45.5	-
15.0	-	-	10	27	27	34.25

Table 8b. Effect of CaCl_2 on percent germination of various cultivars of sunflower grown in pots.

Cultivars	Salinity in mmhos/cm						Ave
	Control (2.5)	5.0	7.5	10.0	12.5	15.0	
Shams	100	99	84	79	42	33	73b
Noor	100	98	90	75	39	30	72c
H01	100	95	91	81	43	34	74a 1/
Ave	100a	97b	88c	78d	42e	32f	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

in Shams and 39% in Noor. Salinization regime at 15.0 mmhos/cm stressed all the cultivars which showed maximum delay and reduction in final emergence; about 30, 33 and 34% germination was recorded in Noor, Shams and H01 respectively.

3.2.3 Effects of $MgCl_2$ on the rate and Germination percentage of ²Sunflower.

The salt effect on germination may be followed from Table 9a and Table 9b. The three cultivars at the control level and 2.5 mmhos/cm did not differ significantly from one another. Germination started after 5 days of sowing and completed to about 99% in Cv. H01, 98% in Shams and 97% in Noor on 9th day of observation. The three cultivars subjected to the 5.0 mmhos/cm salt concentration responded with low rate of germination. Shams and Noor achieved almost the same percentage of emergence at this treatment of salinity as they did at the control level, but H01 showed germination delay of 3 days and the percent germination was also the lowest. Salt concentration at the level of 7.5 and 10.0 mmhos/cm impeded the rate of germination and the final count in all the cultivars was lower than control. Salinization regime. 12.5 mmhos/cm proved drastic to germination/ ^{because} Only 7-11% germination could be observed on 9th day of the sowing and very low rate of germination continued until 18th day. The final count was 29% in H01, 37.5% in Shams and 39% in Noor. At the highest salinity 15.0 mmhos/cm all the cultivars exhibited further delay in germination until 12th day after sowing. The observation on 18th day revealed 21.5% emergence in Noor, 27% in Shams and 28% in H01. Further prolongation could not improve seed germination.

Table 9a. Effects of $MgCl_2$ on rate and percent germination
of various cultivars of sunflower sown in pots.

(i) Cv. Shams

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (Control)	-	67	97.5	-	-	-
5.0	-	53	93.5	-	-	-
7.5	-	44	57	69.5	-	-
10.0	-	-	30	50	54.5	-
12.5	-	-	10	17	32	37.5
15.0	-	-	-	22	-	27

(ii) Cv. Noor

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (Control)	-	58	96.5	-	-	-
5.0	-	51	80	95	-	-
7.5	-	44	58	76	79	-
10.0	-	-	32	44	68.5	-
12.5	-	-	7	-	36	39
15.0	-	-	-	-	18	21.5

Table 9a continued

(14) Cv. H01.

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (Control)	-	62	99	-	-	-
5.0	-	35	80	91	-	-
7.5	-	40	50	67	73.5	-
10.0	-	-	20	32	43	-
12.5	-	-	11	29	29	33.5
15.0	-	-	-	8	26	28

Table 9b. Effect of $MgCl_2$ on percent germination of various cultivars of sunflower grown in pots.

Cultivars	Salinity levels in mmhos/cm						Ave
	Control (2.5)	5.0	7.5	10.0	12.5	15.0	
Shams	97	93	69	54	37	27	63b
Noor	96	95	79	68	39	21	66a
H01	99	91	73	43	33	28	61c 1/
Ave	98a	93b	74c	55d	37e	25f	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at rp 1%.

3.2.4 Effects of Na_2SO_4 on the Rate and Germination Percentage of Sunflower.

The inhibitory effects of the salt on seed germination are shown in Table 10a and Table 10b. There were no differences in seed emergence at the control level. Germination was 100% in all the cultivars after 8 days of sowing. With increasing salinity at the level of 5.0, 7.5, and 10.0 mmhos/cm, germination was delayed but the final emergence was not as drastically reduced as in the other salts used for salinization. The fact is evident from table 10a, wherein 81% germination was recorded in Shams, 74.75% in H01 and 68.25% in Noor in the soil having electrical conductivity of 10.0 mmhos/cm. Salt concentration above this level delayed germination and the final emergence was reduced to less than 50% in all the tested cultivars. At the highest salinity level, 15.0 mmhos/cm, H01 exhibited the lowest resistance and showed only 33.25% final germination, which was followed by 35% in Noor and 41% in Shams.

3.2.5 Effects of Mixture Salts on the Rate and Germination Percentage of Sunflower.

Germination results are presented in table 11a and Table 11b. Germination in control pots was about 98% in Shams and Noor and 95% in H01 on 9th day of observation. Germination of all the cultivars at salinity level 5.0 mmhos/cm was almost 94%, but the final emergence was delayed by 3 days as compared with control. Increase in salinity to 7.5 and 10.0 mmhos/cm delayed germination and the final emergence was inhibited accordingly. Above 10.0 mmhos/cm salinity, the seed emergence was delayed further and final count on 18th day was reduced to

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Table 10a. Effects of Na_2SO_4 on the rate and percentage germination of various cultivars of sunflower grown in pots.

(i) Cv. Shams

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (control)	-	70	100	-	-	-
5.0	-	57	95	-	-	-
7.5	-	48	89	-	-	-
10.0	-	41	70	81	-	-
12.5	-	-	30	41	49	-
15.0	-	-	-	16	35	41

(ii) Cv. Noor

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5	-	66	100	-	-	-
5.0	-	59	91.75	-	-	-
7.5	-	40	68	81.25	-	-
10.0	-	-	41	58.00	68.25	-
12.5	-	-	11	26	41.00	-
15.0	-	-	-	13	28	35

Table 10a continued

(iii) Cv. H01

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (control)	-	64	100	-	-	-
5.0	-	60	95.25	-	-	-
7.5	-	48	65.00	85.75	-	-
10.0	-	43	60	74.75	-	-
12.5	-	-	15	30	35	-
15.0	-	-	-	18	26	33.25

Table 10b. Effect of Na_2SO_4 on percent germination of various cultivars of sunflower grown in pots.

Cultivars	Salinity levels in mmhos/cm						Ave
	Control (2.5)	5.0	7.5	10.0	12.5	15.0	
Shams	100	95	89	81	49	41	76a
Noor	100	92	81	68	41	35	69c
H01	100	95	86	75	35	33	71b <u>1/</u>
Ave	100a	94b	85c	75d	42e	36f	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

Table 11a. Effects of mixture salts on rate and percent germination of various cultivars of sunflower grown in pots.

(A) Cv. Shams

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (Control)	-	68	97.5	-	-	-
5.0	-	60	85	94	-	-
7.5	-	30	70	89.25	-	-
10.0	-	-	20	54	64.25	-
12.5	-	-	11	27	40	43.5
15.0	-	-	-	9	20	23.5

(B) Cv. Noor

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (Control)	-	65	98.25	-	-	-
5.0	-	30	80	93.5	-	-
7.5	-	15	40	84	98.00	-
10.0	-	-	10	47	54.75	-
12.5	-	-	-	27	40	44.5
15.0	-	-	-	20	-	23.0

Table 11a continued

(iii) Cv. H01

Salinity levels in mmhos/cm	Days after sowing					
	3	6	9	12	15	18
2.5 (Control)	-	50	95	-	-	-
5.0	-	24	73	93.75	-	-
7.5	-	9	48	77	-	-
10.0	-	-	18	44	49.25	-
12.5	-	-	5	27	34	36.75
15.0	-	-	-	14	23	26.50

Table 11b. Effects of mixture salts on percent germination of various cultivars of sunflower grown in pots.

Cultivars	Salinity in mmhos/cm						
	Control (2.5)	5.0	7.5	10.0	12.5	15.0	Ave
Shams	97	94	89	64	43	23	68.66a
Noor	98	93	89	54	44	23	67.16b
H01	95	93	77	49	37	26	63.04c ^{1/}
Ave	97a	94b	85c	56d	41e	24f	

^{1/} Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

less than 50%. When the electrical conductivity of the saturation extract was 15.0 mmhos/cm, germination did not start until 12th day. No cultivar could show enough resistance to the high conductivity of the soil. They showed almost the same pattern of final emergence which was 23% in Noor, 23.5 in Shams and 26.5% in H01.

The radicle and plumule length was also measured in different salinization regimes maintained in petri plates either with solution of single salts; NaCl, CaCl_2 , MgCl_2 and Na_2SO_4 or their mixture. The radicle and plumule length of germinating seeds of the three cultivars, Shams, Noor and H01 was recorded at the end of 15 day-experiment conducted in the laboratory.

3.3 Radicle Length of Germinating Seeds

3.3.1 Effects of NaCl on the Radicle Length of Germinating Seeds of Sunflower.

The average radicle length of germinating seeds in the zero salt concentration (control) was about 11.70 cm. The length progressively decreased with each rise in concentration of the salt solution until the minimum average length, 0.42 cm, was achieved in the last treatment/15.0 mmhos/cm (Fig. 1; Plate-1). Noticeable reduction in radicle length occurred at 7.5 mmhos/cm and at the last level, 15.0 mmhos/cm, the radicle length was significantly reduced as compared with control. Cultivar Noor and H01 showed almost the same response to salinity with radicle length averaging about 6 cm whereas Shams revealed the highest average reduction to 4.41 cm.

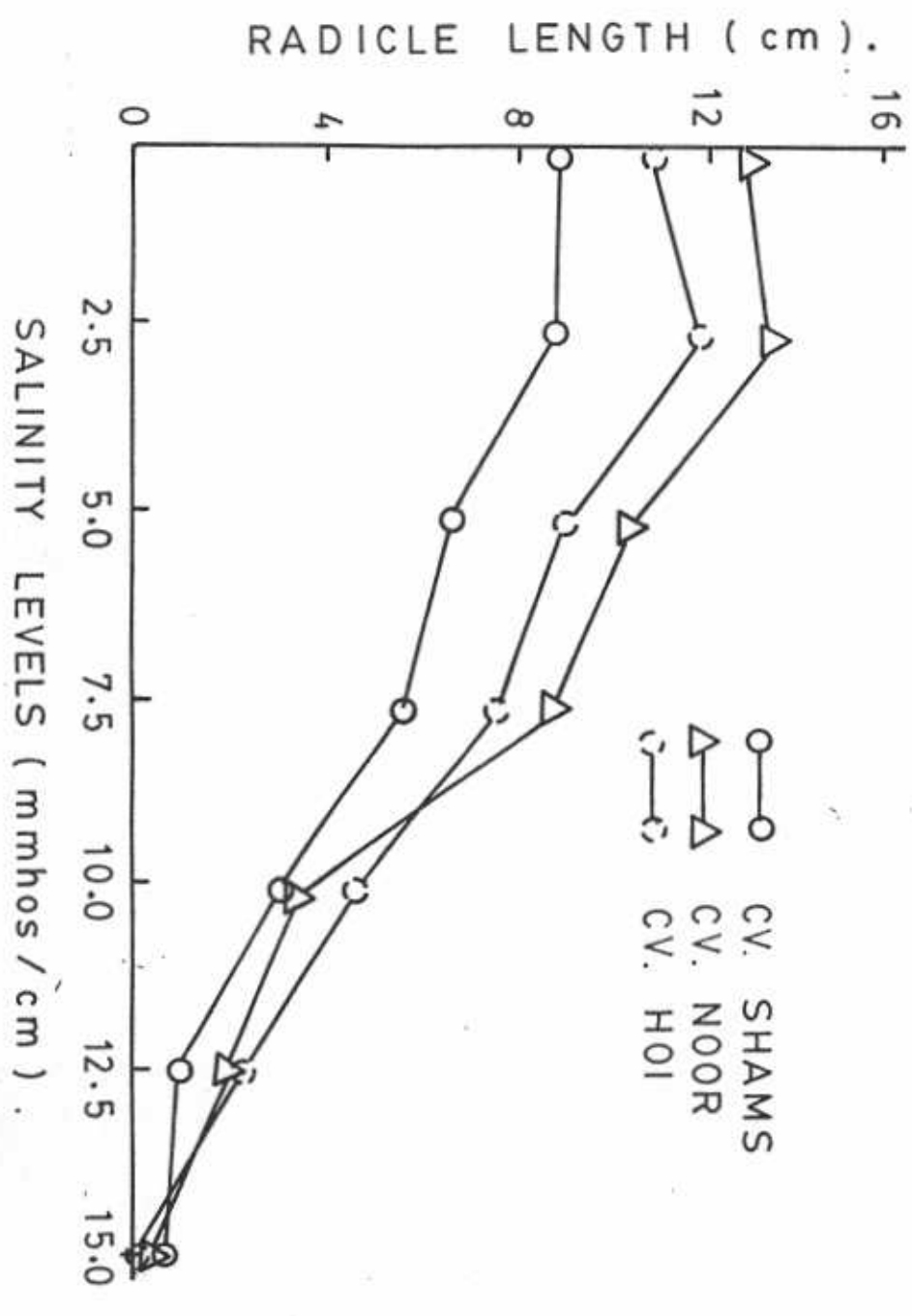


FIG. 1. Effects of sodium chloride on radicle length of germinating seeds of sunflower.



Plate 1. Effects of sodium chloride radicle
length of germinating seeds of sunflower

3.3.2 Effects of Na_2SO_4 on Radicle Length of Germinating Seeds of Sunflower

To begin with, no cultivar showed significant response to the salt concentration upto 2.5 mmhos/cm level. The radicle length was measured to almost 14 cm (Fig.2). Increasing salt concentrations concurrently decreased the radicle length in all the germinating seeds. The toxicity of the salt was especially obvious in the highest salt concentration^{i.e} 15.0 mmhos/cm. Almost similar response was shown by Shams and H01 to different salt concentrations. As evident from Fig.2, among the three cultivars, Noor revealed the lowest resistance to high salt concentration with an average radicle length of 2.57 cm.

3.3.3 Effects of CaCl_2 on Radicle Length of Germinating Seeds of Sunflower.

Different salt concentrations in the culture medium had significant effect on the radicle size of the seeds. However, like Na_2SO_4 the first salinization regime, 2.5 mmhos/cm, had negligible effect on the germinating seeds; the average radicle length was about 12 cm (Fig. 3). Increasing concentration of the salt in the ambient solution reduced the radicle length, but the effect was highly significant at 15.0 mmhos/cm when the average radicle length of all the cultivars was 0.39 cm. In fact this drastic effect could no more be alleviated even with prolongation of the time. Cultivars Shams and H01 were at a par and showed an average radicle length of about 7 cm, while Noor was the most susceptible to the salt effect and revealed the smallest average radicle length of 6.40 cm.



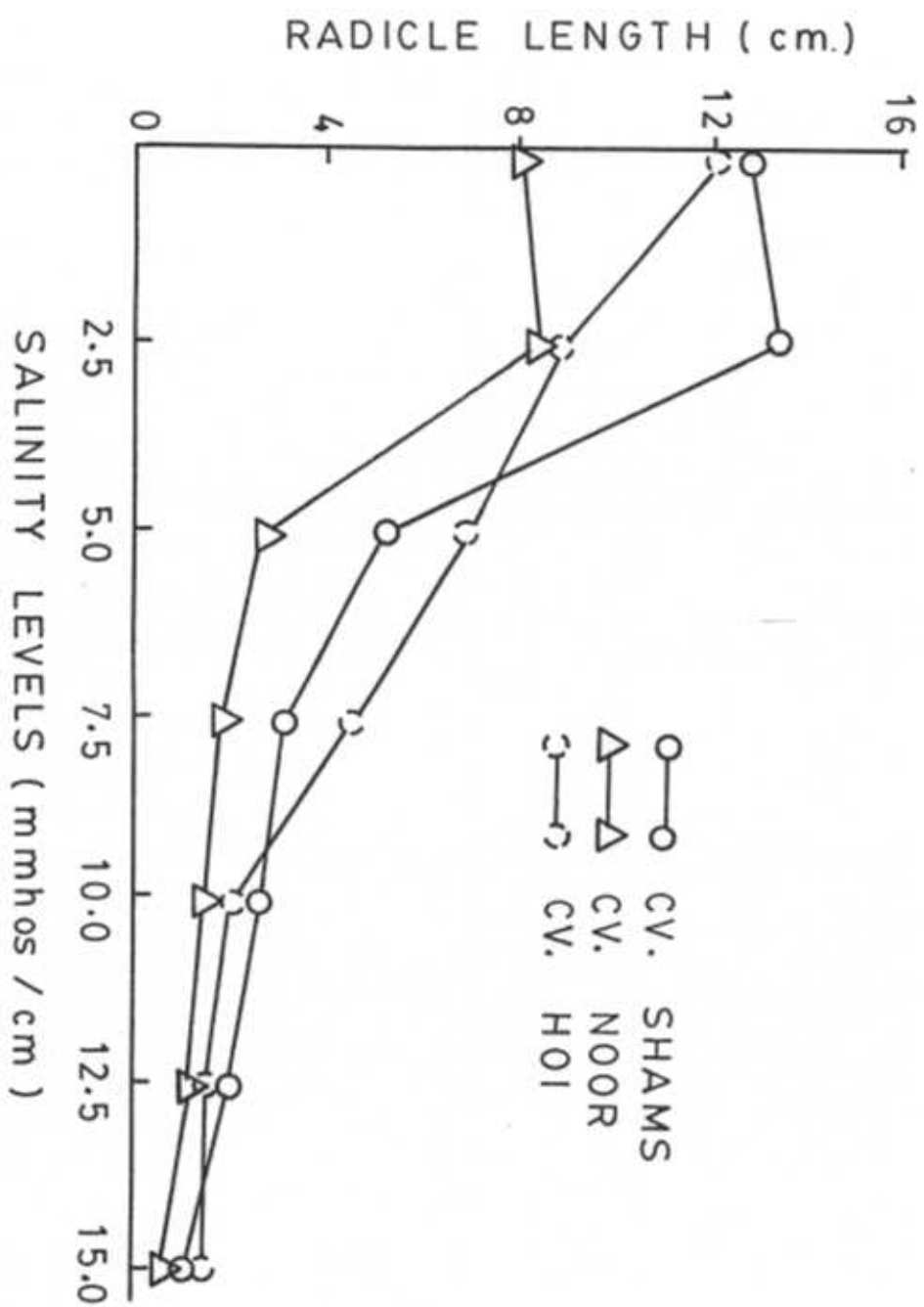
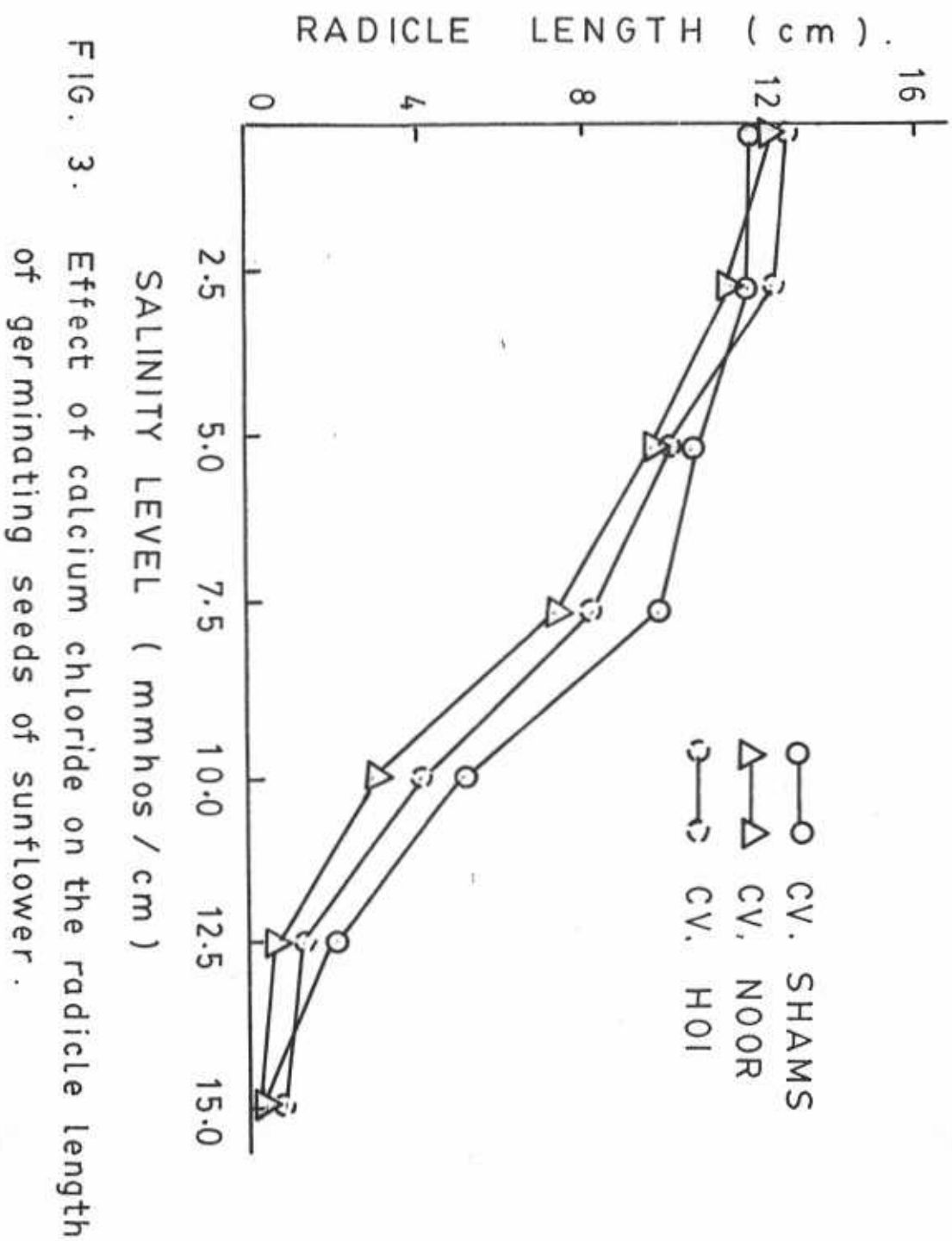


FIG. 2. Effects of sodium sulfate on radicle length of germinating seed of sunflower.



3.3.4 Effects of $MgCl_2$ on Radicle Length of Germinating Seeds of sunflower.

Unlike other salts, $MgCl_2$ proved toxic in as low concentration as 2.5 mmhos/cm in reducing the radicle length of germinating seeds of sunflower (Fig. 4). Adding the salt to the level of higher concentrations reduced the radicle length accordingly. Cultivar Shams was the most affected followed by H01 and Noor. The seeds did not germinate at all in case of the treatment whose EC value was adjusted to 15.0 mmhos/cm level.

3.3.5 Effects of Mixture Salts on Radicle Length of Germinating Seeds of Sunflower.

At low concentrations, the effect of mixture salts on radicle length of the seeds of the three cultivars was not toxic. At first level of the salt concentration, 2.5 mmhos/cm, the radicle length was 13.23 cm, which neared to the radicle size in the control plates (Fig. 5). Reduction in length of the radicles followed increase in conductivity of the salts solution in the ambient medium. At the highest salt concentration, 15.0 mmhos/cm, the radicles dwindled to less than half cm. The average length attained was 0.16 cm. Cv. Shams and Noor were found to be more susceptible than H01 at this level of salt concentration.

3.4 PLUMULE LENGTH OF GERMINATING SEEDS

The procedure adopted for this purpose was the same as in the experiment for radicle length. The experiment continued for 15 days and the plumule length of the seeds was measured in different regimes of salinization. Observations on plumule

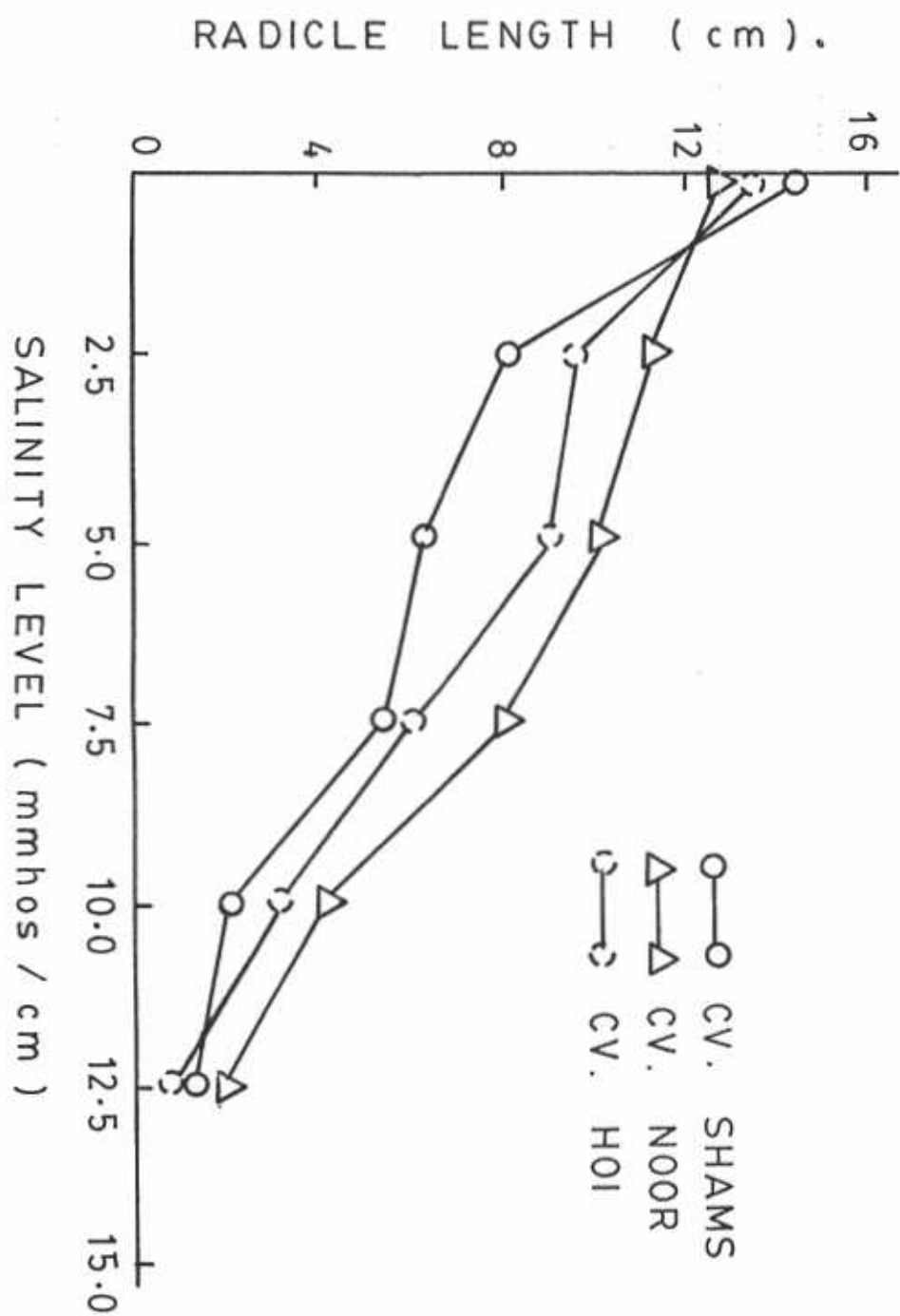


FIG. 4. Effects of magnesium chloride on the radicle length of germinating seeds of sunflower .

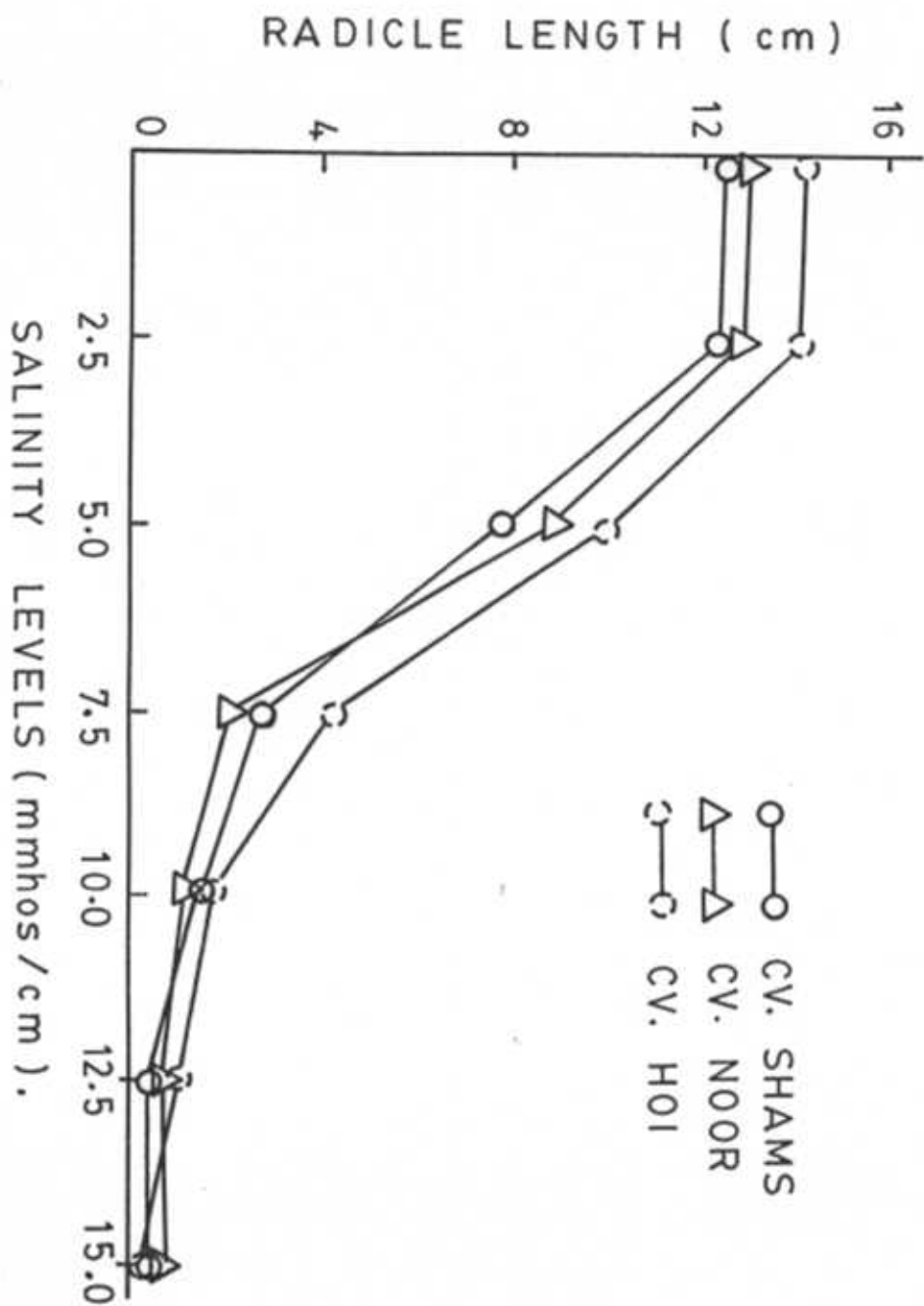


FIG. 5. Effects of mixture salts on radicle length of germinating seeds of sunflower.

length were recorded in individual salt solutions as well as in their mixture. The effect was determined under the following headings:

3.4 Plumule Length of Germinating Seeds.

3.4.1 Effects of NaCl on Plumule Length of Germinating Seeds of Sunflower.

The toxic effect of NaCl on plumule length is evident from (Fig. 6). The worst affected cultivar was Shams which attained an average plumule length of 3.57 cm as compared with control seeds having 10.0 cm plumule length. The reducing effect appeared even in the first salt concentration, 2.5 mmhos/cm, when the plumule length was almost halved. In fact increasing salt concentrations had their dwindling effect on the plumule length of all the cultivars. The plumule length in some of the seeds of Cv. Noor and H01 was reduced to almost 0.0 cm at the highest salinity level i.e. 15.0 mmhos/cm. The minimum plumule length 0.03 cm was recorded in Noor at this salinity level. However, according to the overall performance, Shams proved more susceptible to this salt than Noor and H01.

3.4.2 Effects of Na_2SO_4 on Plumule Length of Germinating Seeds of Sunflower.

This salt at low concentration of 2.5 mmhos/cm was not as toxic as NaCl for plumules of the germinating seeds. The average plumule length at 2.5 mmhos/cm measured to 7.72 cm and was not significantly different from control seeds (Fig. 7). With increasing salt concentrations the plumule length was reduced accordingly. Drastic reduction in plumule length occurred



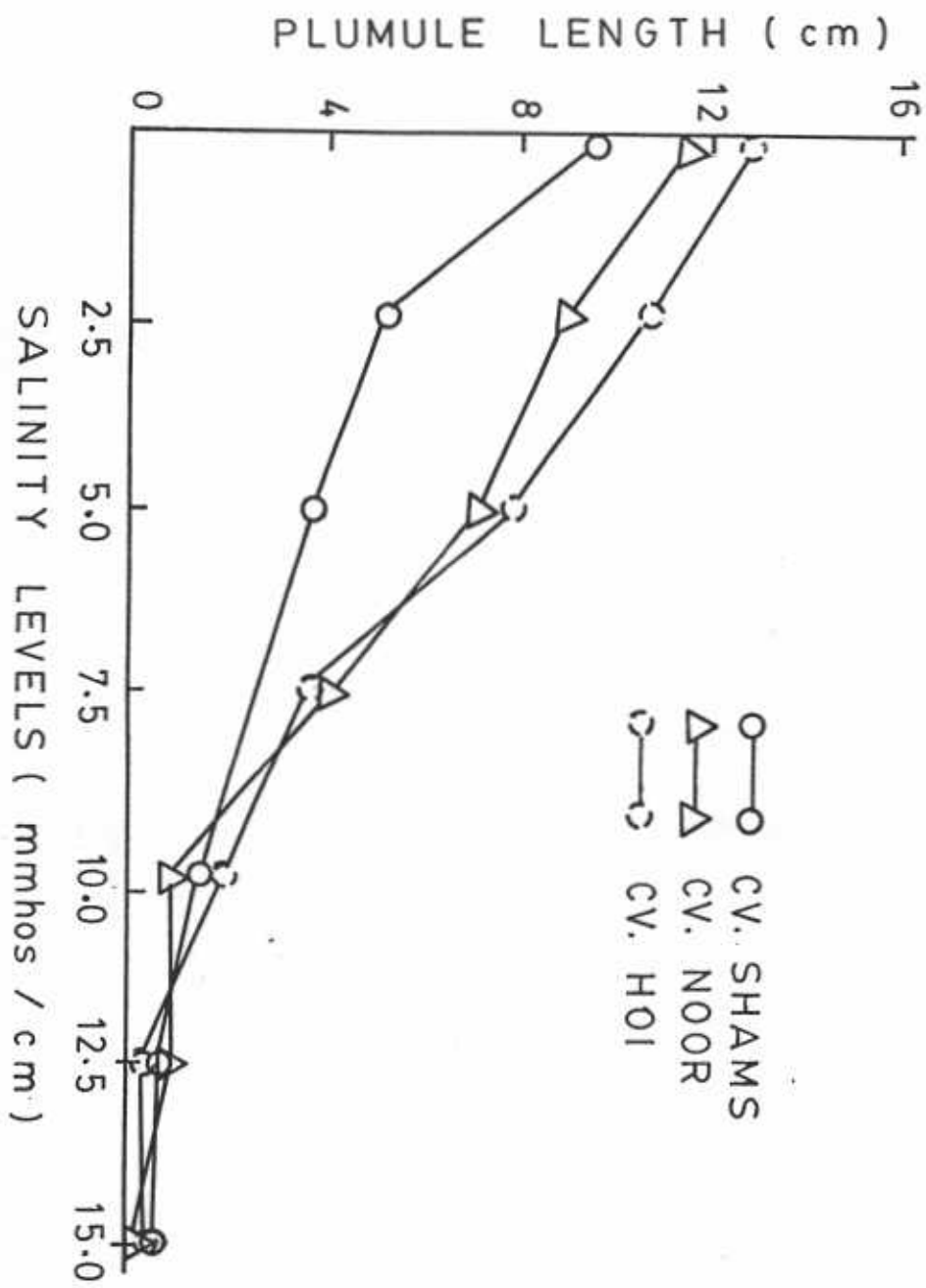


FIG. 6 Effects of sodium chloride on plumule length of germinating seeds of sunflower.

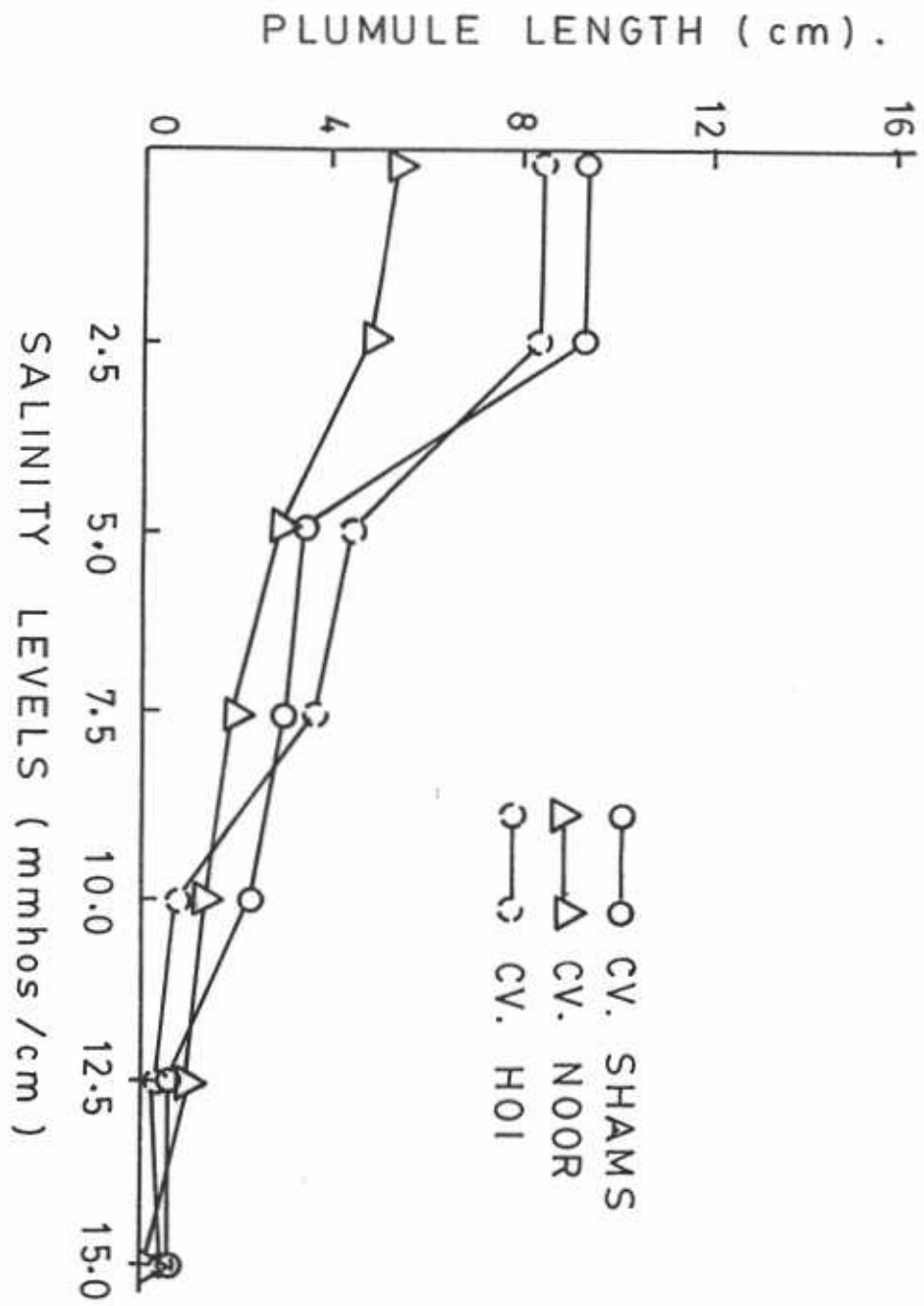


FIG. 7. Effects of sodium sulfate on plumule length of germinating seeds of sunflower.

at higher salinities 12.5 and 15.0 mmhos/cm when the plumule length was reduced to less than 1.0 cm. The plumules at these concentrations turned brown and eventually died away. Shams and H01 were at a par in response and showed an average plumule length of about 4 cm, while Noor had 2.65 cm.

3.4.3 Effects of $MgCl_2$ on Plumule Length of Germinating Seeds of Sunflower

The average plumule length at zero salt concentration was 9.16 cm (Fig.8). All the germinating seeds responded immediately to the increasing salt concentrations and the plumule length was reduced to 6.87 cm at 2.5 mmhos/cm. Drastic reduction in plumule length occurred in Cv. Shams at this level of the salt concentration and the plumule length was reduced to half. Further increase in salt concentration inhibited the plumule length in all the cultivars. At the highest salinization regime, 15.0 mmhos/cm, the plumule length was reduced to almost zero. Thus this salt showed more toxic effects on the growth of plumule than any other salt under test. Shams was found most susceptible to $MgCl_2$ concentration and showed an average plumule length of 2.93 cm followed by H01 with 4.04 cm and Noor 5.31 cm.

3.4.4 Effects of $CaCl_2$ on Plumule Length of Germinating Seeds of Sunflower.

The salt had but little inhibitory effect on the plumule length at 2.5 mmhos/cm conductivity of the culture medium. The average plumule length at this salt level was 8.41 cm as compared with control having 8.66 cm (Fig.9). Increasing salt

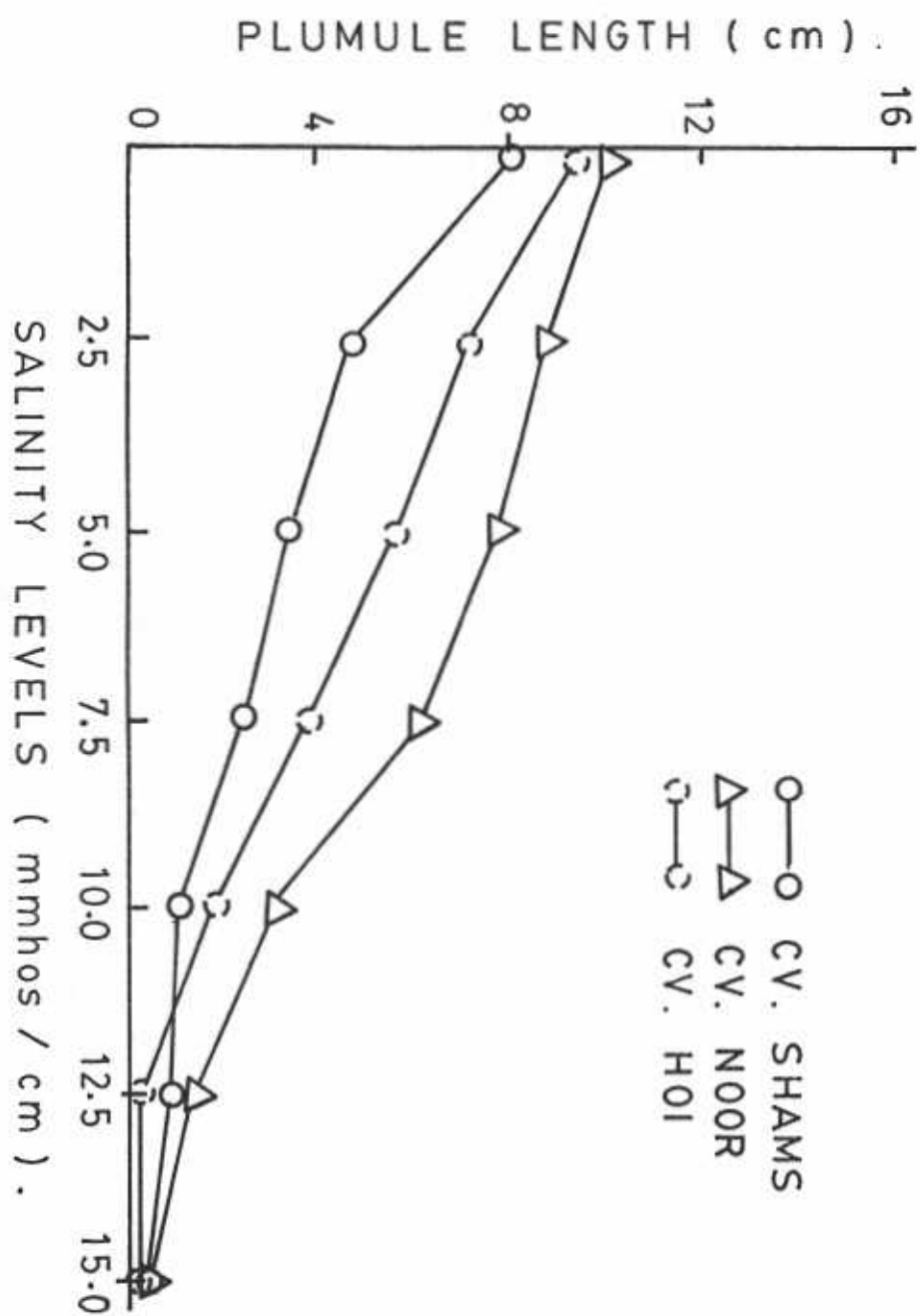


FIG. 8. Effects of magnesium chloride on the plumule length of germinating seeds of sunflower.

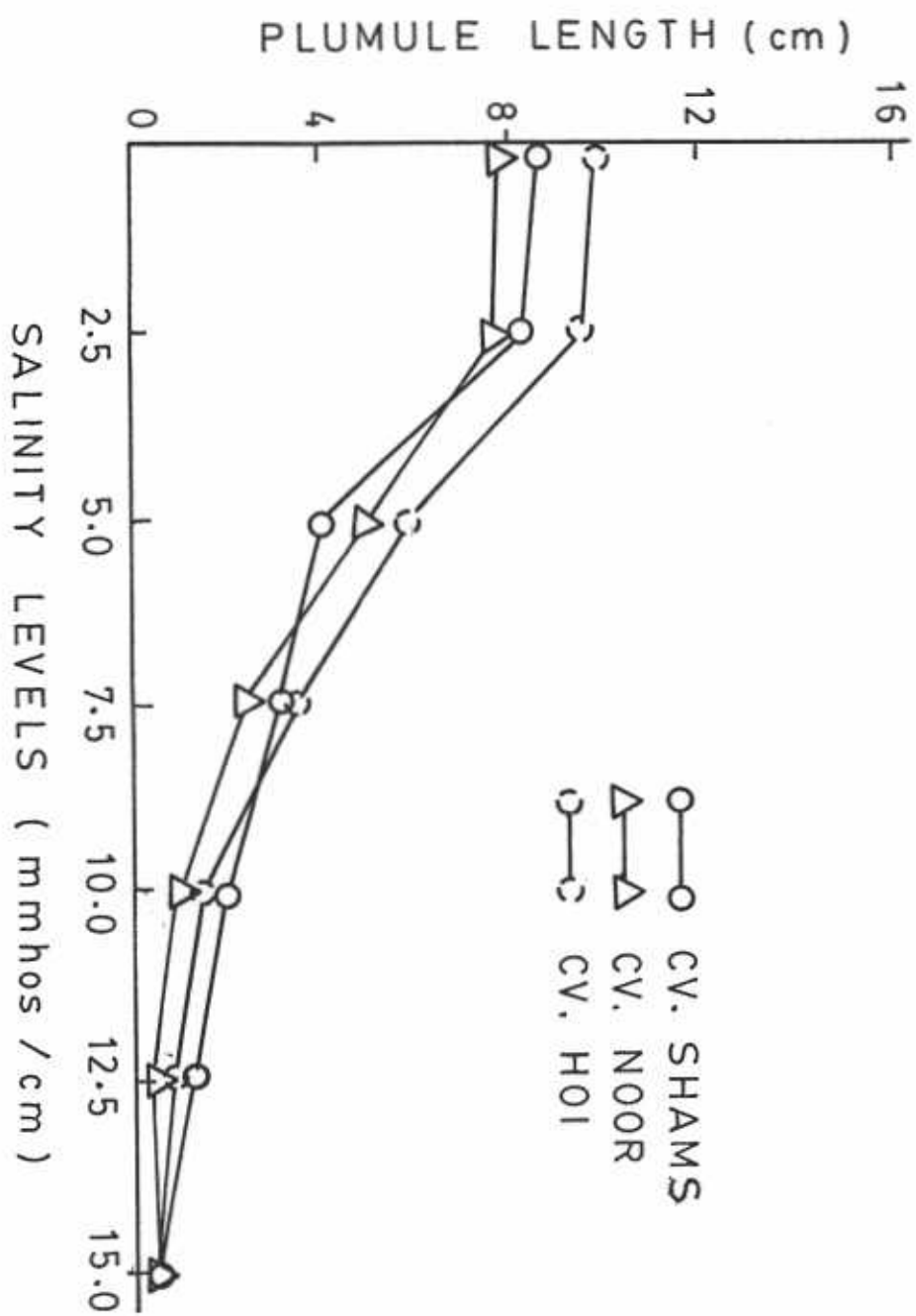


FIG. 9. Effects of calcium chloride on the plumule length of germinating seeds of sunflower.

concentration to 7.5, 10.0 and 12.5 mmhos/cm reduced the plumule length of all the cultivars. Marked decrease in plumule size of all the seeds occurred at the highest salinity, 15.0 mmhos/cm, when the average length was reduced to only 0.3 cm. Cv. Noor had the smallest plumule length of 0.22 cm at this level of salt concentration.

3.4.5 Effects of Mixture Salts on Plumule Length of Germinating Seeds of Sunflower.

At 2.5 mmhos/cm salt concentration, the average plumule size of all the cultivars was 10.95 cm as compared with control having 11.35 cm length (Fig.10). With increase in salinity the plumule length was inhibited concurrently. At the highest salt concentration, 15.0 mmhos/cm the plumule length was reduced drastically to less than half of a centimeter and in Cv. H01, the plumule did not develop at all. Minimum average plumule length of 5.11 cm was exhibited by H01 followed by Noor and Shams with 5.26 cm and 5.41 cm respectively.



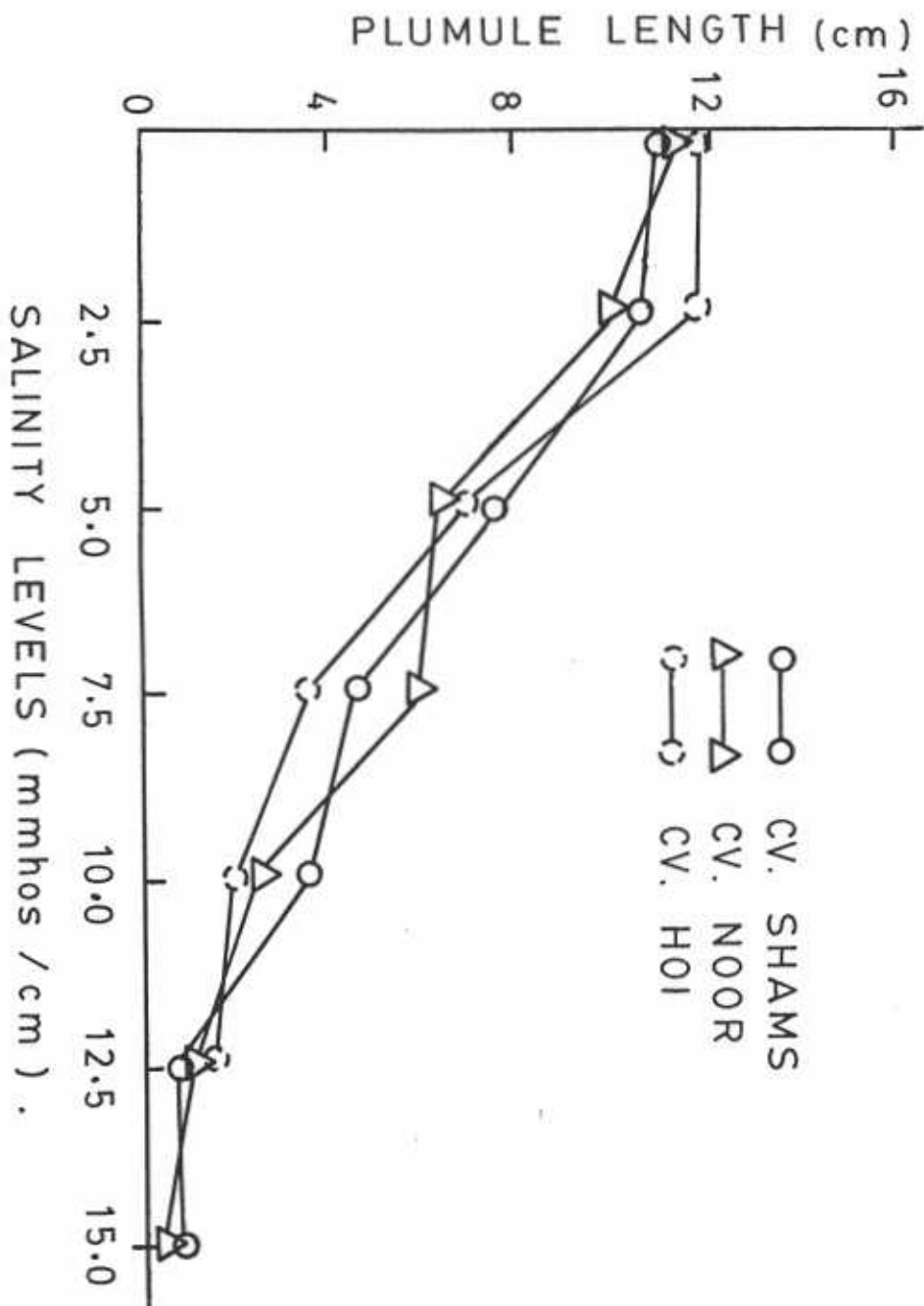


FIG. 10. Effects of mixture salts on plumule length of germinating seeds of sunflower.

3.5 Effects of Different Salinities on Plant Growth

The aim of this study was to find out the effects of different salts on plant height of Cv. Shams, Noor and H01.

3.5.1 Effects of NaCl on Plant Height

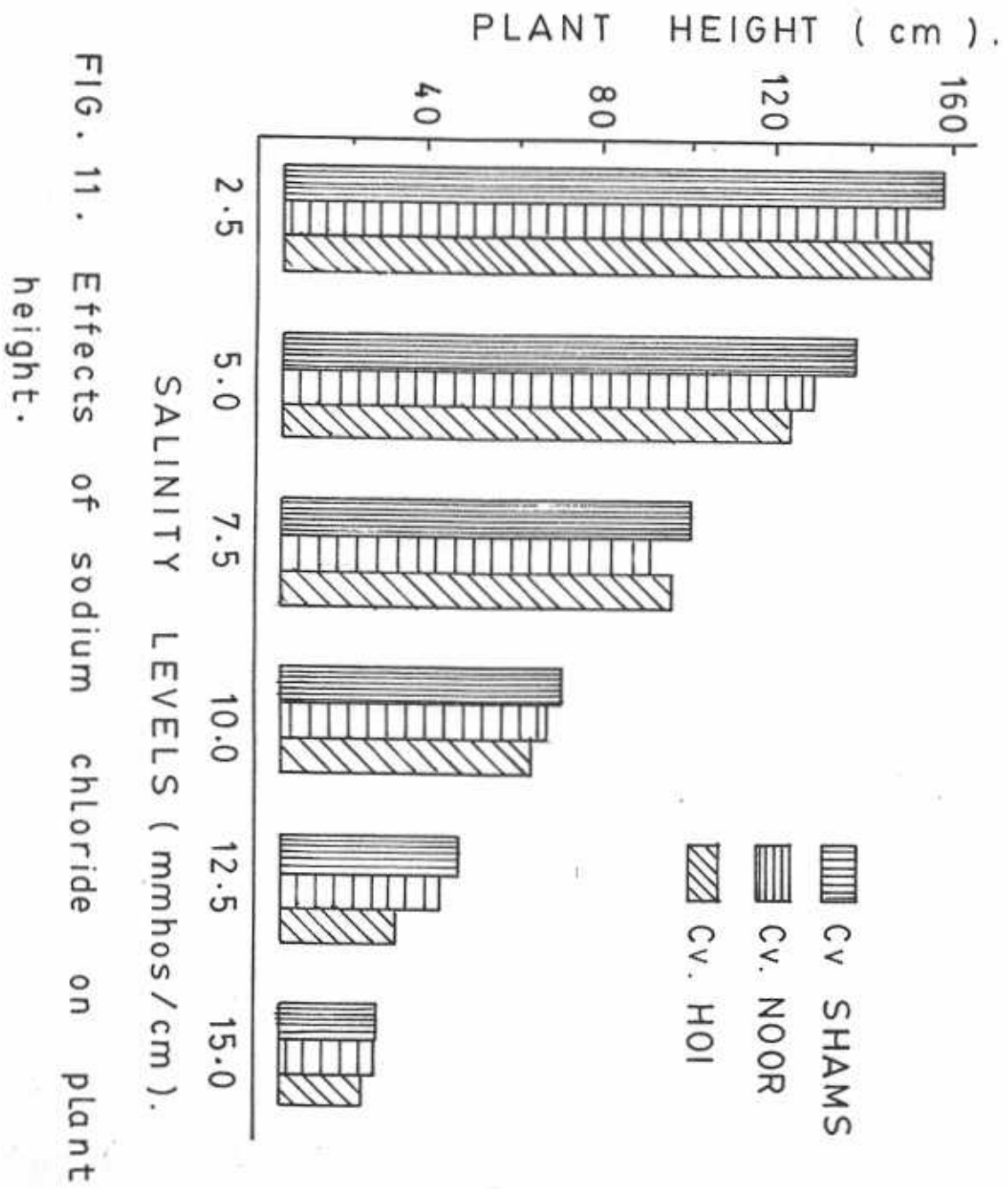
Different concentrations of the salt had significant effect on plant height (Table 12). After two weeks of emergence, plants in control pots having electrical conductivity of 2.5 mmhos/cm exhibited maximum height of 24.8 cm in the Cultivar Shams followed by H01 and Noor with 22.9 and 20.71 cm respectively.

Cultivars Shams and H01 were at a par and reached height of more than 150 cm after 90-days of their emergence. Cultivar Noor, however, exhibited quite slow growth and could not achieve height like those of other varieties. The decrease in size became quite evident when the conductivity of the soil solution was above 7.5 mmhos/cm. At salinity level of 10.0 mmhos/cm a reduction more than three times in plant height occurred during the initial growth of the crop, while a two times reduction when the experiment was terminated (Fig. 11). The plant height was severely affected when the salt concentration in the soil solution was at 15.0 mmhos/cm. At this salinity, the final height of Shams and Noor was about 23 cm and H01 22 cm. Because the plants could not grow further after 60 days they remained stunted. Moreover, leaf margins and stems of these plants at high salinity of this salt turned brown and eventually decayed.

Table 12. Effects of NaCl on plant height of various cultivars of sunflower.

Cultivars	Salinity levels in mmhos/cm						Ave
	Control (2.5)	5.0	7.5	10.0	12.5	15.0	
Shams	153	135	96	65	38	23	85a
Noor	146	124	89	62	38	23	80b
H01	152	121	90	60	29	22	80b <u>1/</u>
Ave	150a	127b	92c	62d	35e	22f	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.



3.5.2 Effects of CaCl_2 on Plant Height

The results are shown in Table 13 and Fig.12. In contrast to NaCl , CaCl_2 salt in the soil upto the level of 5.0 mmhos/cm was found conducive to the luxuriant growth of all the test cultivars of sunflower. After 90 days, maximum final height of 151 cm, at salinity level of 5.0 mmhos/cm, was exhibited by Shams and H01 followed by Noor with 141.0 cm. Plants in the control treatment (2.5 mmhos/cm), however, were smaller in size. With increasing salinity beyond 5.0 mmhos/cm, plants of Noor and H01 were dwarfed except Shams. Drastic reduction in plant height occurred at 15.0 mmhos/cm. First observation on plant height, after two weeks of sowing, revealed that minimum plant length of 3.20 cm was recorded in Cv. Shams followed by about 5 cm in Noor and H01. The final height of all the cultivars was also affected at the highest concentration of the salt. Maximum height of 64.25 cm was observed in H01 followed by Noor and Shams with 61.0 and 55.0 cm respectively.

3.5.3 Effects of MgCl_2 on Plant Height

Addition of MgCl_2 to the soil reduced the final plant height significantly at all levels of salt concentrations as compared with those growing in the non-treated soil (Table 14, Plate-2). In the control treatment (2.5 mmhos/cm), the maximum height of 154.0 cm was achieved by Cv. H01 followed by Shams and Noor having 146.50 and 143.50 cm respectively (Fig. 13). Increasing the soil conductivity reduced the plant height. At 12.5 mmhos/cm the inhibitory effect of the salt was quite obvious, as the

Table 13. Effect of CaCl_2 on plant height of various cultivars of sunflower.

Cultivars	Salinity levels in mmhos/cm						Ave
	Control (2.5)	5.0	7.5	10.0	12.5	15.0	
Shams	132	151	153	131	82	55	117a
Noor	138	141	128	101	72	61	107c
H01	149	150	124	104	75	64	111b ^{1/}
Ave	140b	147a	135c	112d	76e	60f	

^{1/} Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

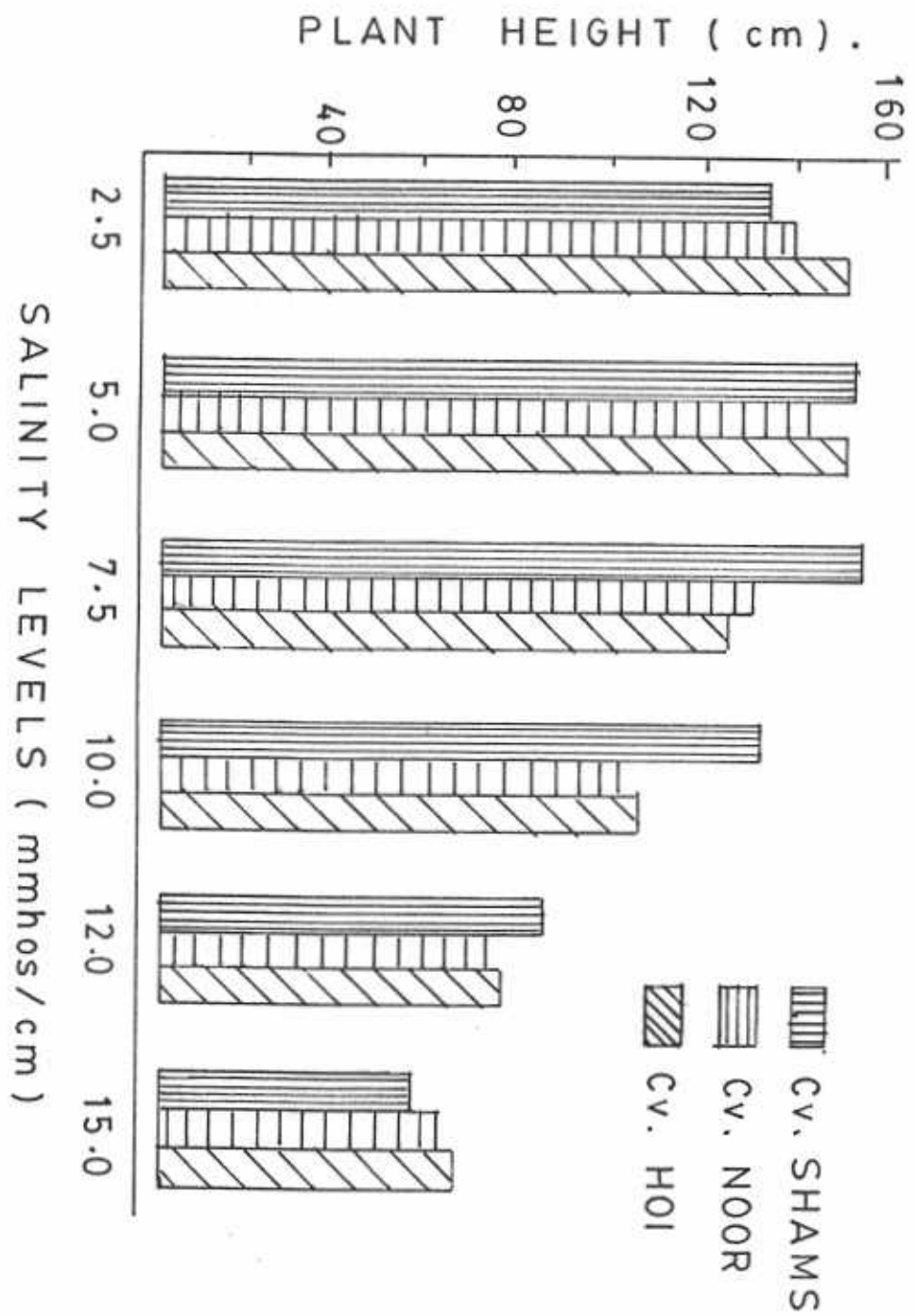


FIG. 12. Effects of calcium chloride on plant height .

Table 14. Effect of $MgCl_2$ on plant height of various cultivars of sunflower (cm).

Cultivars	Salinity in mmhos/cm						Ave
	Control (2.5)	5.0	7.5	10.0	12.5	15.0	
Shams	146	137	113	86	45	25	92a
Noor	143	130	95	88	38	27	87b
H01	154	139	99	65	26	19	84c <u>1/</u>
Ave	148a	135b	102c	80d	37e	23f	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at $\alpha = 1\%$.

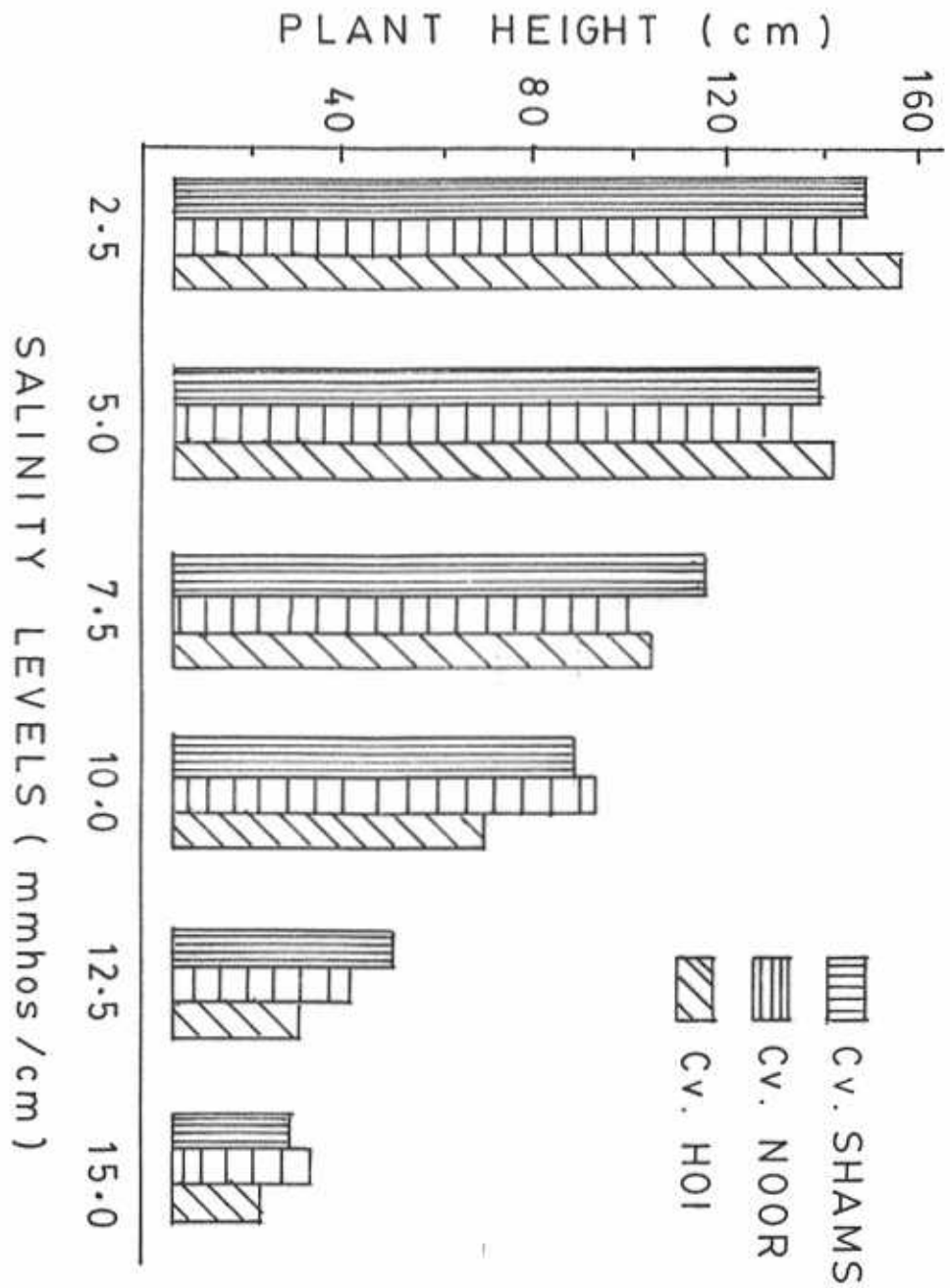
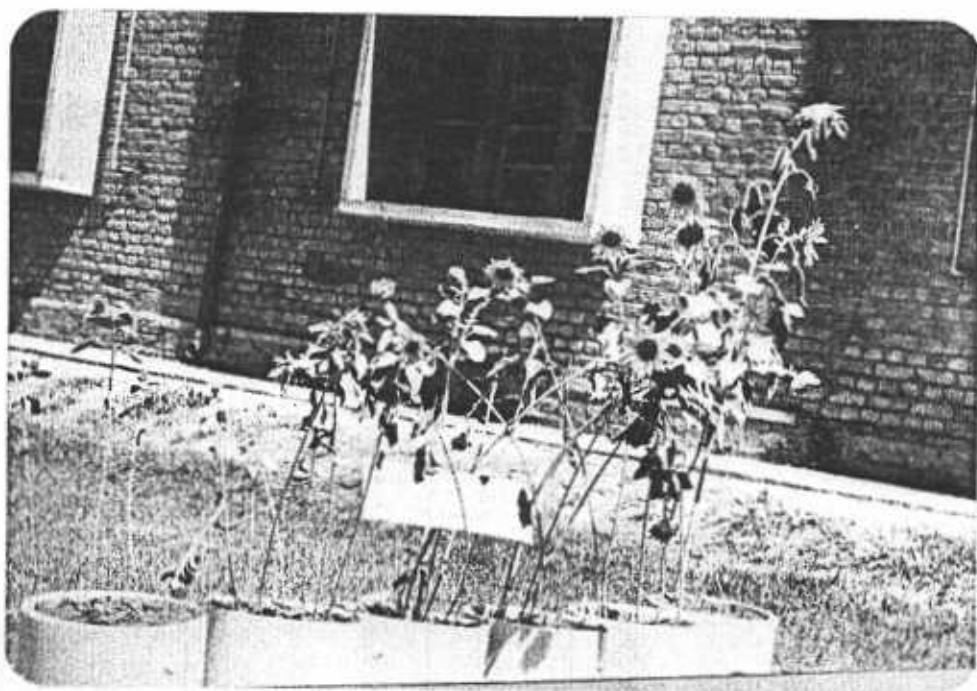


FIG. 13. Effects of magnesium chloride on plant height.



15.0 12.5 10.0 7.5 5.0 2.5 mmhos/cm

Plate. 2. Effects of magnesium chloride on plant height.

plant height got reduced by about three times in Shams, 5 times in Noor and 6 times in H01. At the highest salinity (i.e. 15.0 mmhos/cm) plants were dwarfed and could attain a height of 19 cm in H01, 24 cm in Shams and 28 cm in Noor. Moreover, at this level, plant growth ceased about 30 days earlier as compared with plants in control treatment. The flowers were also small, and devoid of fertilized seeds.

3.5.4 Effects of Na_2SO_4 on Plant Height.

As evident from Table 15 the salt could not induce any significant effect on the growth of plants at a salinity level of 5.0 mmhos/cm. In fact, at this level, the plants were taller by about one cm, than those in the control treatments of all the cultivars (Fig. 14). Above this concentration of the salt, plant height got reduced gradually until salinization regime of 15.0 mmhos/cm, where the minimum height of 67.25 cm was measured in Noor. Cultivars Shams and H01, however, were at a par and attained the same length of about 72 cm.

3.5.5 Effects of Mixture Salts on Plant Height.

Different salinization regimes were produced in the soil by mixing NaCl , CaCl_2 , MgCl_2 and Na_2SO_4 in the ratio as described in the section "Materials and Methods". Increasing salinity in the soil solution decreased the plant height accordingly (Table-16, Plate-3). Maximum final height of 149 cm was attained by Cv. H01 followed by Shams and Noor with 148 and 143 cm respectively in the control treatment (Fig.15). Noticeable reduction

Table 15. Effectsof Na_2SO_4 on plant height of various
cultivars of sunflower (in cm)

Cultivars	Salinity in mmhos/cm						Ave
	Control (2.5)	5.0	7.5	10.0	12.5	15.0	
Shams	149	151	137	118	82	71	118a
Noor	147	148	134	110	76	67	114c
H01	152	153	132	110	80	72	116b <u>1/</u>
Ave	149b	151a	134c	112d	80e	70f	

1/ Means followed by same letters in each row are not
significantly different by Duncan's Multiple range test
at rp 1%.

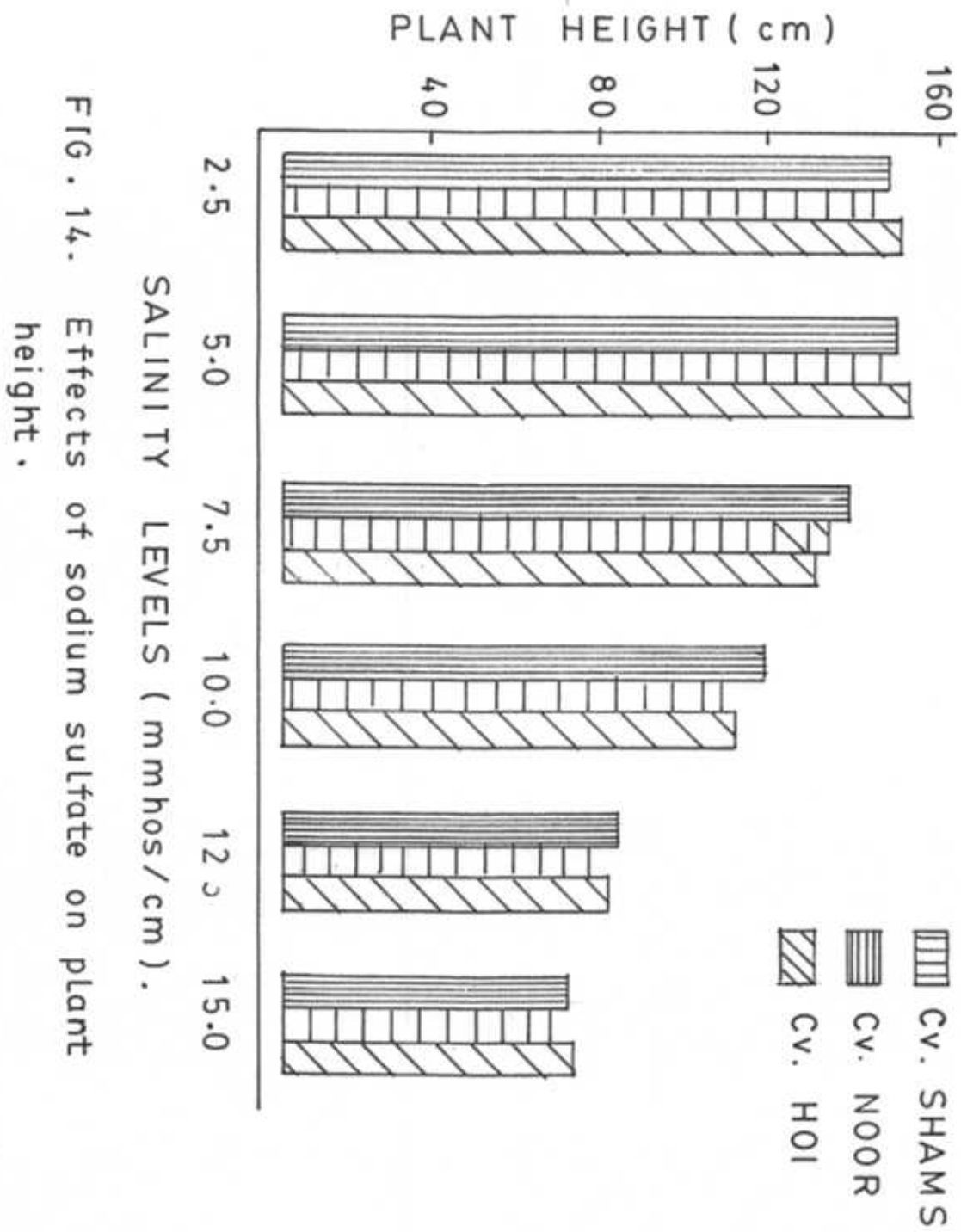


FIG. 14. Effects of sodium sulfate on plant height.

Table 16. Effects of Mixture salts on plant height of
various cultivars of sunflower.

Cultivars	Salinity in mmhos/cm						Ave
	Control	2.5	5.0	7.5	10.0	12.5	15.0
Shams	148	128	109	85	57	40	95b
Noor	143	128	99	82	51	40	91c
H01	149	140	110	85	67	40	99a <u>1/</u>
Ave	147	132	106	84	58	42	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

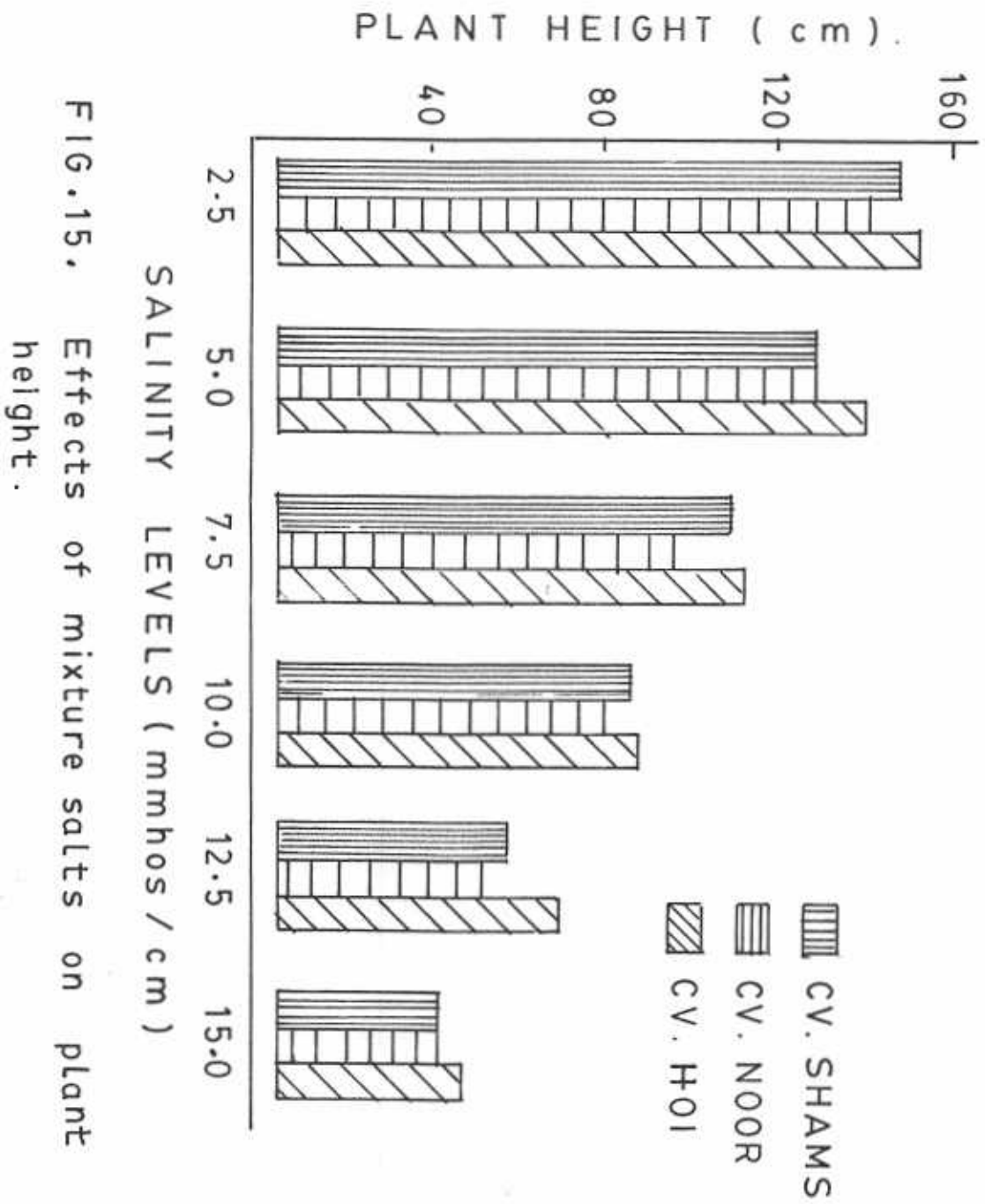


FIG.15. Effects of mixture salts on plant height.



2.5, 5.0, 7.5, 10.0, 12.5, 15.0 mmhos/cm

Plate 3. Effects of mixture salts on plant height.

in plant height occurred at 12.5 mmhos/cm level where it was decreased to less than half of the plants in the control treatment. Plants at 15.0 mmhos/cm salinization, showed stunted growth, leaf burns and measured to only 40.5 cm in Shams and Noor and 44.5 cm in H01.

3.6 Effects of Mixture Salts on the Height of Transplanted Plants

Seedlings grown in the non saline soil to the cotyledonary and primary leaf stages were transplanted in to glazed pots having the same salinization regimes as were produced with mixture salts in the previous direct sowing experiment. This practice was put to test in order to evaluate some of the yield components of sunflower under different sets of circumstances.

3.6.1 Effects of Salinity on the Height of Plants Transplanted at the Cotyledonary Stage.

After transplantation the plants were well established and began vigorous growth in the new soil. Subsequent growth of the plant was affected in the new soil according to the degree of salinity; however, as seen in Fig.16, Plate-4) the plant height was not affected as severely as it was in direct germination in the same soil. In the control treatment maximum height of 158 cm was exhibited by Cv. H01 followed by 155.18 and 150.25 cm in Shams and Noor respectively. At salinity level of 5.0 mmhos/cm, plant height was almost the same as in the control treatment. Although plant growth at higher levels of salinity was depressed this inhibition was so insignificant

that even at the highest salinization regime, 15.0 mmhos/cm, the height of all the test cultivars were reduced not more than 50% of the control treatment. At the highest salinity, minimum plant height of 75.0 cm was observed in Cv. Noor. The greatest resistance to different salt concentrations was shown by H01.

3.6.2 Effects of Mixture Salts on Plants Transplanted at the Primary Leaf Stage.

Plant height was checked significantly, when the seedlings at the primary leaf stage were transplanted to saline soil. Decrease in plant height occurred at the first level^{i.e} 5.0 mmhos/cm (Fig.17). With increasing salinity to 15.0 mmhos/cm, there was about 4 times reduction in height of Cv. Shams and Noor and more than 3 times in H01 as compared with control treatment.

3.7 Flower Size

3.7.1 Effects of NaCl on Flower^{head} Size

The negative effect of NaCl concentrations on the flower size is shown in Fig. 18. The salt, in addition to the inhibitory effect on plant height, reduced the flower^{head} size also. With an increase in salt concentration, there was a gradual effect on flower^{head} diameter. The maximum flower^{head} growth of 6.36 cm occurred in the control treatment. Increasing salinity to 12.5 mmhos/cm reduced the flower size to about half of the control treatment in Cv. Shams and Noor. Furthermore, no flower formation occurred in H01 in this treatment. The highest salinity (15.0 mmhos/cm) inhibited flower formation in all the cultivars tested.

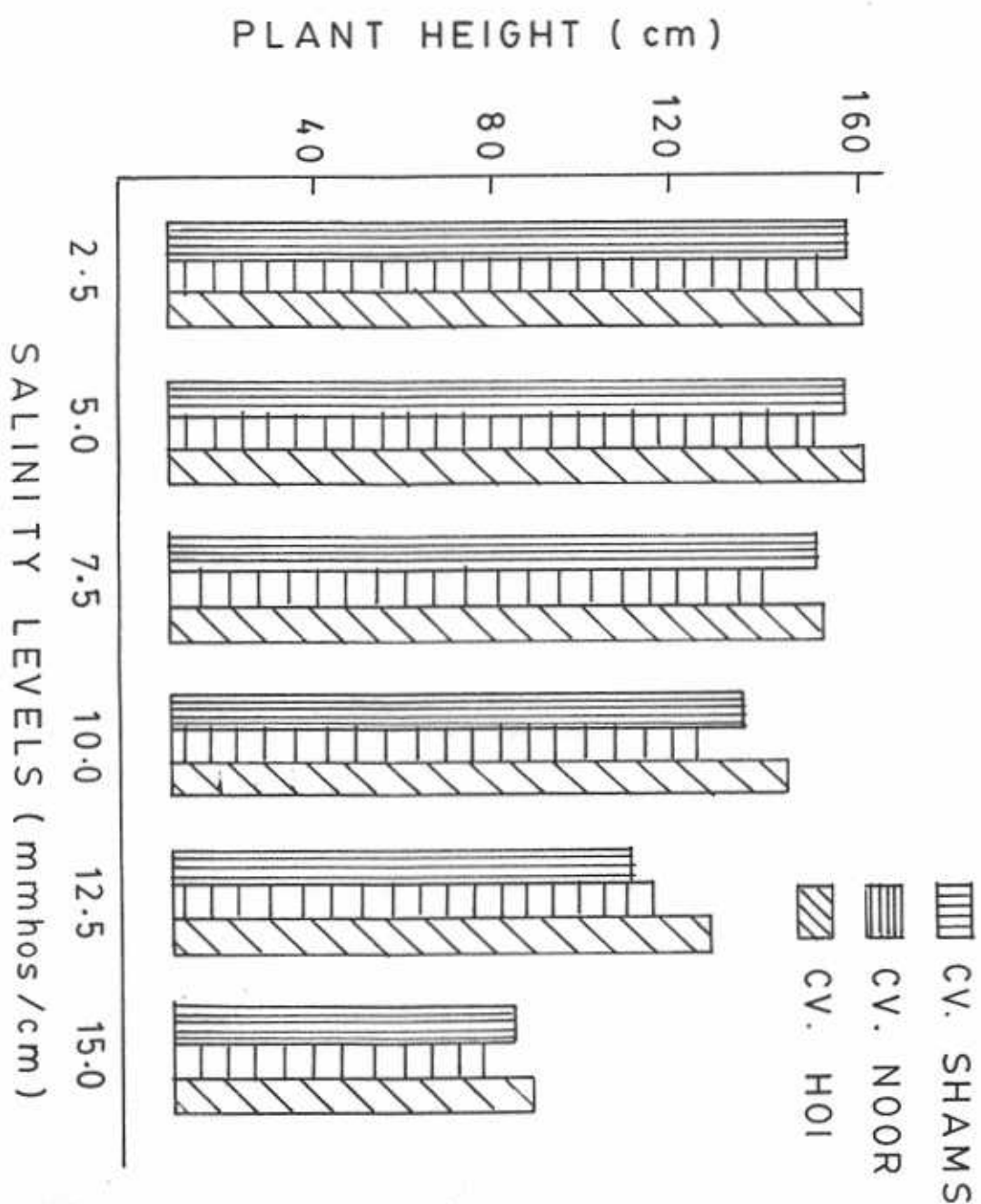


FIG. 16a. Effects of salinity on the height of plants transplanted at the cotyledonary stage.

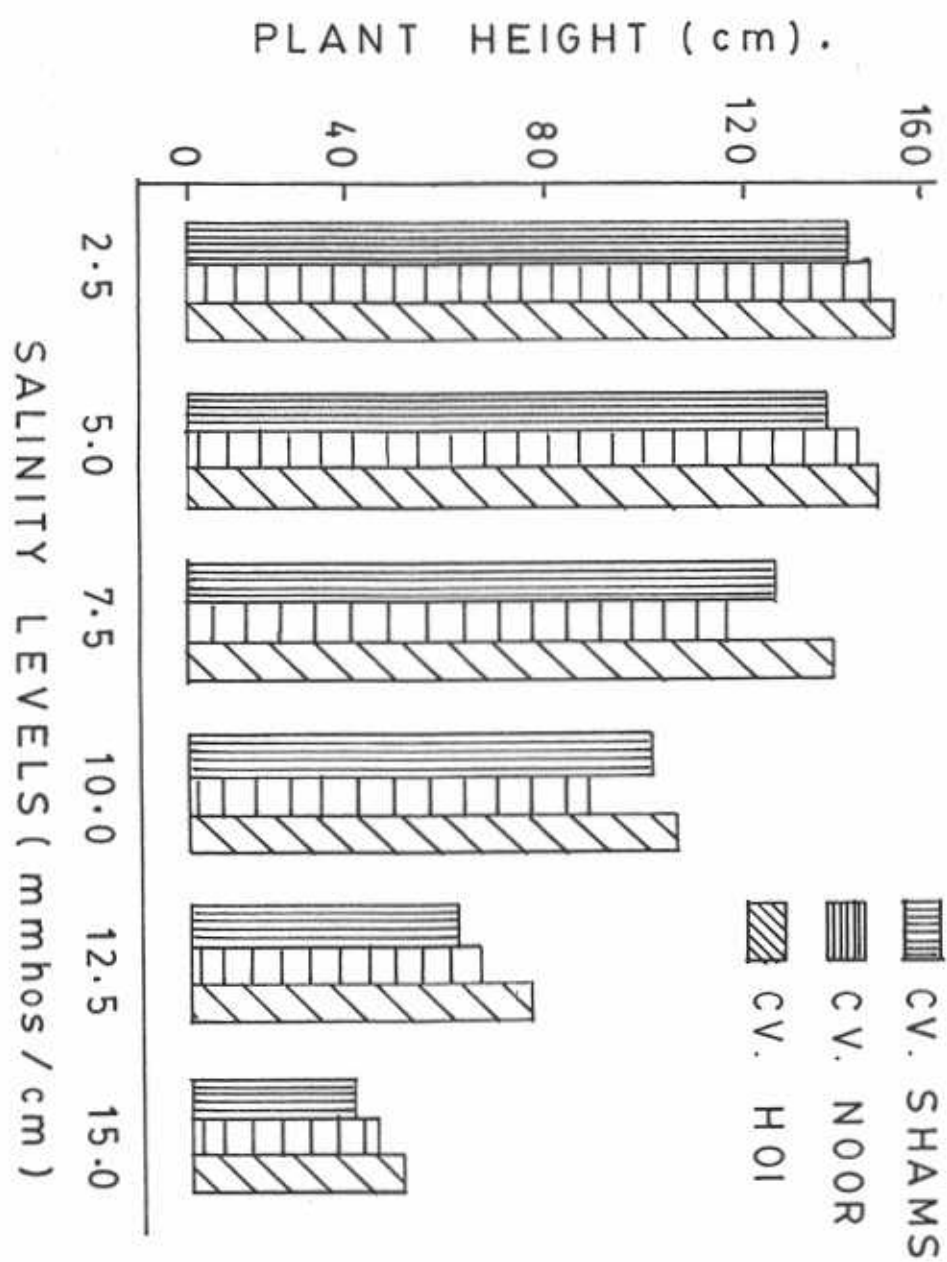
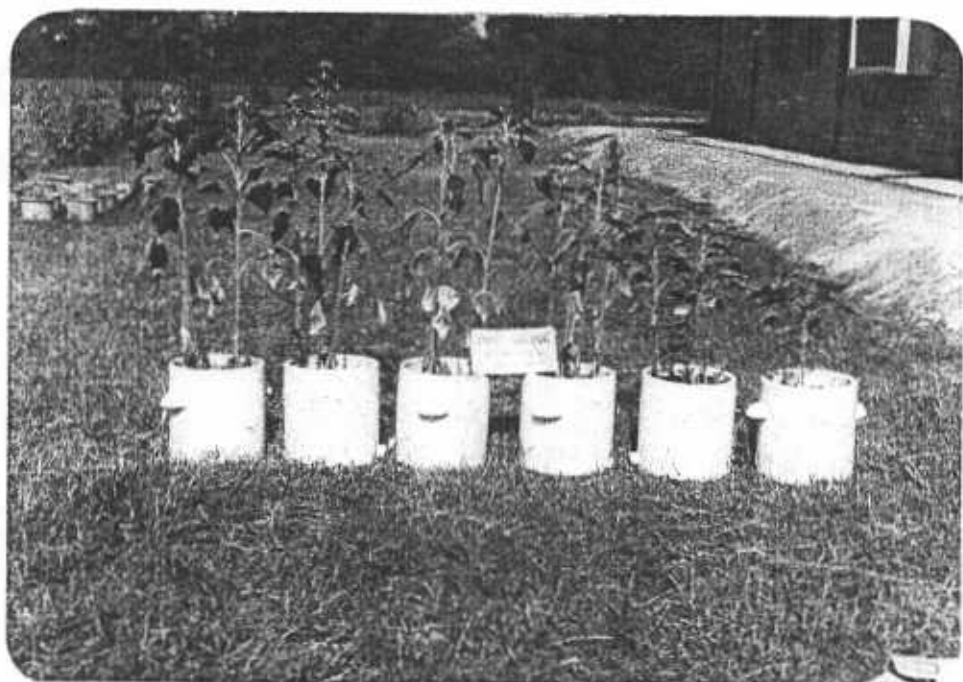


FIG. 16b. Effects of salinity on the height of plants transplanted at the primary leaf stage.



2.5, 5.0, 7.5, 10.0, 12.5, 15.0 mmhos/cm

Plate 4. Effects of salinity on the height of
transplanted plants.

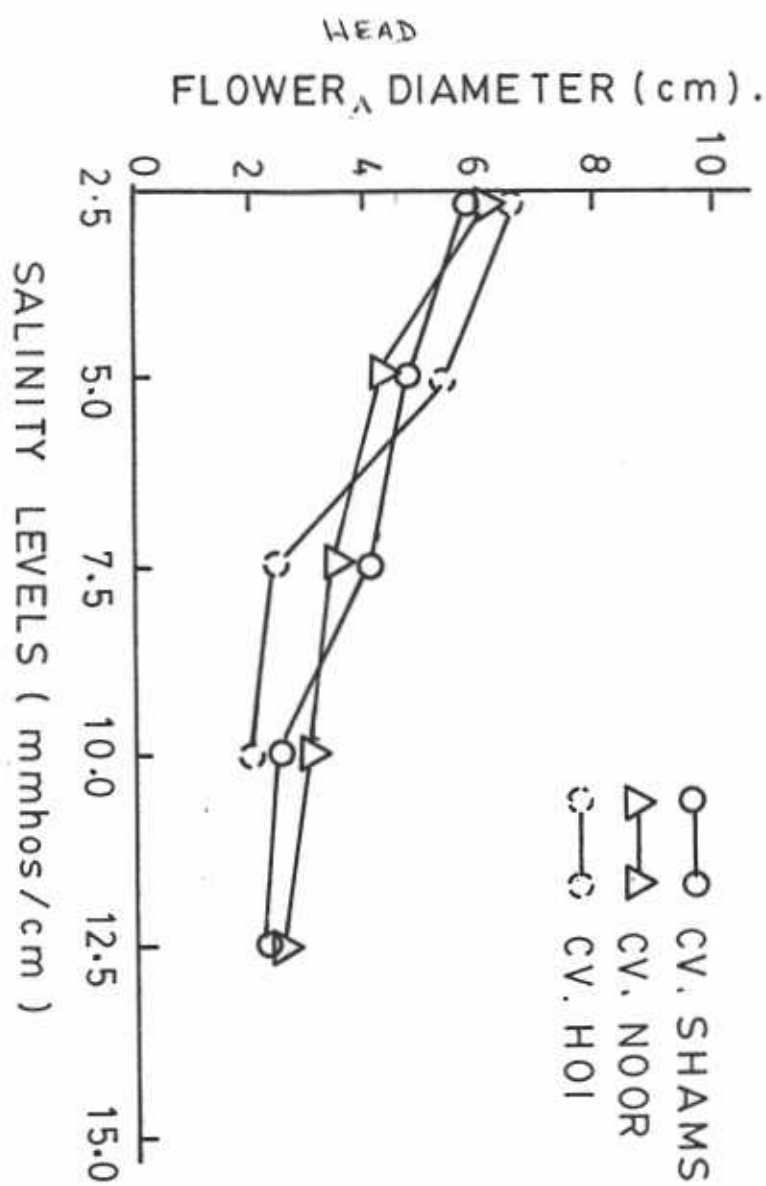


FIG. 17. The effects of sodium chloride on flower ^{head} size.

3.7.2 Effects of CaCl_2 on Flower^{head} Size.

The effect of CaCl_2 at low concentrations was not as severe as that of NaCl . The first salt level of 5.0 mmhos/cm had no effect on the flower diameter; it was almost the same as in the control treatment in all the test cultivars. The largest flower with about 10 cm diameter was found in H01 followed by 9.15 and 8.75 cm in Shams and Noor respectively (Fig. 19). The flowers became smaller with an increase in the salinity level. But the drastic effect of the salt was noticed only at 12.5 mmhos/cm where about 50% reduction in flower size occurred in all the three cultivars. At the highest salinity of 15.0 mmhos/cm, though the plants flowered, yet the flowers were too small to yield viable seeds.

3.7.3 Effects of MgCl_2 on Flower^{head} Size.

This salt in the soil solution was found more toxic for the optimum growth of various plant parts as compared to CaCl_2 . Its inhibitory effect on the flower^{head} size was obvious even at the first level, i.e. 5.0 mmhos/cm (Fig. 20). Flower^{head} size was reduced more at higher salinization regimes. Noticeable reduction in flower^{head} growth was found above 10.0 mmhos/cm. At 12.5 mmhos/cm, the flower^{head} diameter was reduced four times the flowers in the control treatment. These flowers were also devoid of potent seeds, which quickly withered away before maturation. At 15.0 mmhos/cm, the plants were so small and weak that they were virtually without flowers.

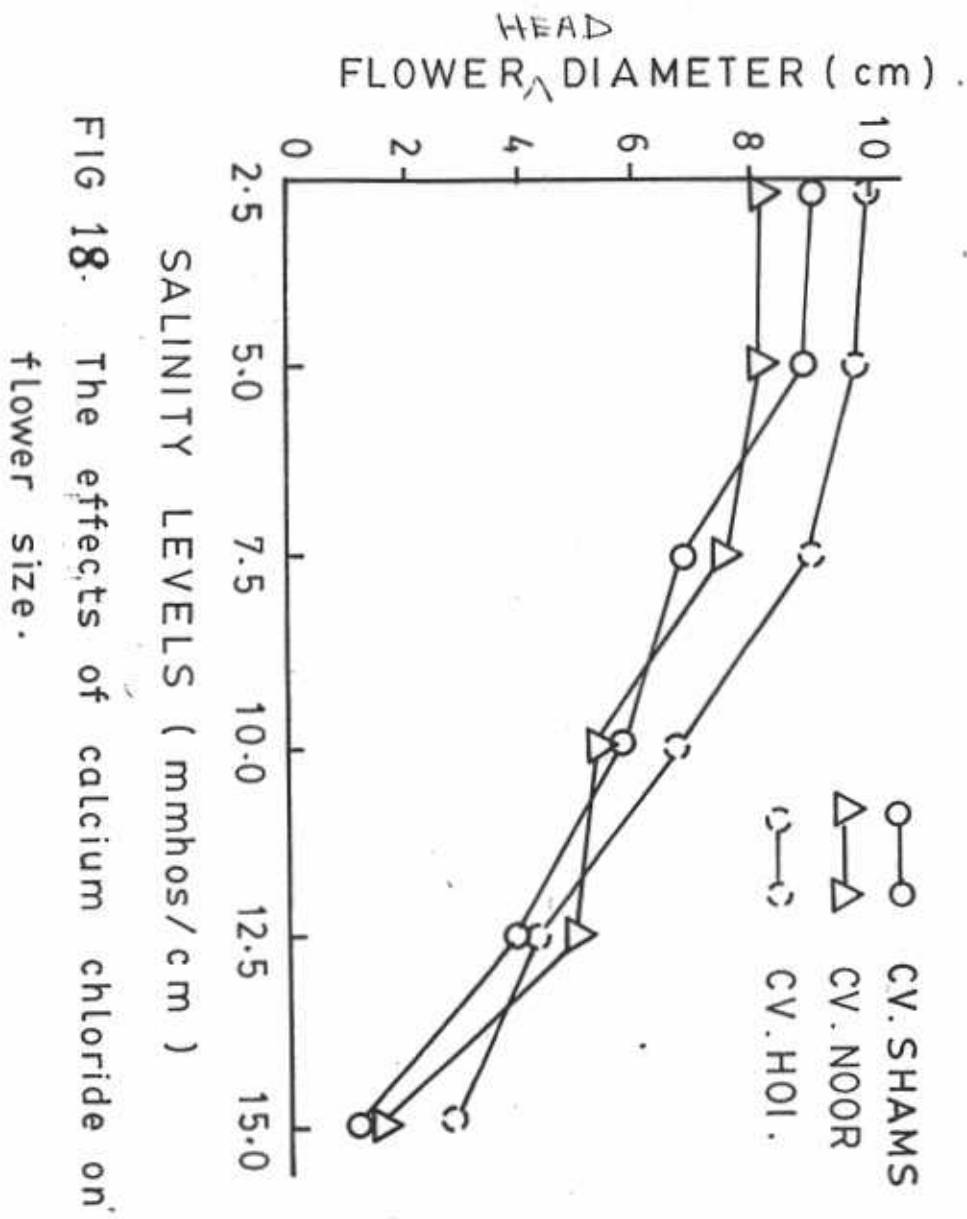


FIG 18. The effects of calcium chloride on flower size.

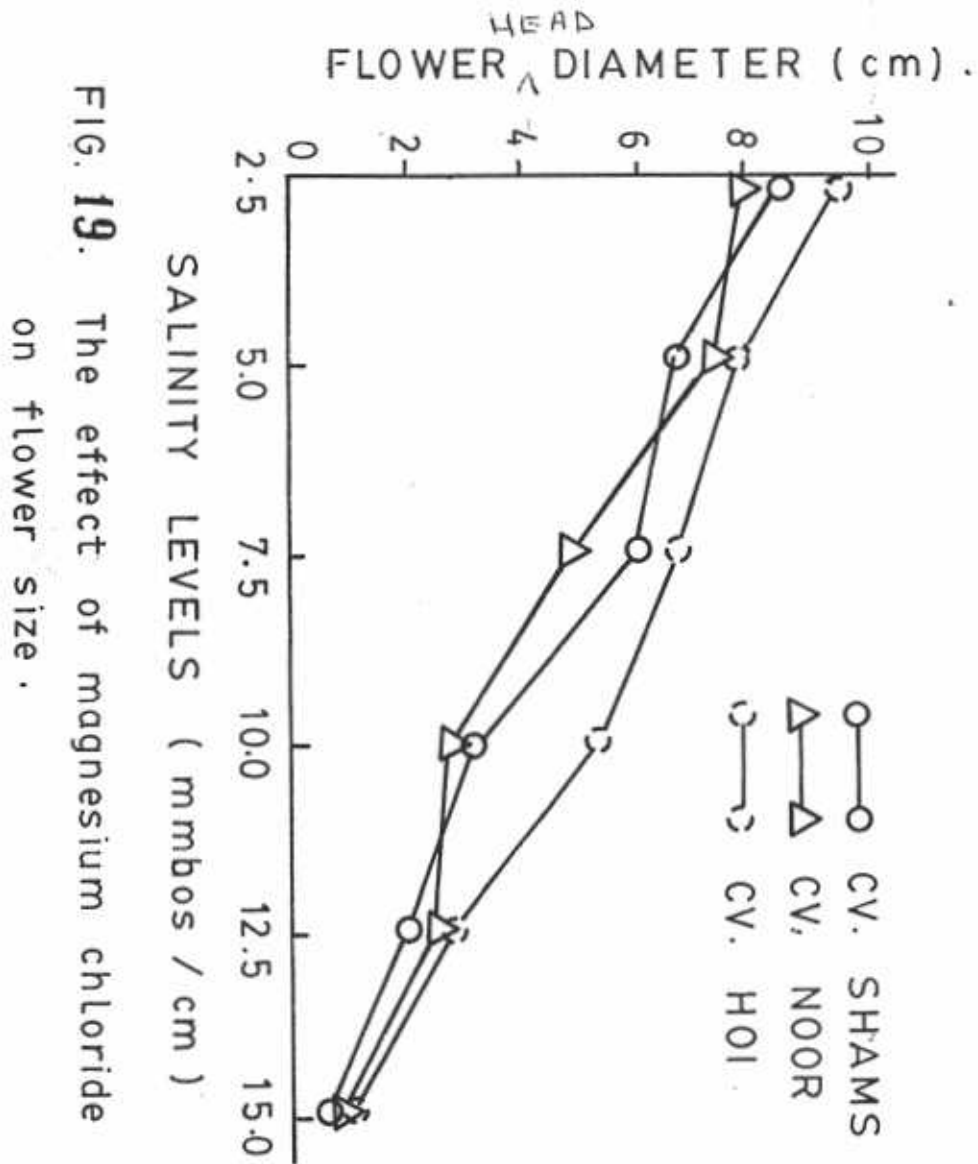


FIG. 19. The effect of magnesium chloride on flower size .

3.7.4 Effects of Na_2SO_4 on Flower Size.

The effect of Na_2SO_4 on flower diameter was less inhibitory than NaCl and MgCl_2 . However, increasing salt concentration in the soil reduced the flower diameter consequently (Fig.21). The maximum flower size of 8.87 cm was exhibited by H01 in the control treatment. Cultivar Shams and Noor were at a par and their flowers attained diameter of 8 cm each. Marked decrease in flower growth occurred beyond 10.0 mmhos/cm level of the soil. At the highest level of salinity, the flower diameter was measured to 3.15, 3.0 and 2.90 cm in Shams, Noor and H01 respectively.

3.7.5 Effects of Mixture Salts on Flower Size.

Different salinization regimes in the soil affected the flower diameter differently. Increasing salinity above 2.5 mmhos/cm (control treatment), thwarted significantly the proper development of flowers in all the test cultivars (Fig.22). Electrical conductivity of the soil solution beyond 10.0 mmhos/cm was quite detrimental for flower growth. Flower diameter at 15.0 mmhos/cm got reduced by more than 3 times in Shams and about 4 times in Noor and H01 as compared with the control treatment.

Effects of Mixture Salts on the Flower Size of Transplanted Plants.

Flower size of the transplanted plants was evaluated under the influence of the same salinization regimes in the soil as in the previous experiments. Salinity in the soil, however, was produced by mixing NaCl , CaCl_2 , MgCl_2 and Na_2SO_4 .

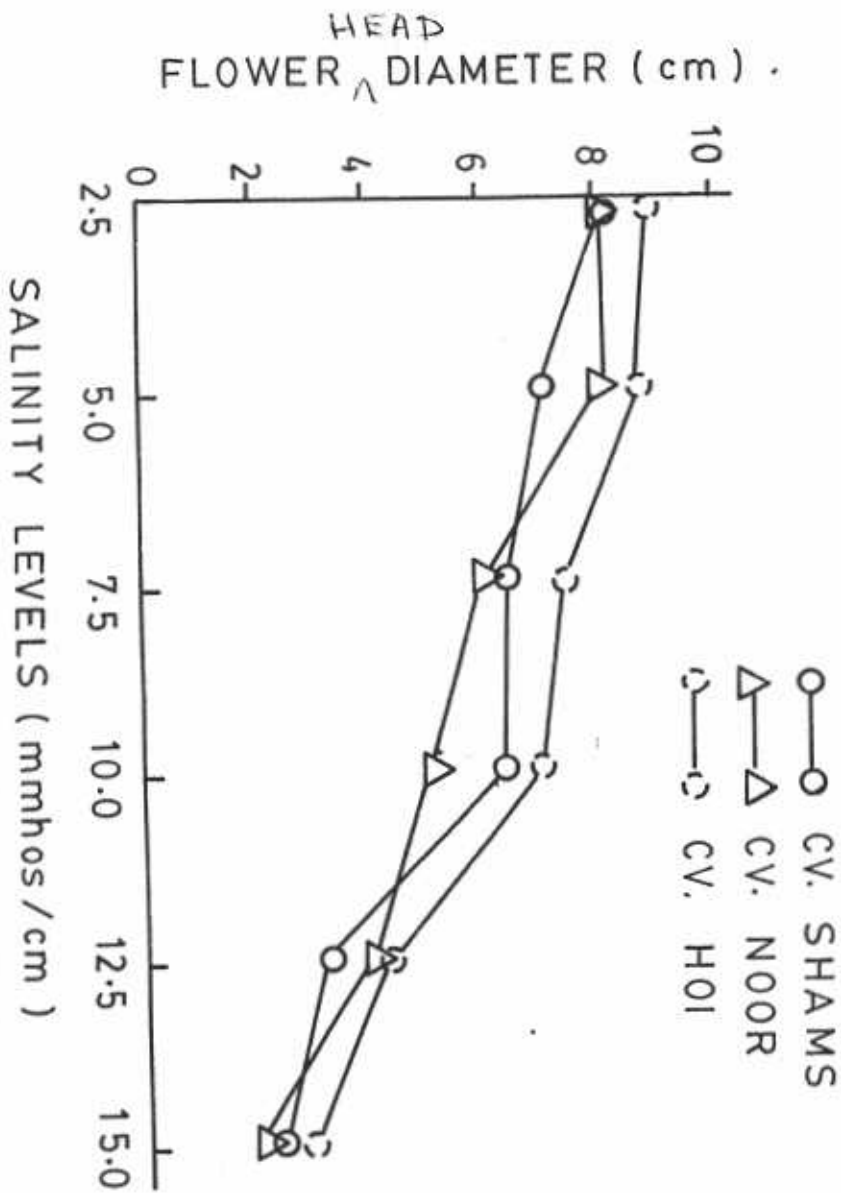
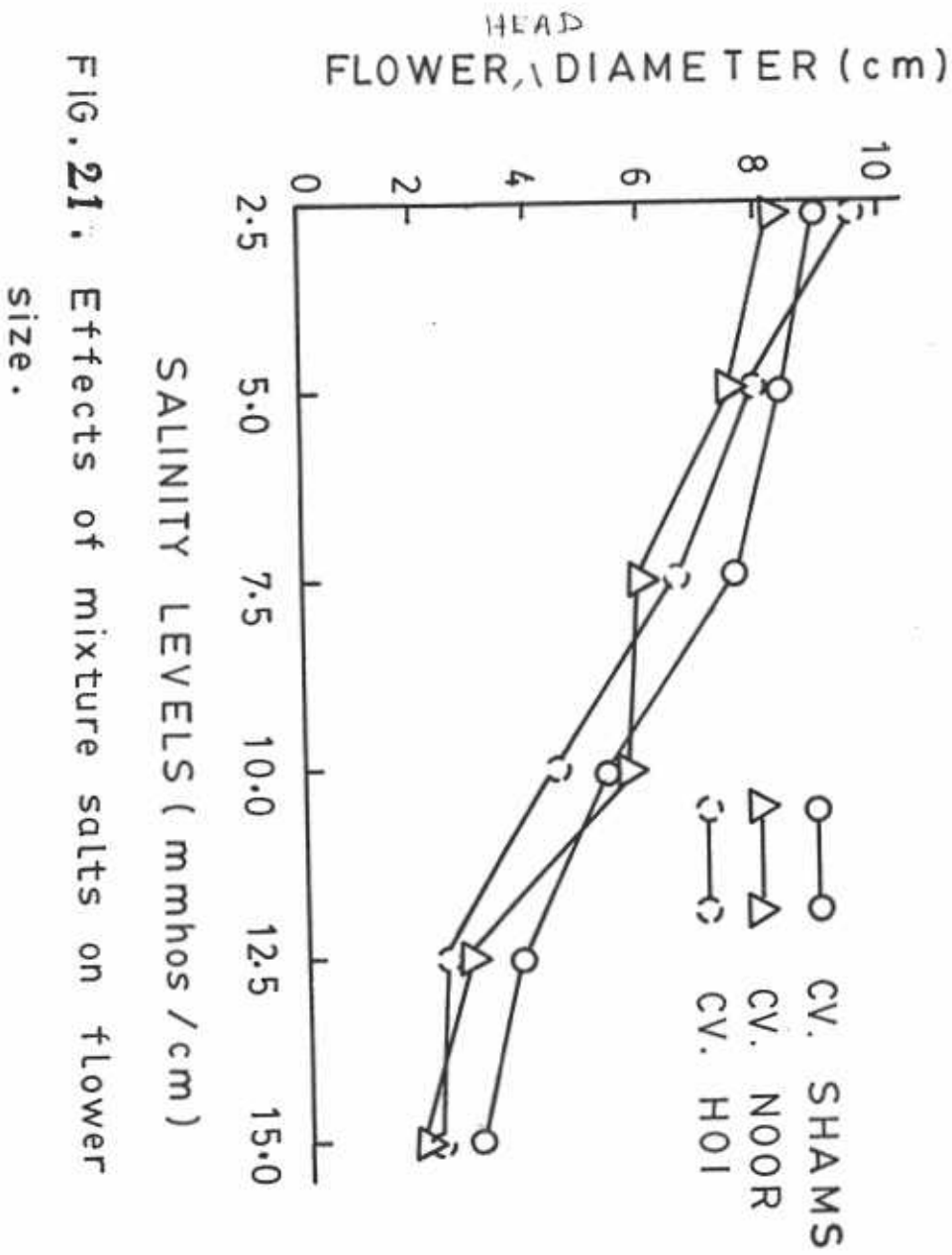


FIG. 20. The effects of sodium sulfate on flower size .



3.7.6 Effects of Salinity on the Flower^{head} Size of
Plants Transplanted at the Cotyledonary Stage.

Flower diameter was measured when the plants were 90 days old. The flower diameter of plants growing in 5.0 and 7.5 mmhos/cm salinity did not differ significantly from those in the control treatment (Fig.23). The largest flower^{head} diameter of 9.95 cm was measured in H01 followed by Shams and Noor. Above 7.5 mmhos/cm there was a gradual decrease in flower size with a gradual increase in salinity levels. However, the change was not as severe as in direct sowing experiment. The minimum flower diameter of 3.10 cm at the highest salinity was recorded in Noor while H01 and Shams still had about 3.50 cm flower diameter.

3.7.7 Effects of Salinity on the Flower^{head} Size of Plants
Transplanted at the Primary Leaf Stage.

The plants transplanted at the primary leaf stage although got established in saline soil, their flower size could not develop properly as in the previous stage of transplantation. Flower size was checked even at the first salinity level of 5.0 mmhos/cm. With an increase in salinity, the flowers got reduced in size (Fig.24). At 12.5 mmhos/cm, the flower diameter was reduced to only 2.0 cm and at the highest salinity, the flower size was less than 2.0 cm in H01 while Noor and Shams were without any flowers. Furthermore flowers at 12.5 and 15.0 mmhos/cm were also abortive.

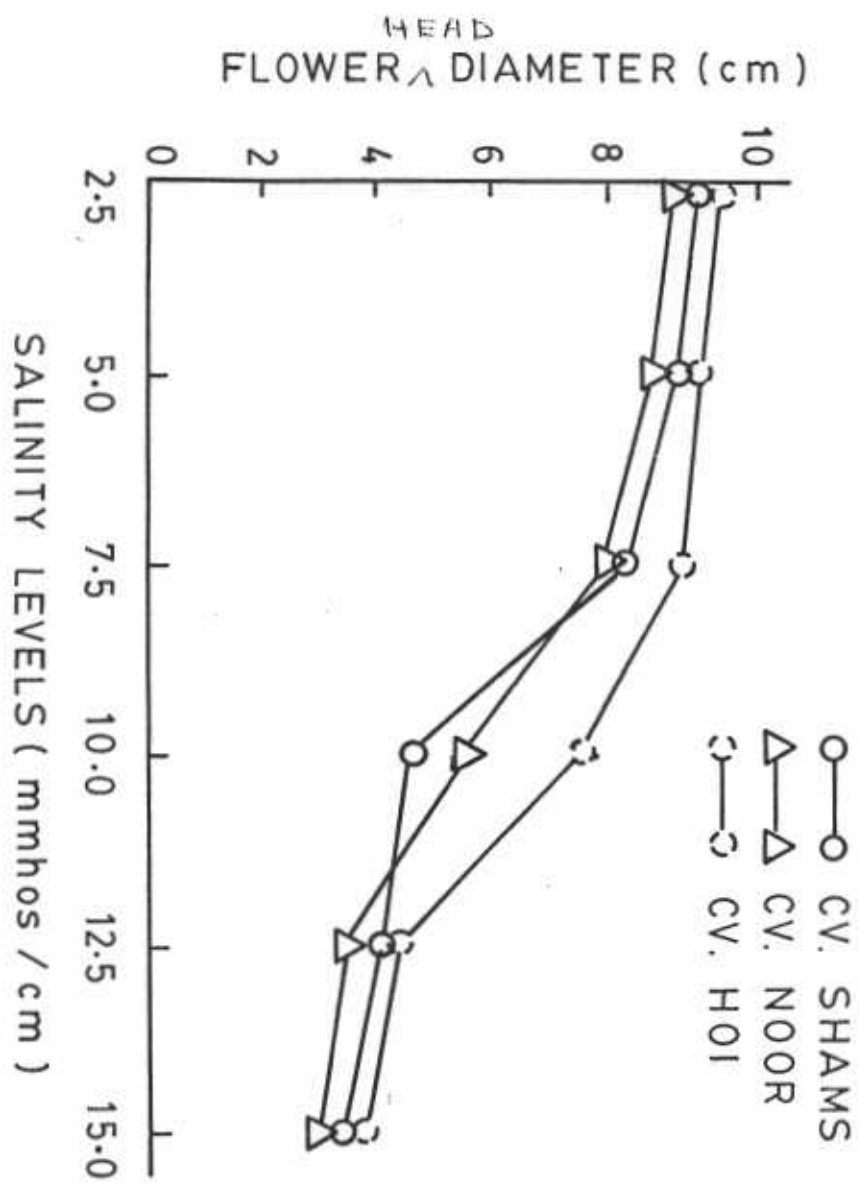


FIG. 22. Effects of salinity on flower size of plants transplanted at the cotyledonary stage.

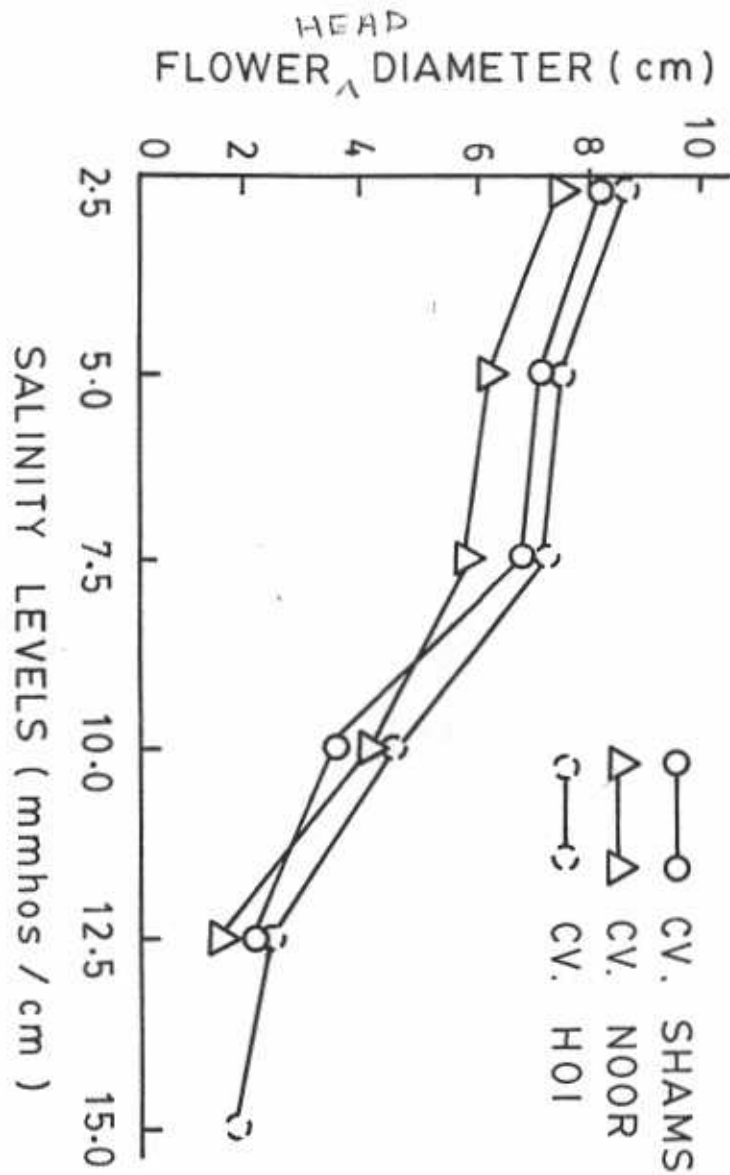


FIG. 23. Effects of salinity on flower size of plants transplanted at primary leaf stage.

3.8 Effects of Different Salinities on Blooming and Maturity of Sunflower.

These experiments were carried out with a view to investigate any change which might occur in the normal life cycle of sunflower plant, when it was subjected to different salinity levels produced either by single salts e.g., NaCl, CaCl_2 , MgCl_2 , and Na_2SO_4 or their mixture. Plantation of the three cultivars of sunflower was made in March, 1983 and their blooming and maturity time with respect to different salinization regimes was recorded under the following headings:-

3.8.1 Effects of NaCl on Blooming and Maturity of Sunflower.

The effect of different levels of NaCl on the above variables was determined in terms of days. Statistical analysis showed that increasing increments of salts in the soil solution had non-significant effect on blooming of sunflower cultivars (Table 17). However, Shams and Noor indicated a trend of earlier blooming at higher salinization regimes of the soil than control treatment. At the highest EC value of the soil, Shams bloomed 9 days earlier and Noor 10 days as compared with the control treatment. On the other hand, maturity of different cultivars was significantly influenced by different levels of salinity in the soil. At the highest salinity level, Shams matured earlier by 23 days, Noor by 18 days and H01 by 21 days as compared with the control treatment. Also, the plants growing in the highest salt concentration were very small and their flowers were devoid of fertilized seeds.

Table 17. Effects of NaCl on blooming and maturity of sunflower.

		Salinity levels in mmhos/cm.							
Growth Stages	Cultivars.	2.5	(Control)	5.0	7.5	10.0	12.5	15.00	Ave NS
Blooming in days.	Shams	70	69	67	64	62	61	65	
	Noor	71	69	68	66	63	61	67	
	H01	58	71	69	67	67	64	66	
	Ave.NS	66	70	68	66	64	62		
Maturity in days.	Shams	120	117	114	107	99	97	109 b 1/	
	Noor	115	112	108	103	99	97	106 c	
	H01	123	119	115	108	104	102	112 a	
	Ave.	119	116	112	106	101	99		

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

3.8.2 Effects of CaCl_2 on Blooming and Maturity of Sunflower.

Blooming in all the test cultivars was achieved earlier with increasing concentration of the salt (Table 18). Maximum average time recorded upto blooming was 74 days in the control treatment. While at 15.0 mmhos/cm level, the plants bloomed earlier by 10 days as compared with control treatment. Similarly, maturity of the plants was also affected by this salt. As revealed in Table 18 all the test cultivars growing in soil with the highest salinity matured earlier by about 16 days than those in the control treatment. The average life cycle of H01 was 115 days followed by Shams and Noor with 110 and 107 days respectively. Varieties and level means were significantly different both in blooming and maturity.

3.8.3 Effects of MgCl_2 on Blooming and Maturity of Sunflower.

The effect of MgCl_2 on blooming of sunflower was found non-significant statistically (Table 19). Nevertheless, there was an indication of earliness in blooming with increasing increments of the salt in the soil solution. At 15.0 mmhos/cm electrical conductivity, there was reduction of 9 days in Shams, 10 days in Noor and 7 days in H01, (Table 19). Maturity, on the other hand, was affected the most. Average maturity in plants at the highest salinization regime was started 20 days ahead of those growing in the control treatment. The average life cycle of 112, 107 and 104 days was revealed by H01, Shams and Noor respectively under the stress of MgCl_2 .

Table 18. Effects of CaCl_2 on blooming and maturity of sunflower.

Growth Stages	Cultivars	Salinity levels in mmhos/cm							
		Control (2.5)	5.0	7.5	10.0	12.0	15.0	Ave.	
Blooming in days	Shams	73	72	70	66	64	63	68b	1/
	Noor	72	70	69	67	64	63	68b	
	HOL	76	75	73	69	67	65	71a	
	Ave.	74a	73a	71b	68c	65d	64d		
Maturity in days	Shams	117	115	112	108	104	101	110b	
	Noor	114	112	109	106	101	98	107c	
	HOL	124	120	117	112	108	106	115a	
	Ave.	118a	116b	113c	108d	105e	102f		

1/ Means followed by same letters in each row are not significantly different by Duncan's multiple range test at $p = 1\%$.

Table 19. Effects of $MgCl_2$ on blooming and maturity of sunflower.

		Salinity levels in mmhos/cm							
Growth stages	Cultivars	Control	5.0	7.5	10.0	12.5	15.0	Ave	NS
		(2.5)							
Blooming in days	Shams	71	70	68	66	62	62	66	
	Noor	71	69	68	64	62	61	66	
	HOL	70	69	67	64	63	63	66	
	Ave	71a	69b	68c	65d	62e	62e		
Maturity in days	Shams	118	115	110	105	99	97	107b 1/	
	Noor	113	111	107	101	98	96	104c	
	HOL	121	118	115	109	104	102	112a	
	Ave	118a	115b	111c	105d	100e	98f		

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at $rp\ 1\%$.

3.8.4 Effects of Na_2SO_4 on Blooming and Maturity of Sunflower.

The effect of Na_2SO_4 on blooming was not as significant as it was on maturity (Table 20). Increasing salinity had shortened the duration of the plants to bloom. It took for all the cultivars about 77 days to bloom in the control treatment against the 68-day-period at the highest salinization regime. Maturity of the plants was enhanced with each rise in salinity (Table 20). Varieties and salinity levels showed significant differences at both levels of significance. In order to mature, H01 took approximately 120 days, Shams 116 and Noor 113 under the stress of Na_2SO_4 .

3.8.5 Effects of Mixture Salts on Blooming and Maturity of Sunflower.

Salinity due to mixture salts enhanced blooming in sunflower gradually from the control treatment to the highest level of electrical conductivity in the soil solution (Table 21). Blooming in plants reached 10 days earlier at the highest salinity level than the untreated plants. Maturity time was also shortened with increasing concentration of the salts. The average life time of the plant in the control treatment was 120 days against 103 days at the highest level of salinity. Varieties and level means were found highly significant.

3.9 Effects of salinity on the dry matter yield of sunflower plant parts at the time of maturity.

These experiments were carried out in glazed pots during the year 1984 and the effects of different salts on the dry

Table 20. Effects of Na_2SO_4 on blooming and maturity on sunflower.

		Salinity levels in mmhos/cm						
Growth stages	Cultivars	Control (2.5)	5.0	7.5	10.0	12.5	15.0	Ave. NS
Blooming in days.	Shams	77	76	75	73	69	68	73
	Noor	76	76	74	72	68	68	72
	H01	77	77	76	74	69	69	73
	Ave:	77a	76b	75c	73d	69e	68f	
Maturity in days.	Shams	122	121	119	116	109	106	116b 1/
	Noor	119	118	117	114	106	104	113c
	H01	128	126	124	122	113	110	120a
	Ave:	123a	122a	120b	117c	109d	107e	

1/ Means followed by same letters in each row are not significantly different by Duncan's multiple range test at $\alpha = 1\%$.

Table 21. Effects of mixture salts on blooming and maturity of sunflower.

		Salinity in mmhos/cm							
Growth stages		Cultivars	Control (2.5)	5.0	7.5	10.0	12.5	15.0	Ave
Blooming in days	Shams	75	73	72	68	65	64	69b	
	Noor	73	72	70	67	65	64	69b	
	H01	78	77	74	71	68	67	73a	
	Ave:	75a	74a	72b	69c	66d	65d		
Maturity in days	Shams	119	117	114	110	103	102	111b	
	Noor	116	114	112	106	102	100	109b	
	H01	125	123	121	116	112	108	118a	
	Ave:	120a	118b	116c	111d	106e	103f		

1/ Means followed by same letters in each row are not significantly different by Duncan's multiple range test at $\alpha = 1\%$.

yield components, seed, leaf, stem and total above ground parts (AGP) of sunflower plant was investigated under the following headings.

3.9.1 Effects of NaCl on the Dry Matter Yield of Plant Parts.

The salt was applied to the soil as given in the section, "Materials and Methods". Data on the harvested seed per plant revealed that the seed weight was decreased with increasing concentration of the soil solution (Table 22). Plants in the control treatment gave the highest average seed yield of 9.49 gms. Drastic reduction in seed yield occurred above 10.0 mmhos/cm salinity level, where the average yield of only 1.43 gm was recorded in 12.5 mmhos/cm. No seed was collected from plants at 15.0 mmhos/cm level. Varieties and level means were found highly significant.

Similar data were recorded on stem weight per plant in different treatments of the salt. Here the varieties means were not significant, but the level means and their interaction with varieties were significantly different from one another at both levels of significance (Table 22). With increasing salinity, the stem weight decreased accordingly. At 12.5 mmhos/cm the average stem weight was reduced by 4 times of the control treatment and at the highest salinity level, the stem weight was negligible.

Table 22. Effects of NaCl on the dry matter yield of Sunflower Plant parts

Plant Parts	Cultivars	Salinity levels in mmhos/cm.							Ave
		Control (2.5)	5.0	7.5	10.0	12.5	15.0		
SEED:	Shams	9.39	7.78	6.77	4.01	0.50	-	4.74 c 2/	
	Noor	8.95	8.07	6.65	4.00	1.62	-	4.88 b	
	Hol	10.13	8.49	7.44	4.89	2.16	-	5.54 a	
	Ave:	9.49a	8.11b	6.99c	4.30d	1.43c	-	NS	
STEM:	Shams	16.62	14.52	10.14	7.32	4.91	8.10	9.22	
	Noor	15.51	14.04	11.82	7.86	4.15	-	8.88	
	HOL	16.62	13.58	11.14	7.86	3.37	-	8.76	
	Ave:	16.25a	13.99b	11.03c	7.64d	4.15c	0.67f		
LEAF:	Shams	11.45	10.07	8.20	6.11	3.03	1.15	6.67a	
	Noor	9.44	8.66	7.29	4.73	2.36	-	5.41b	
	HOL	10.14	8.46	7.41	4.98	2.01	-	5.50b	
	Ave:	10.34a	9.06b	7.63c	5.27d	2.46e	0.38f		
AGP 1/	Shams	43.15	36.97	29.40	20.75	9.59	3.67	23.92	
	Noor	40.24	36.36	30.44	19.68	10.09	-	22.80	
	HOL	42.91	35.30	30.09	20.69	9.48	-	23.08	
	Ave:	42.10a	36.20b	29.98c	20.37d	9.72e	1.22f		

1/ A.G.P. refers to above ground parts

2/ Means followed by same letters in each row are not significantly different by Duncan's multiple range test at $\alpha = 1\%$.

Leaf weight was decreased with each increment of the salt in the soil solution. Leaves at 12.5 mmhos/cm level were five times reduced in weight as compared with the leaves in the control treatment. Small number of leaves was collected in Noor and H01 at 15.0 mmhos/cm. The statistical analysis of the total above ground parts (AGP) revealed that varieties and the interaction means were not significant but means of salinity levels were significant at both levels of significance. From the results, it can be concluded that there was a negative correlation between the increasing salt concentrations and the gram weight per plant of each part tested.

3.9.2 Effects of CaCl_2 on the Dry Matter Yield of Plant Parts.

Different concentrations of the salt were maintained in the soil according to the procedure as given in "Materials and Methods". It is obvious from (Table 23) that the seed yield decreased significantly with increasing electrical conductivity of the soil solution. Varieties, levels and their interaction means were found significantly different at both levels of significance. The highest average seed yield of 13.84 gm was recorded in the control treatment against 0.75 gm in 15.0 mmhos/cm salinity. Cultivar H01 gave the highest average seed yield of 9.18 gm followed by Shams and Noor with 8.12 and 7.76 gm respectively.

Table 23. Effects of CaCl_2 on the dry matter yield of Sunflower plant parts.

Plant parts	Cultivars	Salinity levels in mmhos/cm						Ave.
		Control	5.0	7.5	10.0	12.5	15.0	
SEED: in gms/plant	Shams	13.89	13.32	10.88	7.22	3.39	-	8.12 b 2/
	Noor	13.37	12.35	10.18	7.26	3.42	-	7.76 b
	HOL	14.26	13.37	11.11	8.68	5.39	2.25	9.18 a
	Ave:	13.84a	13.01b	10.73c	7.72d	4.07e	0.75f	
STEN:	Shams	22.60	21.07	17.55	12.18	5.98	3.35	NS 13.79
	Noor	22.79	20.53	17.47	11.49	6.53	3.99	13.80
	HOL	23.59	21.47	17.77	13.47	8.40	3.72	14.74
	Ave:	22.99a	21.02b	17.60c	12.38d	6.97e	3.69f	
LEAF:	Shams	14.37	13.66	11.58	7.70	3.56	1.79	8.78 b
	Noor	14.33	13.06	10.50	7.78	3.80	2.29	8.62 b
	HOL	15.31	13.59	11.76	8.89	5.64	2.94	9.69 a
	Ave:	14.67a	13.43b	11.28c	8.12d	4.33e	2.34f	
AGP 1/	Shams	58.30	54.97	45.75	13.00	15.08	6.17	35.21 a
	Noor	57.87	52.54	43.64	30.34	16.87	7.69	34.82 b
	HOL	61.13	55.67	46.61	35.60	23.25	10.94	34.69 b
	Ave:	59.10a	54.39b	45.33c	32.31b	18.40e	8.26f	

1/ A.G.P. refers to above ground parts.

2/ Means followed by same letters in each row are not significantly different by Duncan's multiple range test at $\alpha = 1\%$.

The effect of the salt on stem was also highly significant (Table 23). With increasing salinity stem weight decreased until at 15.0 mmhos/cm salt level where the reduction effect was about 7 times the control treatment. The maximum average stem weight of 14.74 gm was observed in H01 while Shams and Noor were found at a par and yielded about 13.80 gm stem per plant each.

Leaf weight was also affected with the application of the salt to the soil. Significant differences were found among the means of varieties, levels and their interaction (Table 23). Leaves were severely affected above 10.0 mmhos/cm soil salinity. At 12.5 mmhos/cm level about 5 times reduction occurred in Shams and Noor and 3 times in H01, and at the highest salinity, the reduction effect was the most severe. Statistical analysis of the weight of A.G.P. per plant showed significant differences among the means of varieties, levels and their interaction (Table 23).

3.9.3 Effects of $MgCl_2$ on the Dry Matter Yield of Plant Parts.

The seed yield was reduced significantly with increasing salt concentrations in the soil. Significant differences were found among the means of salinity levels and their interaction at both levels of significance, but the means of varieties were not significant (Table 24). The salt at high concentration proved more toxic to the optimum yield of sunflower as compared with the other salts. The average seed yield at 12.5 mmhos/cm was diminished to 1.75 gm as compared with 10.15 gm in the control

Table 24. Effects of $MgCl_2$ on the dry matter yield of sunflower plant parts.

Plant Parts	Cultivars:	Salinity levels in mmhos/cm						
		Control (K ₂ O)	5.0	7.5	10.0	12.5	15.0	Ave.
in gms/plant								
SEED:	Shams	9.94	8.29	6.64	4.81	1.37	-	5.17 N.S.
	Noor	9.70	8.81	6.52	4.11	1.94	-	5.18
	HOL	10.80	9.24	7.59	3.95	1.93	-	5.58
	Ave:	10.15a	8.78b	6.92c	4.29d	1.75e 2/	-	
STEM:	Shams	16.88	14.36	11.26	7.70	3.43	0.87	9.09 N.S.
	Noor	17.04	14.53	11.05	7.48	4.41	-	9.08
	HOL	19.70	15.98	13.16	8.03	4.58	-	10.24
	Ave:	17.87a	14.96b	11.82c	7.73d	4.15e	0.19f	
LEAF:	Shams	12.40	9.82	7.50	4.67	2.23	2.00	6.19 N.S.
	Noor	12.00	9.60	7.50	4.85	2.50	-	6.07
	HOL	12.49	10.28	8.45	4.64	2.13	-	6.35
	Ave:	12.29a	9.90b	7.81c	4.72d	2.29e	0.16f	
AGP 1/	Shams	44.92	37.31	27.05	20.44	8.36	1.37	23.24 N.S.
	Noor	44.24	37.68	28.74	18.92	11.75	-	23.55
	HOL	50.03	41.04	34.01	19.68	10.32	-	25.84
	Ave:	46.40a	38.67b	29.93c	19.68b	10.15c	0.46f	

1/ A.G.P. refers to above ground parts.

2/ Means followed by same letters in each row are not significantly different by Duncan's multiple range test at $\alpha = 1\%$.

treatment. No seed was obtained at 15.0 mmhos/cm salinity. The highest average yield of 5.58 gm was achieved in H01 followed by 5.18 and 5.17 gm in Noor and Shams respectively. Stem portion was also affected with the intensity in electrical conductivity of the soil solution. However, varieties and their interaction means were not significant; only salinity levels were found significant at both levels of significance (Table 24). Increasing salt concentrations reduced stem weight. The drastic effect of the salt was noticeable at high salinities. An average quantity of 0.19 gm of the stem was collected at 15.0 mmhos/cm. Cv. H01 gave the highest average stem weight of 10.24 gm while shams and Noor were at a par and yielded about 9.09 gms.

The dry weight of the leaves was significantly decreased with rising salinity in the soil solution. The largest average weight of 12.29 gms was determined in the control, while the lowest leaf weight of 0.16 gm was found in plants growing at 15.0 mmhos/cm level. Variety means and their interaction with the level means did not differ significantly, because all the cultivars yielded about 6.0 gm of the dry leaf (Table 24). The salt effect on the dry weight of the above ground parts (AGP) per plant was also determined. Varieties in respect of AGP weight did not differ significantly; all the cultivars weighed an average AGP of more than 23 gm. But different salt levels and their interaction with varieties were different at both levels of significance (Table 24). The dry weight of A.G.P. decreased concurrently with increasing salinization regimes in the soil.

The marked effect of the salt on A.G.P. was noticed at 15.0 mmhos/cm level where less than one gm of AGP was collected as against the 46.40 gm in the control treatment.

3.9.4 Effects of Na_2SO_4 on Dry Matter Yield of Plant Parts .

Like any other salt, the effect of Na_2SO_4 at high concentrations on the seed yield of sunflower was found inhibitory, but at low concentration upto 7.5 mmhos/cm it was not as toxic as NaCl and MgCl_2 . Increasing salinity decreased the dry seed weight of all the test cultivars, but the salt was especially toxic at 15.0 mmhos/cm where less than two gm of seed was collected as compared with 13.68 gms in the control treatment (Table 25). Varieties in respect of the dry seed weight were highly significant. Cultivar H01 produced excellent average yield of 9.18 gm followed by Shams and Noor with 8.12 and 7.76 gm weight respectively.

Increasing salinity of the soil inhibited the proper development of the stem and its total dry weight per plant at the time of maturity. Significant differences were found among varieties, levels and their interaction means in respect of the dry stem weight (Table 25). With increasing salt concentration the dry stem weight was decreased accordingly. The maximum average stem weight of 15.89 gm was recorded in Cv. H01 and the minimum of 12.75 gm in Noor on such saline soil.

Dry leaf weight of all the cultivars was significantly decreased with intensification of electrical conductivity in the

Table 25. Effects of Na_2SO_4 on the dry matter yield of sunflower plant parts.

Plant parts in gms/plant	Cultivars	Salinity levels in mmhos/cm						Ave
		Control	5.0	7.5	10.0	12.5	15.0	
SEED:	Shams	13.60	12.22	9.73	4.99	2.83	1.15	8.12b ^{2/}
	Noor	13.12	11.42	8.91	6.41	2.23	-	7.76b
	H01	14.34	13.45	11.27	7.83	3.01	1.91	9.18a
	Ave:	13.68a	12.36b	9.97c	6.41d	2.69e	1.02f	
STEN:	Shams	23.15	21.24	16.48	11.43	7.88	3.58	13.96b
	Noor	22.56	20.37	15.57	11.26	6.75	-	12.75b
	H01	25.34	23.31	19.83	14.55	8.02	4.29	15.89a
	Ave:	23.68a	21.64b	17.29c	12.41d	7.55e	2.62f	
LEAF:	Shams	15.02	13.86	10.74	7.19	4.13	2.00	NS ^{1/} 8.83
	Noor	15.06	13.27	10.78	8.77	4.48	-	8.78
	H01	16.67	14.95	12.77	9.40	4.63	2.68	10.18
	Ave:	15.58a	14.03b	11.43c	8.45d	4.51e	1.56f	
AGP 1/	Shams	59.23	54.14	43.36	27.73	17.46	7.86	34.80b
	Noor	57.97	51.74	40.11	30.17	15.88	-	32.64b
	H01	65.10	59.76	50.94	37.23	18.13	10.80	40.33a
	Ave:	60.77a	55.19b	44.47c	31.71d	17.16e	6.22f	

^{1/} A.G.P. refer to above ground parts.^{2/} Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at $p = 1\%$.

soil solution. Again the toxicity of the salt was obvious at the highest salt concentration where the dry leaf weighed only 1.56 gm as compared with 15.58 gm in the control treatment (Table 25). Variety means, however, did not differ significantly and all of them yielded about 10.9 gm of the dry leaf.

On the basis of total A.G.P. weight, varieties, levels and their interaction means were significant at both levels of significance (Table 25). Minimum average weight of 6.22 gm of the 3 cultivars was obtained at the highest salinity level as compared with 60.77 gm in the control treatment. The maximum average yield of 40.33 gm over all salinities was observed in Cv. H01 and the minimum of 32.64 in Noor which was found most susceptible to high salinities on such soils. From the results it was concluded that although all the yield components were decreased with increasing salinity of Na_2SO_4 , the ultimate average yield was still higher than that obtained on soils having excess amounts of NaCl or MgCl_2 .

3.9.5 Effects of Mixture Salts on the Dry Matter Yield of Sunflower Plant Parts.

Different levels of salinity produced by mixture salts of NaCl , CaCl_2 , MgCl_2 and Na_2SO_4 in the soil significantly affected the seed yield, stem, leaf and above ground parts (AGP) of sunflower. Increasing salinity caused these parameters to decrease. At the highest salinity level, seed yield was reduced by 6 times, stem weight 5 times and leaf quantity 7 times of the control

treatment (Table 26). Cultivar Noor was found most susceptible and showed the lowest yield. The total dry weight of above ground parts (AGP) of sunflower also indicated a negative relationship with increasing salts in the soil solution. At the highest salinity, AGP weight of the 3 cultivars averaged 12.15 gm as compared with 56.53 gm in the control treatment. The greatest AGP weight of 38.28 gm over all salinity levels was recorded in Cv. H01 followed by 34.93 and 28.26 in Shams and Noor respectively (Table 26).

Table 26. Effects of mixture salts on the dry matter yield of sunflower plant parts.

Plant parts in gms/plant	Cultivars	Control	Salinity levels in mmhos/cm				
			5.0	7.5	10.0	12.5	15.0
SEED:	Shams	12.85	11.57	9.78	6.48	3.59	2.69
	Noor	11.01	9.09	7.34	4.86	2.84	1.62
	H01	15.08	13.08	10.75	7.47	4.27	2.83
	Ave:	12.98a	11.25b	9.29c	6.27d	3.57e	2.38f
STEM:	Shams	21.62	19.03	15.95	12.59	8.38	6.23
	Noor	19.11	16.54	13.03	9.77	5.13	3.47
	H01	23.89	20.47	16.17	9.85	6.00	4.87
	Ave:	21.54a	18.68b	15.05c	10.73d	6.50e	4.86f
LEAF:	Shams	14.39	11.19	8.98	6.85	4.48	2.71
	Noor	13.00	10.79	7.98	5.29	2.58	1.37
	H01	16.02	13.60	11.13	7.97	5.16	4.15
	Ave:	14.47a	11.86b	9.46c	6.70d	4.07e	2.74f
AGP 1/	Shams	56.23	48.22	40.21	30.98	19.88	14.04
	Noor	49.42	42.11	33.21	23.59	13.00	9.27
	H01	63.95	55.02	45.25	31.33	19.98	14.43
	Ave:	56.53a	48.46b	39.55c	28.63d	17.62e	12.15f

1/ AGP refers to above ground parts.

2/ Means followed by same letters in each row are not significantly different by Duncan's multiple range test at $\alpha = 1\%$.

3.10 Absorption of Minerals by Sunflower under Saline Conditions

The purpose of these experiments were to relate saline soil conditions induced by increasing amounts of mixed salts to the uptake and concentration of eight mineral nutrients (Na, Ca, Mg, K, N, P, Cl and S) in the leaf and stem parts of the sunflower plant. The amounts of some of these elements in the vegetative portions of sunflower with respect to different salinization regimes in the soil differed significantly and are shown in Table 27 through table 34. The results are grouped in the following headings.

3.10.1 Sodium Concentration

At maturity, considerable differences in the content of Na in the tissues of treated plants were found due to different concentrations of the salts in the soil solution. In general, the concentrations of Na in the leaf and stem were increased with increasing levels of salinity, although to varying degrees. The higher Na content was determined in the stem, the lower in the leaf (Table 27).

Statistical analysis revealed significant differences among the means of varieties, salinity levels and their interaction on Na percentage in the leaf of sunflower. Increases in Na content occurred across the entire range of salinity established, but were particularly sharp above a threshold EC value of 10.0. The concentrations of leaf Na ranged from 0.16, 0.23,

0.38, 0.50, 0.80 to 1.10% respectively in plants growing in control treatment through 5.0, 7.5, 10.0, 12.5 and 15.0 mmhos/cm soil salinities. Among the cultivars, the highest positive correlation between the soil salinity and the uptake of Na was indicated by H01 and the lowest by Shams.

The Na content of stem was much higher than that found in the leaf. Statistical analysis also showed significant differences among the means of varieties, salinity levels and their interaction on Na percentage of the stem. The amounts of stem Na with respect to control treatment and 5.0, 7.5, 10.0, 12.5 and 15.0 mmhos/cm soil salinities were 0.64, 0.71, 1.11, 1.31, 1.46 and 1.99% respectively. The greatest Na value of 1.46% was estimated in Shams and the lowest, 0.93%, in Noor.

3.10.2 Calcium Concentration.

Increases in Na content in various plant parts, with increase in EC value of the soil have not brought out any corresponding decrease in Ca content of sunflower plant. To the contrary, percent Ca of the leaf and stem at the time of maturity, progressively increased with increasing levels of salinity. All interactive effects of salinity levels on Ca concentration in the plant were round highly significant; however, the Ca amount was more pronounced in the leaf than in stem. The concentration of Ca in the leaf was lower in the non-treated plants than treated ones (Table 28). The amount of leaf Ca was augmented with increasing levels of salinity in

Table 27. Effect of salinity levels on Sodium concentrations of sunflower plant parts.

Plant Parts	Cultivars	Salinity levels in mmhos/cm						Ave:
		Control (3.5)	5.0	7.0	10.0	12.5	15.0	
LEAF		% Na.....						
	Shams	0.16	0.18	0.35	0.45	0.75	0.97	0.48 c
	Noor	0.12	0.19	0.30	0.46	0.84	1.06	0.50 b
	H01	0.20	0.33	0.47	0.60	0.82	1.27	0.61 a 1/
	Ave.	0.16f	0.23e	0.38d	0.50c	0.80b	1.10a	
STEM	Shams	0.68	0.72	1.77	1.81	1.85	1.96	1.46 a
	Noor	0.51	0.60	0.68	0.77	0.87	2.12	0.93 c
	H01	0.73	0.80	0.89	1.36	1.66	1.89	1.22 b
	Ave.	0.64f	0.71e	1.11d	1.31c	1.46b	1.99a	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at $p = 1\%$.

Table 28. Effects of salinity levels on Calcium Concentrations of sunflower plant parts.

Plant Parts.	Cultivars	Salinity levels in mmhos/cm						Ave.
		Control (1.5)	5.0	7.5	10.0	12.5	15.0	
LEAF		% Ca.....						
	Shams	3.60	3.63	3.69	3.77	3.84	4.08	3.77 a 1/
	Noor	3.25	3.51	3.57	3.66	3.70	3.77	3.58 b
	H01	3.07	3.20	3.33	3.43	3.63	3.71	3.40 c
	Ave.	3.31f	3.45e	3.53d	3.62c	3.72b	3.85a	
STEM	Shams	0.50	0.62	0.71	0.80	0.87	0.97	0.75 b
	Noor	0.50	0.53	0.60	0.71	0.76	0.81	0.65 c
	H01	0.67	0.70	0.81	0.92	1.04	1.12	0.88 a
	Ave.	0.55f	0.62e	0.71d	0.81c	0.89b	0.97a	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at $p = 1\%$.

the soil. The greatest estimated Ca value was 3.85% at 15.0 mmhos/cm. level, while the lowest 3.31% was found in the non-treated plants. Cultivars also differed significantly with regard to the amount of Ca percentage; the greatest accumulation of 3.77% Ca in the leaf was recorded in Shams and the lowest, 3.40%, in H01.

The concentration of Ca in the stem was also enhanced with an increase in salinity level. The lowest stem Ca, 0.55%, was determined in the control treatment. Nevertheless with rising EC values of the soil, Ca was increased in the stem in the order of 5.0 mmhos/cm (0.62%) 7.5 (0.71%), 10.0 (0.81%), 12.5 (0.89%), and 15.0 (0.97%) (Table 28). The extent of Ca uptake from such soils varied significantly among the three test cultivars. The highest average Ca value, 0.88%, was in H01 and the lowest, 0.68%, in Noor.

3.10.3 Magnesium Concentration.

Mg content of both the leaf and stem of sunflower got significantly decreased at all the salinity levels. With increasing salinity in the soil, Mg concentration of the leaf was depressed, particularly above 10.0 mmhos/cm level until the highest level, 15.0 mmhos/cm, when Mg averaged 0.60% as compared with 1.17% in the control treatment (Table 29). Significant differences were found in Mg content in the three cultivars under test. The average highest Mg, 0.95%, was determined in Shams, followed by 0.85% in H01 and 0.76% in Noor.

Table 29. Effects of salinity levels on magnesium concentrations of sunflower plant parts.

Plant Parts	Cultivars	Salinity levels in mmhos/cm						Ave.
		Control (1.5)	5.0	7.5	10.0	12.5	15.0	
LEAF		% Mg.....						
	Shams	1.28	0.98	0.91	0.89	0.95	0.67	0.95 a 1/
	Noor	1.12	0.90	0.68	0.72	0.61	0.53	0.76 c
	HOL	1.11	0.96	0.78	0.81	0.80	0.62	0.85
	Ave.	1.17a	0.95b	0.79d	0.81c	0.78d	0.60e	
STEM	Shams	0.46	0.40	0.29	0.32	0.28	0.23	0.33 b
	Noor	0.40	0.28	0.31	0.22	0.22	0.29	0.29 c
	HOL	0.51	0.46	0.47	0.28	0.24	0.21	0.36 a
	Ave.	0.45a	0.38b	0.36c	0.27d	0.25e	0.25e	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

Accumulation of Mg in the stem was lower than in leaf of sunflower plant. The greatest value of Mg, 0.45% was determined in plants growing in the control treatment (2.5 mmhos/cm). With increasing EC value in the soil solution, Mg content was accordingly lowered until 12.5 mmhos/cm, but beyond this level there was no further decrease in Mg and its value (0.25%) remained constant even at EC value of 15.0 mmhos/cm. The average Mg content in the stem portions of H01, Shams and Noor was 0.36, 0.33 and 0.29% respectively (Table 29).

3.10.4 Potassium Concentration

The results presented in Table 30 indicated that salinity caused a highly significant decrease in K content of leaves of all the test plants as compared with the control; the decrease was regular with the increase of salinity levels. The change in K content was quite noticeable at 15.0 mmhos/cm level, where it was more than 50% as compared with other treatments. The highest average K content, 3.50%, was estimated in H01, followed by 3.34% in Shams and 2.70% in Noor.

The content of K was comparatively higher in the stem than in leaf. However, it decreased with increasing levels of salinity in the soil (Table 30). Varieties, levels and their interaction means . . . revealed significant differences at both levels of significance on K percentage of the stem. Drastic reduction in K content occurred at the highest salinity level,

Table 30. Effects of salinity levels on Potassium Concentration of sunflower plant parts.

PLANT PARTS	Cultivars	Salinity levels in mmhos/cm						
		Control (2.5)	5.0	7.5	10.0	12.5	15.0	Ave.
LEAF:		% K.....						
	Shams	4.60	4.45	3.88	2.97	2.78	1.34	3.34 b
	Noor	4.35	3.53	3.34	2.13	1.79	1.06	2.70 c
	H01	5.04	4.17	3.89	3.15	2.68	2.08	3.50 a 1/
	Ave.	4.66a	4.05b	3.71c	2.75d	2.42e	1.49f	
STEM:								
	Shams	5.87	5.89	4.66	3.53	2.88	2.56	4.22 b
	Noor	5.21	4.88	4.75	3.29	2.16	1.96	3.71 c
	H01	6.12	5.80	5.05	4.36	3.66	2.12	4.52 a
	Ave.	5.71a	5.52a	4.82a	3.73ab	2.90b	2.21cd	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

where average K accumulation was only 2.21% as compared with 5.71% in the control treatment. Potassium accumulated highly in H01 followed by Shams and Noor. The reduction in K in the leaf and stem of sunflower was apparently compensated by the high uptake of other cations like Na and Ca on such saline soils.

3.10.5 Nitrogen Concentration

The concentrations of N in the leaf and stem at maturity stage increased with increasing salinity; however the total N content was higher in the leaf than in stem. It is evident from Table 31 that maximum N content of 3.33% was estimated at the highest level as compared with 2.30% in the non-treated plants. Cultivars Shams and H01 were found at a par statistically and accumulated about 2.85% N in their leaves, against 2.54% of Noor.

The content of N in the stem increased highly beyond 7.5 mmhos/cm level, because more than 50% increase occurred at 10.0 mmhos/cm and about double and triple increase over the control treatment was noticed at 12.5 and 15.0 mmhos/cm respectively. With regard to N concentration, varieties means differed significantly. The highest average N content, 0.72%, was found in H01 and the lowest 0.60% in Noor.

3.10.6 Phosphorus Concentration

In general, concentration of P in the leaves and stems of sunflower at maturity decreased with increasing salinity levels. Varieties and level means showed significant differences

at both levels of significance, but their interaction was non-significant (Table 32).

The decrease in leaf occurred over the entire range of salinities. However, even at the highest salinity level, the reduction was only 40.74% as compared with control treatment. The highest average P, 0.23% was recorded in Noor followed by 0.22 and 0.21% in H01 and Shams respectively (Table 32).

Phosphorus content was lower in the stem than in leaf of sunflower. The maximum P, 0.07%, was estimated in the non-treated plants and it decreased regularly over salinities of 5.0, 7.5, 10.0, 12.5 until 15.0 mmhos/cm. Drastic reduction in P percentage occurred above 10.0 mmhos/cm; only 0.03 and 0.02% P was determined at levels 12.5 and 15.0 mmhos/cm respectively. Cultivars Shams and H01 were at a par and both revealed 0.05% P, while Noor averaged 0.04% on such saline substrates (Table 32).

3.10.7 Chloride Concentration

A highly significant positive relationship existed between soil salinity and Cl concentration (Table 33) in the leaf and stem of sunflower at the stage of maturity. In the leaf, Cl accumulated to 1.98%(5.0), 2.23%(7.5), 2.51%(10.0), 2.82%(12.5) and 3.10% (15.0 mmhos/cm) against 1.92% in the control treatment. The data revealed that more than 50% increase in chloride content was induced only at the highest

Table 32. Effects of salinity levels on Phosphorus concentrations of sunflower plant parts.

PLANT PARTS	Salinity levels in mmhos/cm						
	Cultivars	Control	5.0	7.5	10.0	12.5	15.0
.....% P.....							
LEAF: Shams	0.26	0.25	0.23	0.20	0.17	0.14	0.21 c
Noor	0.28	0.27	0.26	0.25	0.19	0.17	0.23 a
H01	0.27	0.25	0.24	0.23	0.17	0.16	0.22 b
Ave.	0.27a	0.26b	0.24c	0.22d	0.18e	0.16f	
STEM: Shams	0.07	0.06	0.05	0.04	0.03	0.02	0.05 a
Noor	0.07	0.06	0.05	0.04	0.03	0.02	0.04 b
H01	0.08	0.07	0.06	0.05	0.04	0.03	0.05 a
Ave.	0.07a	0.06a	0.06a	0.04b	0.03c	0.02	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at 1%.

Table 33. Effects of salinity levels on Chloride Concentrations of sunflower plant parts.

PLANT PARTS	Salinity levels in mmhos/cm						
	Cultivars	Control	5.0	7.5	10.0	12.5	15.0 Ave.
LEAF:							
	Shams	1.86	1.89	2.06	2.36	2.72	2.88 2.30 c
	Noor	1.79	1.83	2.19	2.50	2.86	3.17 2.39 b
	HOL	2.12	2.23	2.44	2.67	2.89	3.24 2.59 a 1/
	Ave.	1.92f	1.98e	2.23d	2.51c	2.82b	3.10a
STEM:							
	Shams	1.80	1.86	1.90	2.33	2.59	2.77 2.21 a
	Noor	1.72	1.76	1.80	2.12	2.30	2.46 2.03 b
	HOL	1.90	1.93	1.98	2.22	2.51	2.80 2.22 a
	Ave.	1.81f	1.85e	1.89d	2.22c	2.47b	2.68a

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at $\alpha = 1\%$.

salinity level. Varietal differences were also found highly significant; the greatest Cl concentration, 2.59%, was determined in H01 and the lowest, 2.30%, in Shams.

The Cl content in the stem did not differ very much from that estimated in leaf (Table 33). The Cl percentage increased with increasing salinization regimes of the soil. The lowest value of Cl, 1.81%, was found in the non-treated plants and the highest value, 2.68%, was attained at 15.0 mmhos/cm level. Variety means differed significantly with regard to Cl concentration in the stem. Nevertheless, H01 and Shams were found at a par and showed about 2.22% Cl, while Noor was quite different in response and revealed only 2.03% Cl in the stem.

3.10.8 Sulphur Concentration

Sulphur concentrations (Table 34) in the leaf and stem of sunflower plant decreased as linear functions of salinity. The greatest S-concentration, 0.90%, in the leaf was estimated in the non-treated plants.

The content of S in the leaf decreased with increasing EC values of the soil in the order of 0.85% (5.0), 0.81% (7.5), 0.72% (10.0), 0.62% (12.5), and 0.56% (15.0 mmhos/cm). The response of Shams and H01 to salinity levels was almost the same because both these cultivars indicated about 0.76% S in the leaf. On the other hand they were significantly different from Noor, which showed 0.72% S.

Table 34. Effects of salinity levels on sulphur concentrations of sunflower plant parts.

PLANT PARTS	Cultivars	Salinity levels in mmhos/cm							
		Control	5.0	7.5	10.0	12.5	15.0	Ave.	
LEAF:		% S.....							
	Shams	0.93	0.89	0.85	0.76	0.60	0.54	0.76 a	1/
	Noor	0.87	0.81	0.75	0.67	0.64	0.59	0.72 b	
	H01	0.90	0.86	0.84	0.73	0.63	0.55	0.75 a	
	Ave.	0.90a	0.85b	0.81c	0.72d	0.62e	0.56f		
STEM:									
	Shams	0.30	0.27	0.25	0.22	0.21	0.16	0.24 a	
	Noor	0.27	0.27	0.25	0.20	0.17	0.15	0.22 a	
	H01	0.24	0.24	0.23	0.20	0.16	0.14	0.20 ab	
	Ave.	0.27a	0.26a	0.24b	0.21c	0.18d	0.15e		

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at $p = 1\%$.

The amount of S in the stem was lower than in leaf (Table 34). The S percentage differed significantly at all salinity levels, however, at 5.0 mmhos/cm, it did not differ significantly from that in the control treatment. Increasing salinity decreased S-content above this level. The lowest average value, 0.15%, of S, was determined at the highest salinity level as compared with 0.27% in the control treatment. The decreased S-content may be attributed to the negative effect of Cl on S.

3.11 Effects of Mixture Salts on Percentage Moisture of the Seeds of Sunflower.

The relative content of water in the seed, which to some extent is a measure of the seed maturation, decreased significantly with increasing salinity of the soil. Data in Table 35 revealed that at the highest level of salinity (15.0 mmhos/cm) the seeds could attain a maximum moisture of only 4.72% as compared with 6.02% in the seeds of non-treated plants. The seeds of the three cultivars of sunflower tested for moisture percentage differed significantly from one another. The average moisture of 5.63% was determined in the seeds of H01 followed by 5.48% in Shams and 5.19% in Noor.

3.12 Effects of Mixture Salts on the Oil of Sunflower Seed.

Salinity variously affected the different biochemical activities of sunflower. From the results in Table 36, it can be seen that the oil content of each of the 3 cultivars tested decreased significantly with the addition of each increment of

Table 35. Effects of salinity (mixture salts) on the moisture percentage of sunflower seeds.

Cultivars	Salinity levels in mmhos/cm						Ave
	Control (2.5)	5.0	7.5	10.0	12.5	15.0	
Shams	5.98	5.85	5.60	5.50	5.20	4.75	5.48 b
Noor	5.82	5.55	5.37	5.15	4.77	4.47	5.19 c
H01	6.27	6.05	5.77	5.51	5.22	4.95	5.63 a 1/
Ave.	6.02a	5.82b	5.58c	5.39d	5.06e	4.72f	

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

Table 36. Effects of mixture salts on the oil content of sunflower seeds.

Cultivars	Salinity levels in mmhos/cm					
	Control (2.5)	5.0	7.5	10.5	12.5	15.0 Ave.
Shams	36.57	35.20	34.60	34.00	33.17	32.40 34.32 b
Noor	34.87	33.70	33.07	32.75	31.15	30.50 32.67 c
H01	38.22	37.17	36.97	36.40	35.70	34.20 36.51 a 1/
Ave.	36.52a	35.53b	34.88c	34.38d	33.34e	32.36f

1/ Means followed by same letters in each row are not significantly different by Duncan's Multiple range test at α 1%.

salts in the soil solution upto the level of 15.0 mmhos/cm, where it dropped to its minimum. The maximum oil content of 36.52% was determined in the control pots having EC value of 2.5 mmhos/cm and it decreased gradually over the salinity levels, 5.0, 7.5, 10.0, 12.5 and 15.0 mmhos/cm. At the highest level of salinity, the ultimate oil content evidently resulted from the hastened onset of maturity and the decreased kernel percentage of the seed due to soil salinity, especially at EC value of 15.0 mmhos/cm. Also it is worthy to notice that the three cultivars tested, differed significantly with regard to oil content in their seeds. The greatest amount of 36.51% of the oil was analyzed in the seeds of H01 followed by 34.32% in Shams and 32.67% in Noor.

3.12.1 Refractive Index

The statistical analysis of the data (Table 37) revealed that salts in the soil solution had no effect on refractive index of the oil of the 3 cultivars of sunflower. The average values of refractive index fluctuated between 1.465 and 1.464, but there was no correlation between the various salinity levels of the soil and the refractive index of the oil of sunflower seed.

3.12.2 Specific Gravity and Acid Value

It is evident from the results in Table 38 and Table 39, that different salinization regimes of the soil had no significant effect on specific gravity and acid values of the oil of the 3 cultivars of sunflower.

Table 37a, . Effects of mixture salts on the refractive index of the
oil of sunflower seeds.

		Salinity levels in mmhos/cm					
Cultivars	Control (2.5)	5.0	7.5	10.0	12.5	15.0	Ave. NS
Shams	1.465	1.465	1.467	1.466	1.463	1.464	1.465
Noor	1.463	1.465	1.463	1.464	1.465	1.464	1.464
H01	1.466	1.464	1.465	1.463	1.465	1.467	1.465
Ave.	1.464	1.465	1.465	1.464	1.464	1.465	

Table 37a. Effects of mixture salts on the specific gravity of the
oil of sunflower seeds.

Cultivars	Control (2.5)	Salinity levels in mmhos/cm					Ave.
		5.0	7.5	10.0	12.5	15.0	
Shams	0.918	0.916	0.917	0.917	0.917	0.919	0.917
Noor	0.914	0.913	0.914	0.915	0.914	0.914	0.914 <u>N.S</u>
HOL	0.916	0.917	0.916	0.916	0.914	0.914	0.915
Ave.	0.916	0.915	0.915	0.916	0.915	0.916	

Table 38. Effects of mixture salts on the acid value of the oil of
sunflower seeds.

Cultivars	Salinity levels in mmhos/cm					
	Control (2.5)	5.0	7.5	10.0	12.5	15.0 Ave
Shams	2.4	2.4	2.5	2.4	2.4	2.5 2.4
Noor	2.4	2.5	2.5	2.6	2.3	2.5 2.4 N.S
H01	2.3	2.3	2.4	2.6	2.3	2.5 2.4
Ave.	2.3	2.4	2.5	2.5	2.3	2.5

3.12.3 Iodine and Saponification Values

The effects of salinity on the iodine and saponification values of the oil of sunflower seed were found non-significant (Table 40 and Table 41). There was no correlation between the various salinization regimes of the soil and the iodine and saponification values of the oil. The inability of salinity to change the saponification value indicated that the salts had no effect on the chain length of fatty acids of the oil of sunflower seed.

3.12.4 Fatty acid Composition of the Oil of sunflower seeds

Chemical compositional data of the oil of the 3 cultivars of sunflower are shown in (Fig 1-9). With rising salinity, the percentage composition of different fatty acids of the oil changed but insignificantly. However, in some cultivars the trend was quite obvious. For instance in Shams increasing salinity from 2.5 to 15.0 mmhos/cm caused Palmitic acid to decline from 7.0241 to 5.873%, but H01 and Noor were not affected. Stearic and Oleic acids, on the other hand, increased with increasing increments of salinity levels. Minimum content of 34.4006% of these two acids, was found at the control level in Noor and 55.4869 at EC value of 15.00 mmhos/cm in Shams. In Noor, the quantity of these acids was 22.7014% at the control level and 52.8228% at the highest salinization regime. Cultivar H01, however, was unaffected. Linoleic acid decreased with

Table 39. Effects of mixture salts on the iodine value of the oil of
sunflower seeds.

Cultivars	Salinity levels in mmhos/cm						
	Control (2.5)	5.0	7.5	10.0	12.5	15.0	Ave. N.S
Shams	119.65	117.53	117.95	118.6	118.53	118.30	118.42
Noor	117.17	117.22	117.75	118.17	117.12	116.90	117.88
H01	117.72	117.55	117.32	117.32	117.47	117.72	117.51
Ave.	118.18	117.43	117.67	118.03	117.70	117.64	

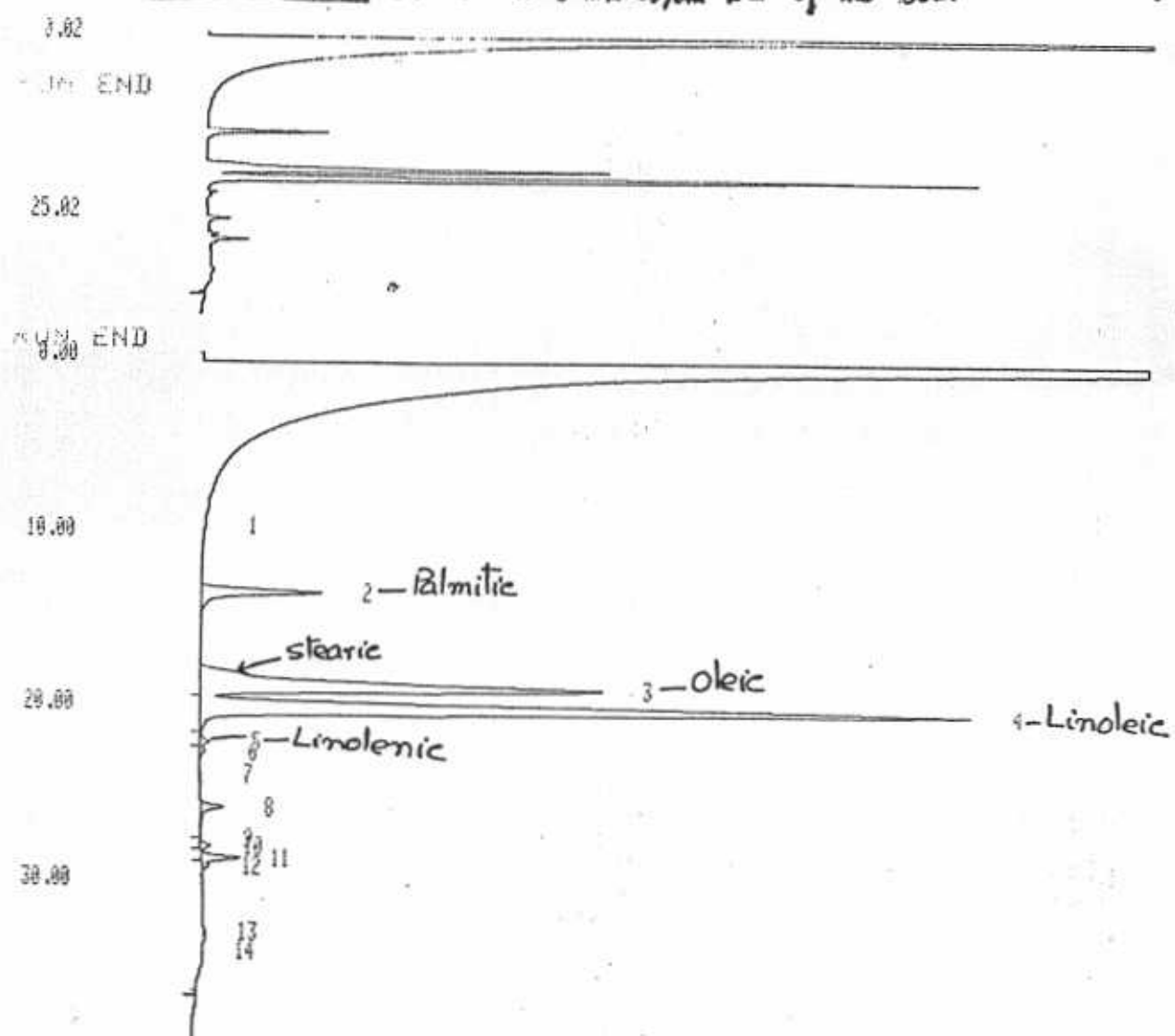
Table 40. Effects of mixture salts on the saponification value of the oil of sunflower seeds.

		Salinity levels in mmhos/cm.					
Cultivars	Control (2.5)	5.0	7.5	10.0	12.5	15.0	Ave.
Shams	188.52	188.2	188.5	188.37	187.90	187.50	188.16
Noor	187.35	187.47	187.62	187.60	187.07	183.50	186.76
H01	188.60	188.05	188.87	189.25	189.42	188.25	188.78
Ave.	188.15	187.90	188.33	188.40	188.13	186.41	

NS.

increasing salinity from 54.1777% (2.5 mmhos/cm) to 36.142% (15.0 mmhos/cm) in Shams and 65.5480% (2.5 mmhos) to 38.4304% (15.00 mmhos) in Noor. The change in percentage composition of this acid was not regular in H01. Linolenic acid revealed no relationship with salinity, although it ranged from a minimum of 0.2682 to a maximum of 0.6483% in the oil of these cultivars.

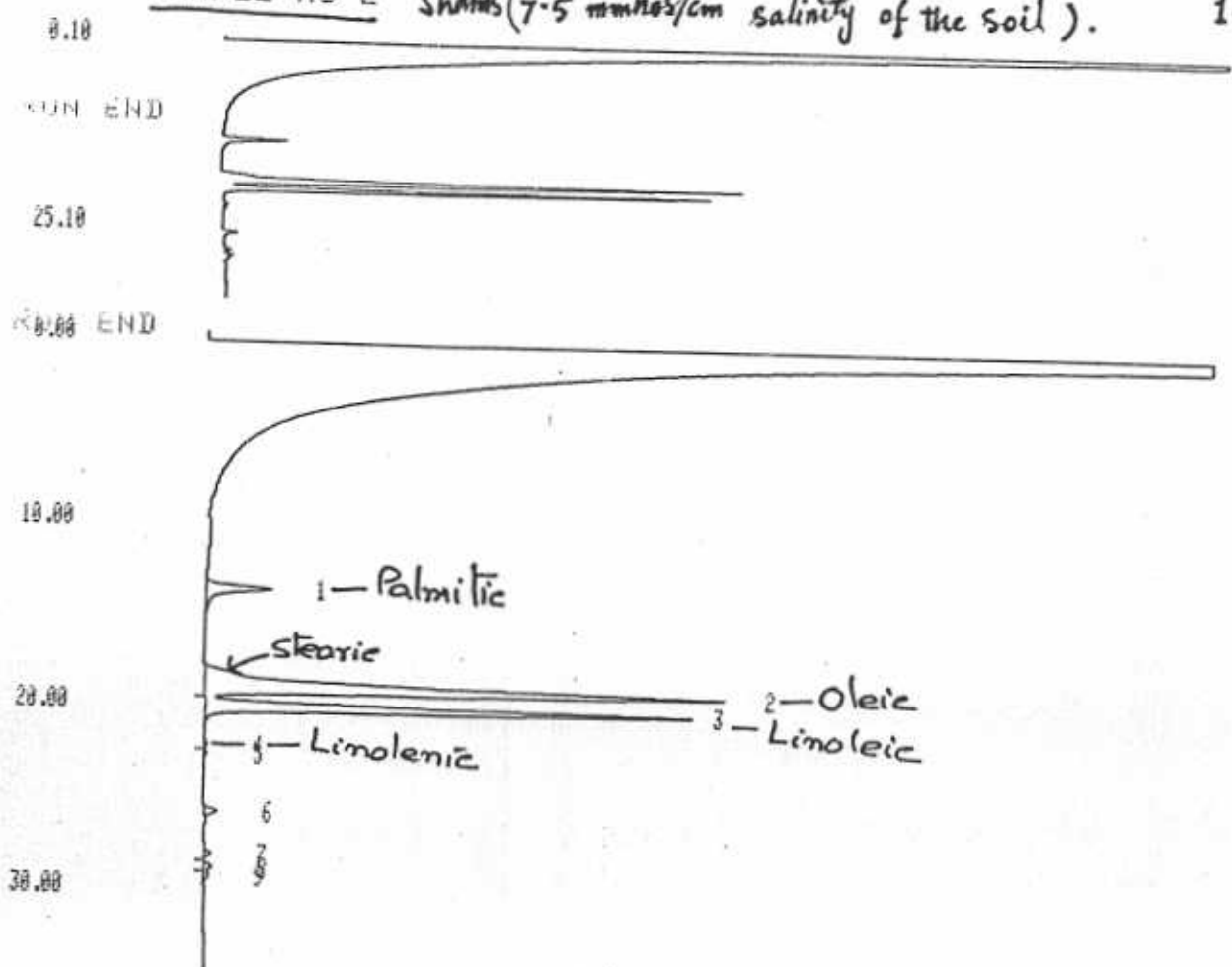
FIG 24. FATTY ACID COMPOSITION OF SUNFLOWER SEEDS
 SAMPLE NO 1 Shams at 2.5 mmhos/cm EC of the soil



RON	END	NAME	RT	A OR H	MK	CONC
1	9.82		19			~~9.0014~~
2	13.73		93760			C16:0 - 7.0241 - Palmitic
3	19.26		459186	M		34.4006 - C18:0, C18:1 - Stearic
4	20.56		723176	M		54.1777 - C18:2 - Linoleic
5	22.31		5940	M		0.4450 - C18:3 - Linoleic
6	22.81		3073			0.2302
7	24.08		5			0.0004
8	25.95		16385			1.2275
9	27.72		296	M		0.0222
10	28.19		5681	M		0.4256
11	28.87		22778	M		1.7064
12	29.31		3638			0.2726
13	33.11		866			0.0649
14	34.11		12			0.0009
TOTAL			1334820			99.9999

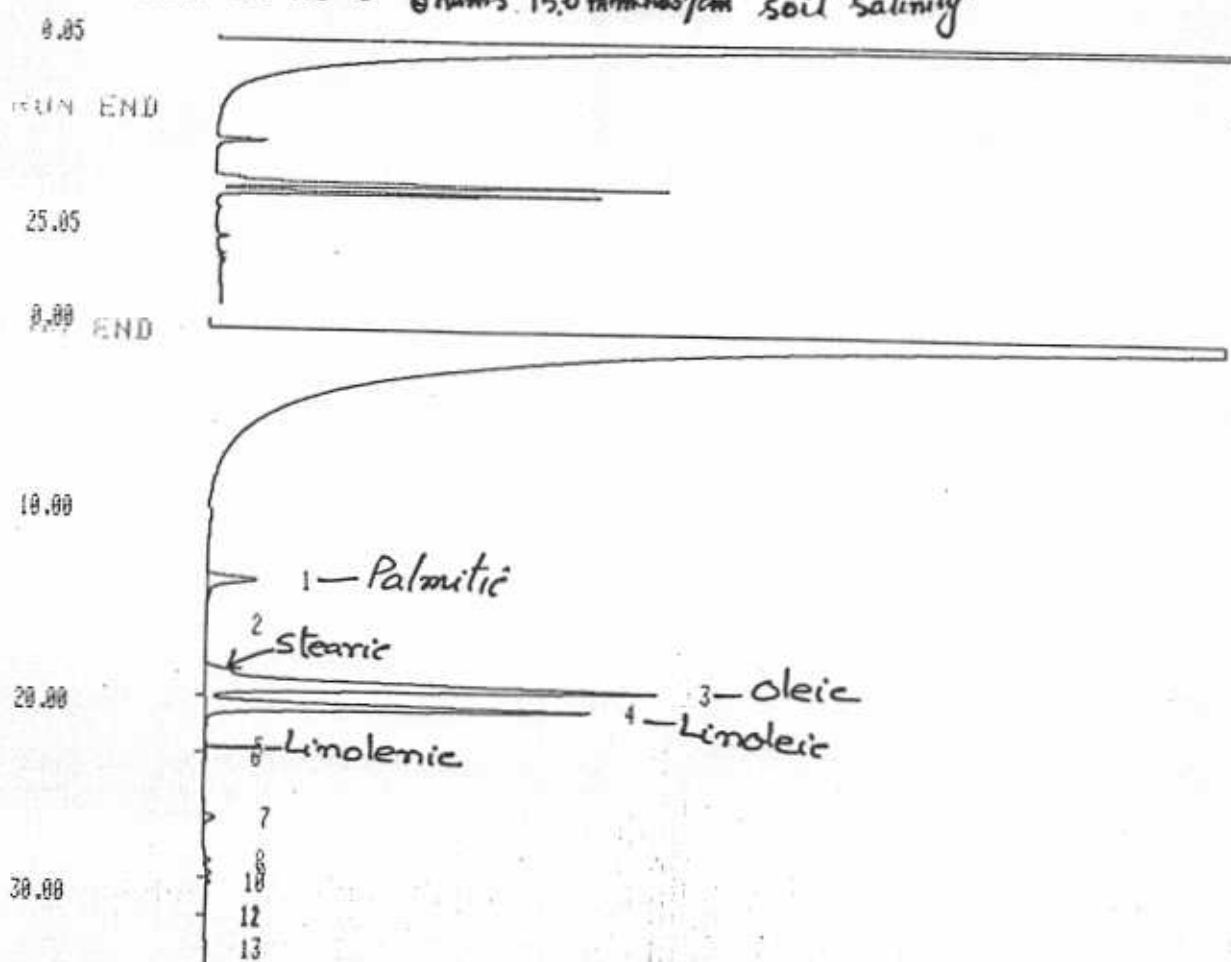


FIG. 25. FATTY ACID COMPOSITION OF SUNFLOWER SEEDS
 SAMPLE NO 2 *Shams (7.5 mmhos/cm salinity of the soil).*



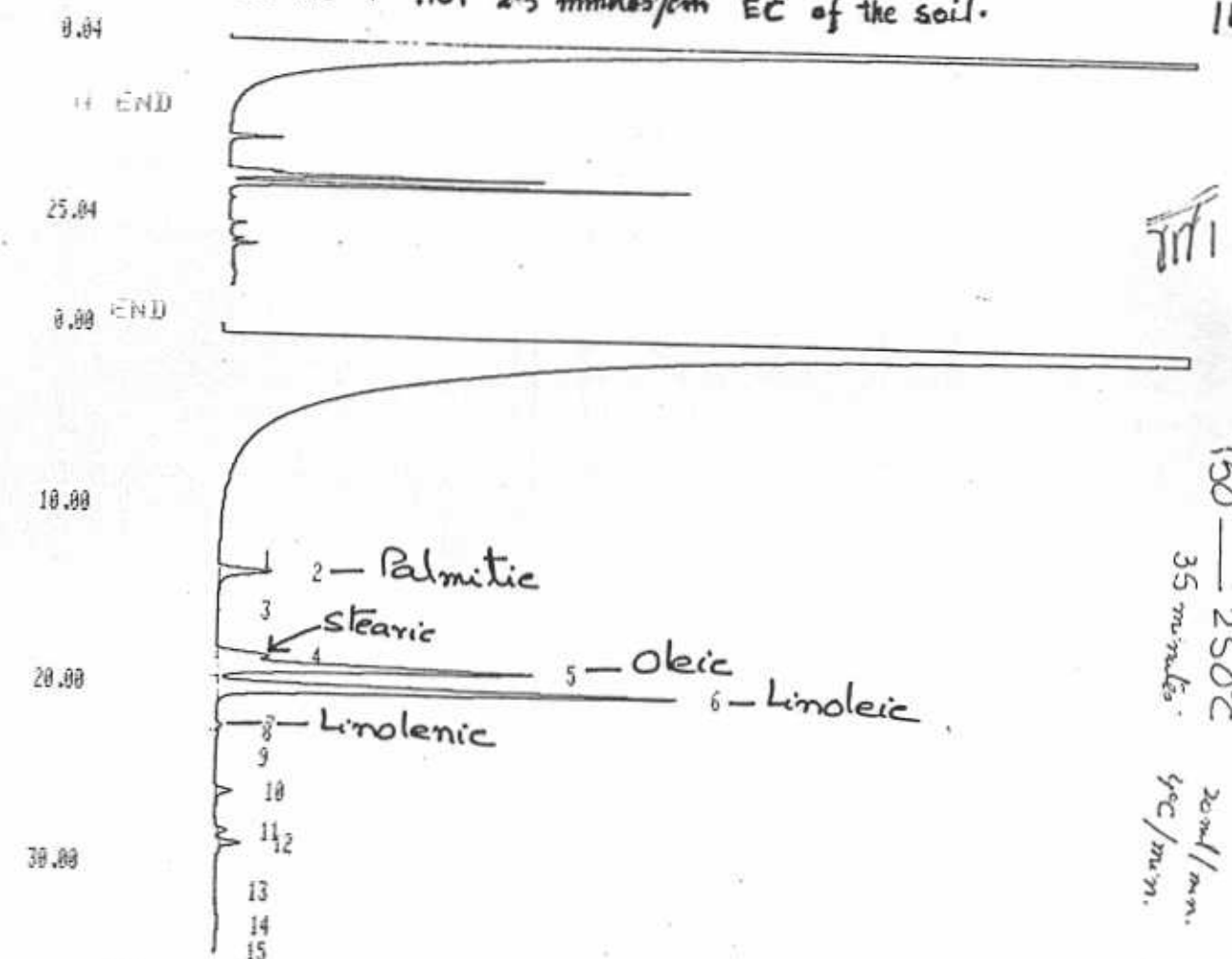
RET. TIME	NAME	RT	A OR H	MK	CONC
2		13.73	48955		5.8769-C16:0-Palmitic
3		19.33	445325	M	53.4605-C18:0,C18:1-Stearic
4		20.35	316607		38.0081-C18:2, Linoleic
5		22.37	2234	M	0.2682-C18:3, Linoleic
6		22.87	1626		0.1951
7		26.05	7906		0.9491
8		28.28	3516	M	0.4221
9		28.97	4326	M	0.5194
		29.43	2500		0.3001
TOTAL			832998		99.9999

FIG. 26. FATTY ACID COMPOSITION OF SUNFLOWER SEEDS
 SAMPLE NO 3 Shams^{15.0 mmhos/cm} soil salinity



NO	RT	A OR H	MK	CONC.
1	13.67	38541		5.8734-C16:0, Palmitic
2	16.00	6		0.0015
4	19.25	364108	M	55.4869-C18:0, C18:1, Stearic
5	20.26	237166		36.1420-C18:2-Linoleic
6	22.37	1858	M	0.2831-C18:3-Linolenic
	22.86	1327		0.2023
	26.03	6113		0.9315
	28.26	2411		0.3674
	28.94	2461	M	0.3751
	29.39	2185		0.3330
	31.13	11	M	0.0017
	31.17	10		0.0016
	32.84	3		0.0004
TOTAL		656205		99.9999

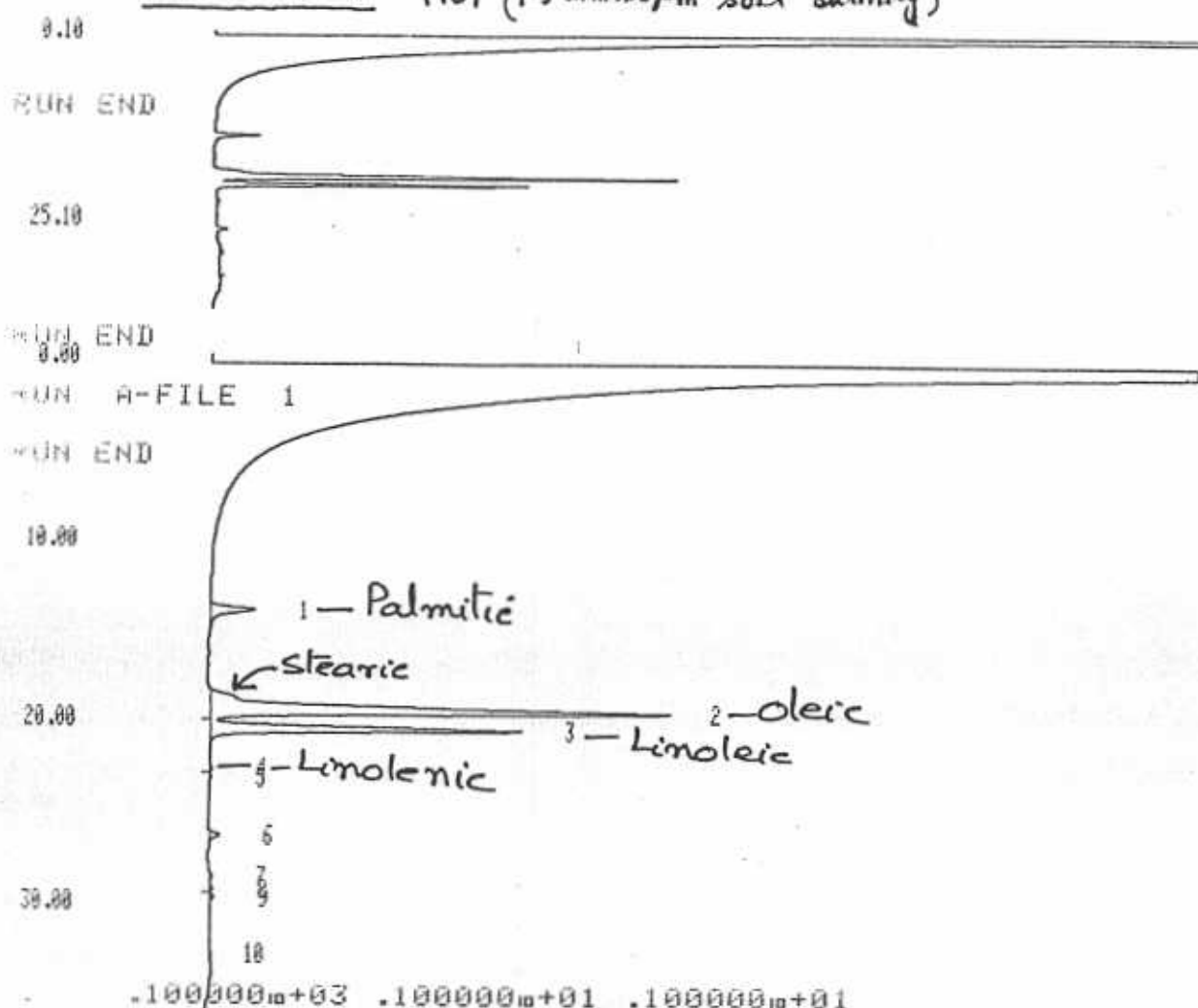
FIG. 27. FATTY ACID COMPOSITION OF SUNFLOWER SEEDS
 SAMPLE NO 4 HO1st 2.5 mmhes/cm EC of the soil.



NO. GND	NAME	RT	A OR H	MK	CONC
H OR H	MK		CONC		
		13.00	5		0.0000
		13.70	41140		6.1287 - C16:0 - Palmitic
3		15.91	76		0.0113
4		18.47	40099	M	5.9735 - C18:0 - Stearic
		19.14	237407	M	35.3668 - C18:1 - Oleic
		20.30	320574		47.7563 - C18:2 - Linoleic
		22.34	2680	M	0.3993 - C18:3 - Linolenic
8		22.64	69		0.0103
9		24.09	11		0.0017
10		25.97	11620		1.7311
		28.20	5877		0.8755
12		28.86	11671		1.7387
13		31.55	5		0.0007
14		33.38	27		0.0040
15		34.83	4		0.0005
TOTAL			671270		99.9999

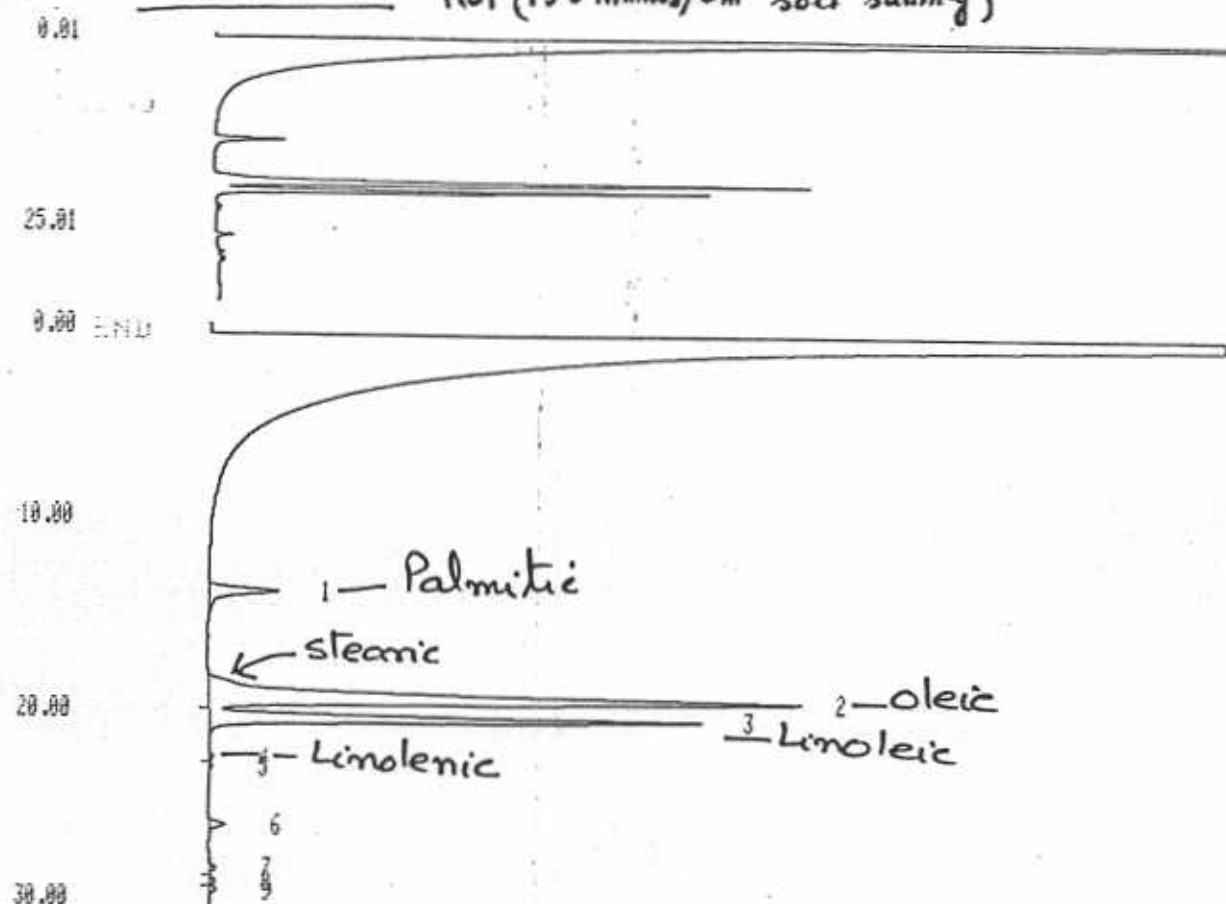
FIG. 28. FATTY ACID COMPOSITION OF SUNFLOWER SEEDS
 SAMPLE NO 5 HOI^{at} (7.5 mmhos/cm soil salinity)

14



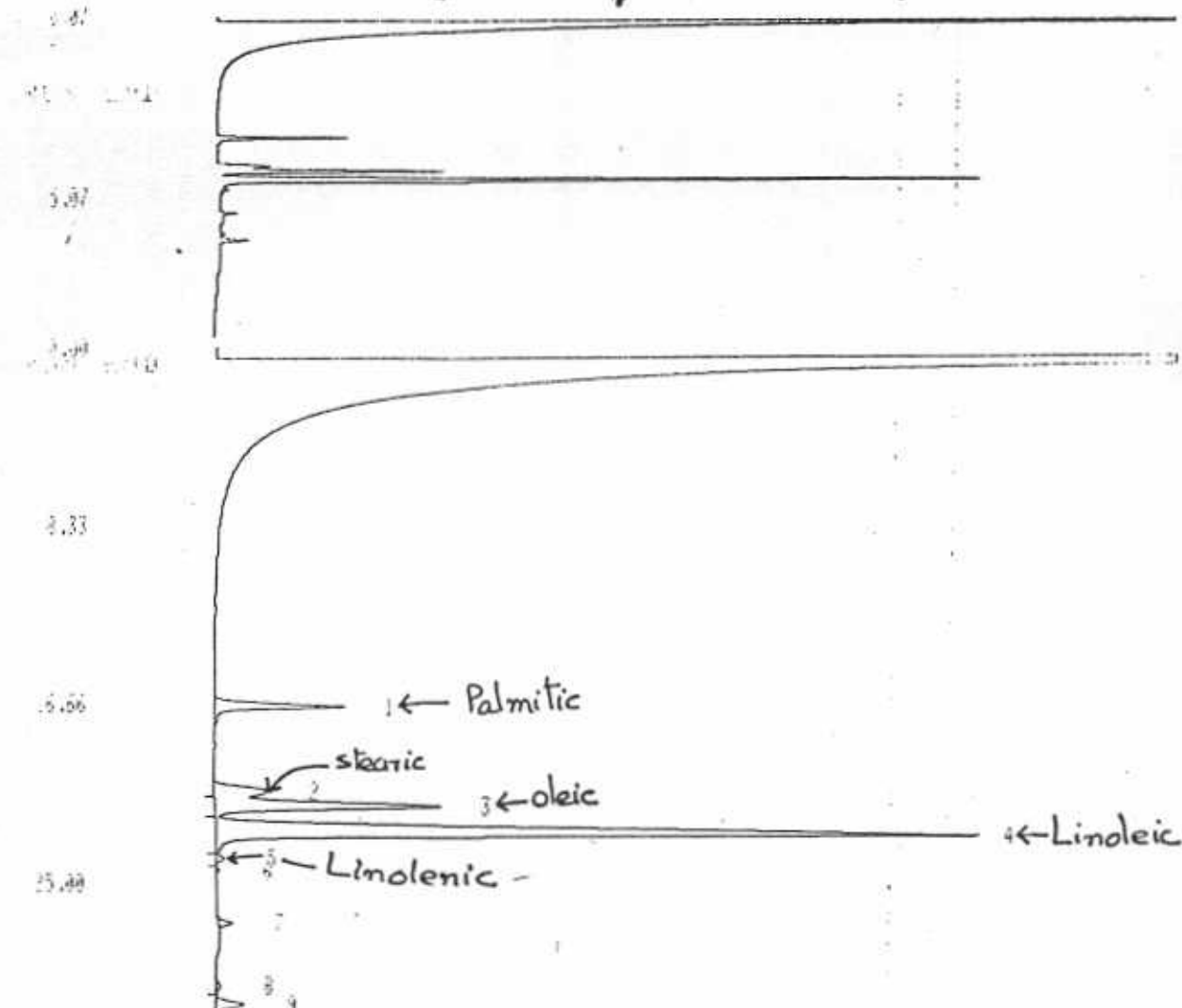
UN END	NAME	RT	A OR H	MK	CONC
1		14.13	34688		5.6626 - C16:0 Palmitic
2		19.69	374819	M	61.1866 - C18:0, C18:1 Stearic
3		20.65	188325		30.7428 - C18:2 - Linoleic
4		22.79	1896	M	0.3096 - C18:3 - Linolenic
5		23.30	1241		0.2026
6		26.42	6242		1.0190
7		28.65	1632		0.2665
8		29.32	1602	M	0.2615
9		29.77	2099		0.3427
10		32.85	34		0.0056
TOTAL			612583		99.9999

FIG. 29. FATTY ACID COMPOSITION OF SUNFLOWER SEEDS
 SAMPLE NO 6. HOI (15.0 mmhos/cm soil salinity)



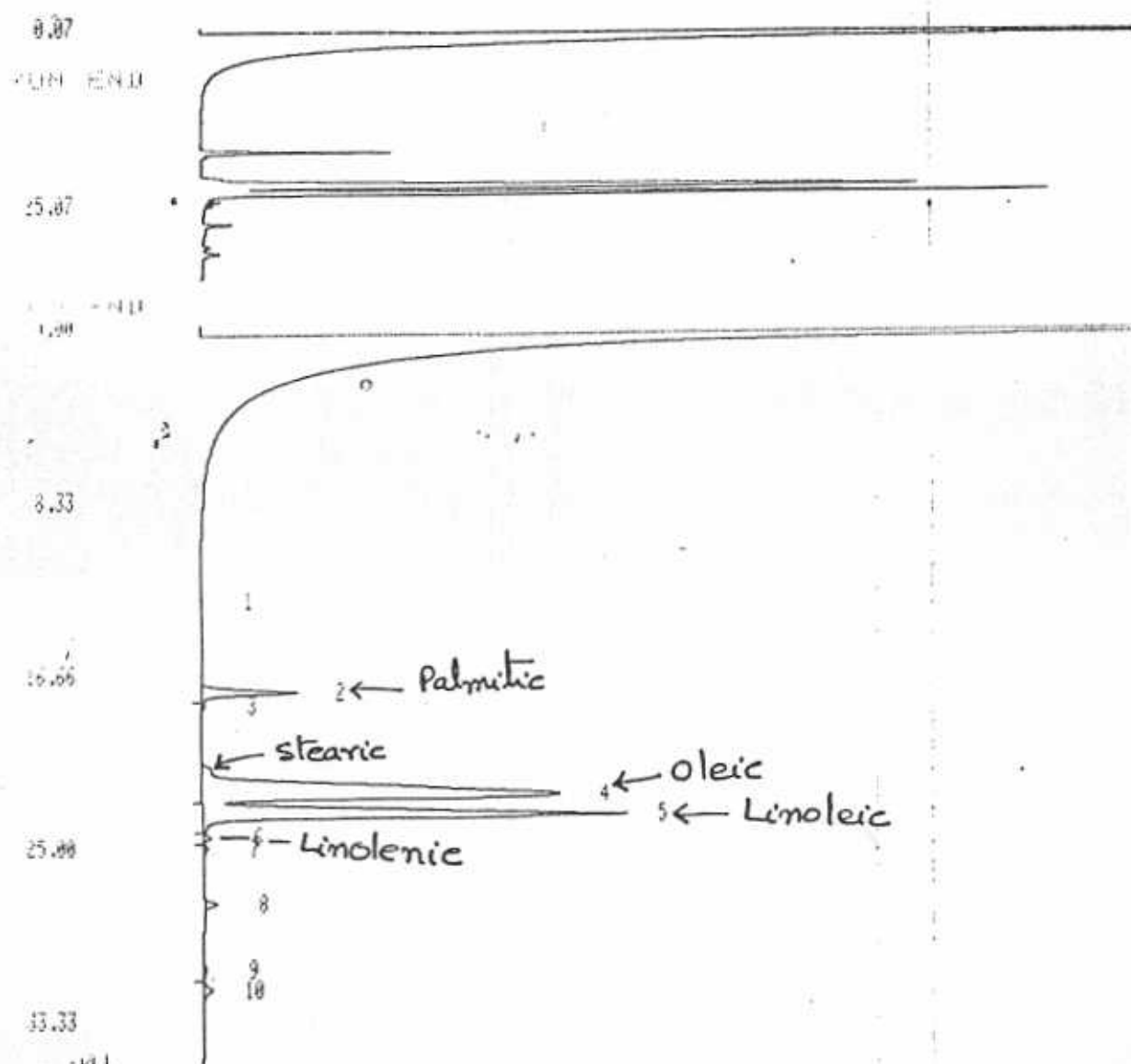
NAME	RT	A OR H	MK	CONC
RUN END	13.87	52992		5.7103 - C16:0 Palmitic
	19.62	532082	M	57.3356 - C18:0, C18:1 Stearic
	20.61	319578		34.4368 - C18:2 Linoleic
4	22.64	2736	M	0.2948 - C18:3 Linolenic
5	23.15	1962		0.2114
6	26.28	9056		0.9758
7	28.51	2967	M	0.3197
8	29.19	3022	M	0.3257
9	29.65	3615		0.3896
TOTAL		928012		99.9999

FIG. 30 FATTY ACID COMPOSITION OF SUNFLOWER SEEDS
SAMPLE NO. 100R⁹ (2.5 mmhos/cm soil salinity)



N03.33G	NAME	RT	A OR H	MK	CONC
1		16.82	69302		7.5361 - C16:0 → Palmitic
2		20.69	45942	M	4.9958 - C18:0 → Stearic
3		21.35	162820	M	17.7056 - C18:1 → oleic
4		22.69	602778	M	65.5480 - C18:2 → Linol
41.96		23.83	5366	M	0.5836 - C18:3 → Lino
5		24.40	1953		0.2124
7		26.96	7346		0.7988
RUN END		29.93	3249	M	0.3533
9		30.83	20838		2.2660
TOTAL			919097		99.9999
RUN END					

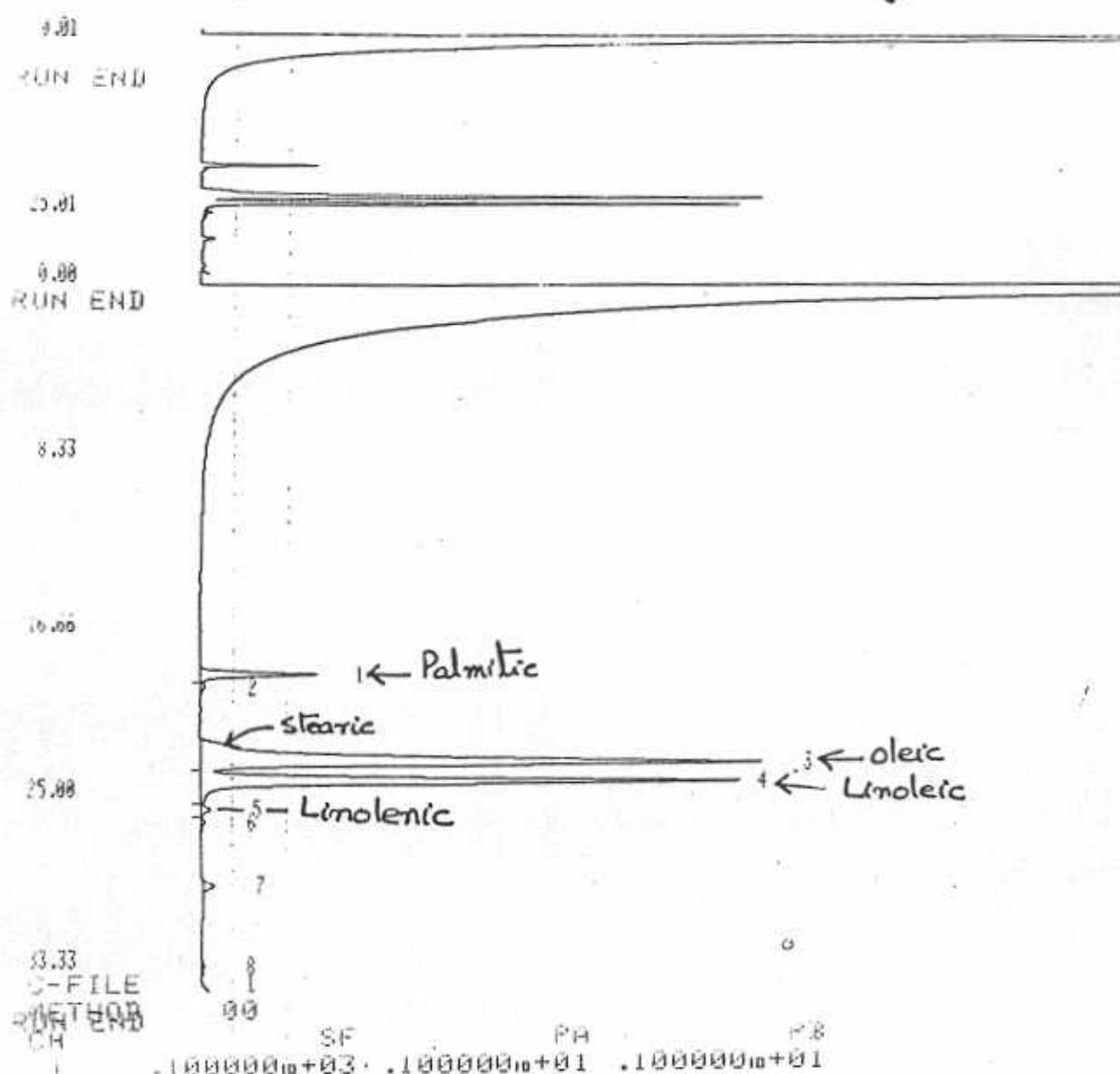
FIG. 3 FATTY ACID COMPOSITION OF SUNFLOWER SEEDS
SAMPLE NO NOOR (7.5 mmhos/cm soil salinity).



RUN END NO. 5	NAME	RT	A OR H	PK	CONC
1		13.15	648		~~0.8361~~ $C_{16:0}$ Palmitic
2		17.62	104427	M	5.8243 $\nearrow$
3		18.21	3451		~~0.1924~~
4		22.52	934220	M	52.1054 $C_{18:0}, C_{18:1}$ Stearic
5		23.55	703352	M	39.2289 $C_{18:2}$ Linoleic
6		24.55	8657	M	0.4828 $-$ Linolenic
7		25.11	4745		0.2646
8		27.79	15825		0.8826
9		30.97	4334	M	0.2417
10		31.94	13278		0.7405
TOTAL			1792941		99.9999

FIG. 32 FATTY ACID COMPOSITION OF SUNFLOWER SEEDS
SAMPLE NO (NOOR 15.00 mmhos/cm soil salinity).

15



NO.	NAME	RT	A OR H	NK	CONC
1		19.25	59234	M	6.4078 - ~~C18:0~~ → Palmitic
2		19.89	2479		~~0.2682~~
3		23.90	488289	M	52.8228 - C18:0, C18:1 + Stearic
4		24.83	355247	M	38.4304 - C18:2 → Linoleic
5		26.09	5993	M	0.6483 - C18:3 → Linolenic
6		26.70	2502		0.2707
7		29.83	8686		0.9396
8		33.75	1958		0.2118
TOTAL			924391		99.9999

DISCUSSION

In view of the increasing demand of edible oil, sunflower in addition to other crops, has recently been introduced in our country. Relatively little is known about the tolerance of this crop to different salinities prevailing in our soils.

Although the Staff at the U.S. salinity Laboratory (1954), Bowling and Ansari (1971) and some Russian Scientists, Asaliev (1977) and Strogonov (1964) have categorized the salt tolerance of sunflower as medium, decreased yield occurs with late planting as found by Shari Nazir et al. (1986).

The stage of growth at which sunflower plant is subjected to a salinity stress was found to be an important factor in determining the final response of that plant to the stress of different salts in different concentrations. Many crops seem to be particularly sensitive to salts during the germination stage (Ayers & Hayward, 1948) and yet are quite salt tolerant during the later part of the growth cycle, while the opposite was proved true by Francois et al. (1984). Observations were, therefore, recorded on the effects of different levels and types of salinization on seed germination, salt uptake from the soil and different yield components of sunflower plant. Besides, studies were also made on the transplantation of sunflower at various stages of growth. It is known that most of the crop plants fail to germinate satisfactorily on saline soil. Information about the effects of different individual

salts and their mode of action on germinating seeds of sunflower is scanty at present. The issue is controversial and different authors have different explanations for the inhibitory effects of salts on germinating seeds. According to Kaho (1934), the toxicity of salts to germinating seeds was directly correlated to their permeability. Novikov (1942) is of the opinion that the failure of seeds to germinate in saline solutions resulted from the fact that the osmotic pressure of the solution was higher than that of the cells, and therefore the seeds could not absorb all the water required for their germination. While Sergeev (1953) claimed that the toxic effect of salts on germinating seeds resulted from the disturbances of enzymatic reactions.

At zero salt concentration in petri dishes, all the three cultivars, viz. Shams, Noor and H01 of sunflower exhibited 100% germination after 7 days of sowing. In the control treatment (2.5 mmhos/cm) in the pots, however, minor differences in percent emergence were observed among these cultivars on the 9th day of their sowing. Increasing salinization due to single salts, as well as their mixture, delayed germination and reduced the final emergence accordingly, but to different degrees. Such differences in percent and rate of emergence were commonly observed in seeds of other crops and likely due to inherited factors and not to differences in seed quality (Thornberry and Smith, 1955). Seeds subjected to the lower

salinities of 2.5, 5.0, 7.5 and 10.0 mmhos/cm levels of all the salts generally exhibited more than 50% germination. However, H01 showed susceptibility to NaCl and $MgCl_2$ even at 10.0 mmhos/cm level where their germination was 39 and 43% respectively. Salinities above 10.0 mmhos/cm caused more than 50% decrement in all the cultivars of sunflower. This may have been due to combined effects of osmotic pressure and toxicity of the salt (Bornstein, 1958, Uhvits and Rachel, 1946). Some salts at higher salinity levels, however, had greater inhibitory effects than others on the germinating seeds. At 15.0 mmhos/cm level, for instance, the greatest reduction in germination occurred in $MgCl_2$ treated seeds; the germination was only 15% in Noor and 20% both in Shams and H01. While at the same EC value some resistance was shown towards Na_2SO_4 and the germination was 41% in Noor and 45% both in Shams and H01. With increasing concentrations of the salts in pots (having salinized soil), almost the same trend of decreased rate and percent emergence was observed in all the cultivars of sunflower. The same results were also reported by Ghorashy and Kheradnam (1972), Ogasa (1939), Rudolfs (1921), Abel and Mackenzie (1964), Karami (1974), Arunsiri Kumlung (1983) and Jadhav (1985). At the same highest salinity level, the responses of these cultivars were quite pronounced to individual and mixture salts. Cultivars Noor and H01 showed the greatest susceptibility to NaCl and only 19% and 25% seeds germinated respectively, while the lowest emergence

of 23.5% was observed in Shams in the soil treated with mixture salts. Again, Na_2SO_4 showed the least inhibitory effects on sunflower germination. The lower toxic effect of Na_2SO_4 compared to NaCl at the same concentrations on crop plants is well illustrated by the works of Tulaikov (1912) and Novikov (1942). Working with barley varieties, Ayers et al. (1952) found a good correlation between seed emergence in salinized soil and later growth. The same results were reported for sunflower by Francois and Bernstein (1964)^{and}/Karami (1974). Ayers and Hayward (1948) are of the opinion that salt tolerance during seed germination is not always positively correlated with that of the crop during later stages of growth. Further studies were, therefore, carried out on radicle length of sunflower seeds germinating in single and mixture salts.

Radicle and plumule length decreased almost linearly with increasing electrical conductivity of the salt solution from 0.0 to 15.0 mmhos/cm. At high concentrations, the specific response of different salts was quite marked. Magnesium-chloride proved to be more toxic for germinating seeds. Although the seeds germinated in the highest concentration of the salt, their plumules and radicles became dehydrated and died eventually. On the other hand, Na_2SO_4 was found less toxic to the developing plumules and radicles. Other salts, viz: NaCl , CaCl_2 and mixture salts showed intermediate effects on these growth parameters.

The reducing effect of increasing concentrations of salts on the radicle and plumule length of seeds is in agreement with the work of Durrant et al. (1974). Similarly, with increasing concentrations of the salts in the soil, plant height was affected in all the 3 cultivars tested. However, at lower levels of electrical conductivity (5.0 mmhos/cm), Na_2SO_4 and CaCl_2 had ameliorative effect on plant growth. Above 5.0 mmhos/cm level, these two salts, like NaCl and MgCl_2 and mixture salts, impeded the normal growth of all the plants tested. Nevertheless, at the highest EC value, these salts affected plant growth quite differently. According to the adverse effect on plant height, these salts were found in the order of $\text{Na}_2\text{SO}_4 > \text{CaCl}_2 > \text{Mixture salts} > \text{MgCl}_2 > \text{NaCl}$.

Transplanting sunflower at the cotyledonary and primary leaf stage in the new soil salinized by mixture salts showed reducing effect on the plant height. Plants transplanted at the cotyledonary leaf stage were not as severely affected as they were in direct germination in the same soil. In fact, at the highest salinization regime plant height was inhibited not more than 50%. When the seedlings at the primary leaf stage were transplanted to saline soil, plant height decreased with each increment of salinity level. Contrary to the cotyledonary stage, transplantation at the primary leaf stage showed unsatisfactory plant growth. At the highest EC value there was more than three times reduction in height of H01 and four times in Shams and Noor as compared with control treatment.

Sunflower plant showed differential responses in flower diameter when different salts were added to the soil. Increasing increments of individual and mixture salts in the soil reduced the flower diameter accordingly. However, the inhibition was more pronounced in $MgCl_2$ and Na Cl treated plants than those growing in soil salinized with other salts. At the highest salinization regime these two salts completely suppressed flower formation. Sodium sulphate, however, was found less toxic to the formation of flowers in this plant. Flowers harvested from plants which were transplanted at the cotyledonary stage, were not as much reduced as they were in plants transplanted at the primary leaf stage or in direct sowing plants.

The retarded growth in stem and flower may have been caused by the direct effect of excess salts on plant tissues and more possibly by the unavailability of adequate water from the salinized soil for normal functioning of the plant body. The decreased growth in different plant parts, with increasing increments of salts in the substrate has also been reported by Lessani and Marschner (1978), Karami (1974), Chabra *et al.* (1978), Francois and Bernstein (1964), Abel and Mackenzie (1964), Ayers *et al.* (1952), Asaliev (1976), Charsalli and Cherif (1979) and Nand Kishore (1985). Blooming and maturity in sunflower cultivars growing in saline soil generally reached earlier than those on non-saline soil. However, different salts had different effects on these parameters on the plant. At the highest salinity, sunflower bloomed 4 days earlier in NaCl treated soil,

9 days earlier each in MgCl_2 and Na_2SO_4 and 10 days earlier in CaCl_2 and mixture salts. Similarly, maturity was enhanced by 16 days each in CaCl_2 and Na_2SO_4 , 17 days in mixture salts and 20 days each in NaCl and MgCl_2 series. In order to avoid unfavourable climatic and soil conditions, plants have to shorten their life cycle, which is a natural phenomenon. High salinity, in this case, was also found to be an abnormal condition for sunflower plant which resulted in early blooming and maturity of its flowers. These findings of early blooming and maturity in sunflower plant are in agreement with the results of Asaliev (1976). With the exception of its blooming, Chabra *et al.* (1978) also found a reduction in maturity time of sunflower on saline soils. Early blooming and maturity on such soils have also been demonstrated for safflower by Francois and Bernstein (1964).

High concentrations of all the salts tested, caused depressions in dry matter production of seed, stem, leaf and total above ground parts in the three cultivars of sunflower. Although a significant negative relationship between salinity levels and dry matter yield of various plant parts was observed, not all the cultivars were affected by different salts equally. At the highest level of salinity, NaCl and MgCl_2 were found toxic to the development of seed in sunflower plant, whereas some yield was recorded in mixture salts, Na_2SO_4 and CaCl_2 series. With regard to the seed yield and above ground parts, H01 showed comparatively better performance than Shams and Noor. The

decreased yield of sunflower plant parts could be due to the retarded photosynthesis resulting from high salinity in the soil. The decreased photosynthesis in glycophytic plants in proportion to salt concentration has been reported by Gale and Poljakoff-Mayber (1970), Hoffman and Phene (1971), Ahmad et al. (1979). The results of decreased yield components of sunflower on saline soil are in agreement with those of Shuang Cheng (1983), Chabra et al. (1978), Yermanos et al. (1964), Asliev (1976), Abel and Mackenzie (1964), Francois and Bernstein (1964), Ayers et al. (1952), Hassan et al. (1970), Reikal (1977), Ahmad et al. (1978), Lessani and Marschner (1978), Chavan and Karadge (1980), Arunsiri Kumlung (1983), Francois et al. (1984), Nand Kishore (1985) and Patricio (1984).

The mineral composition of the leaf and stem of sunflower plant indicated as to what extent ion accumulation and ion imbalance might be involved. The uptake of Na increased in these parts in all the test cultivars with increasing intensities of salinization in the growth medium. However, the rate of Na accumulation was higher in the stem than the leaf.

Increased concentration of Na in the plant parts apparently resulted from the high availability of this element in saline soil. The dominant increase in the value of Na is usually associated with a decrease in yield components of the plant. The significant increase in the content of Na observed within the 3 cultivars after being salinized, was

generally in accordance with the results obtained previously by Shuang Cheng (1983), Heikal (1977), Chabra et al. (1978), Bhat and Indirakutty (1973), Lessani and Marschner (1978) using sunflower, Lunin et al. (1964) working with vegetable crops, Abdullah and Ahmad (1981) experimenting with potato and El-Shourbagy and Missak (1975) testing with 3 varieties of castor bean. Francois and Bernstein (1964), Muhammad Rashid (1983), Patricio (1984) and Dedeck and Peacock (1985) were also of the opinion that increasing salinity in the soil caused Na increase in the tissues of safflower, rice and Paspalum turfgrass. According to Hayward and Wadleigh (1949) and Bernstein (1962), a more tolerant plant to high levels of Na was that which normally accumulated considerable amounts of Na, whereas the more sensitive one was that which tended to exclude Na.

Positive correlation between increasing salinity in the soil and Ca content in the leaf and stem of sunflower was found during the present investigations. The high uptake and accumulation of Ca in the plant tissue may be due to the high concentration and availability of this element in saline soils. Francois and Bernstein (1964) with sunflower leaves, Asana and Kale (1965) with four varieties of wheat, George (1967) with some cereal crops, Heikal (1977) with safflower and sunflower and Muhammad Rashid (1983) with rice indicated that Ca content appreciably increased with increasing salinity.

The increase in Ca content was associated with a decrease in Mg content and this may be due to high levels of Ca in the saline nutrient solution. Radi et al. (1973) stated that the high Ca levels resulted in high Ca absorption and was generally associated with low power of Mg absorption by tomato, maize and sunflower plants. The percentual change of Mg between normal (2.5 mmhos/cm) and 15.0 mmhos/cm for both the leaf and stem was about 50% and this significant decrease is in agreement with the results obtained by Ramzan (1967) with rye seedlings, Lashin and Atanaziue (1972) with cotton, Chyong et al. (1973) with leaves of sunflower, maize and bean, El-Shourbagy and Missak (1975) with three varieties of Castor bean plants, Heikal (1977) with sunflower, safflower, wheat and raddish, Chabra et al (1978) with sunflower, Francois and Bernstein (1964) with safflower, Pakroo and Kashirad(1981) with sunflower and Dedeck and Peacock (1985) with turfgrass.

The decrease in Mg content in leaf and stem of sunflower in relation to high salinity in the soil may be explained in the context of the opinion of Long (1943), who stated that salt in the culture solution in contact with membranes of absorbing root cells and/or accumulated salt within the plant may produce deleterious effects on the protoplasm directly. One result of such injury is the reduced nutrient intake. Also, the changes in some cation concentrations could be a means of osmotic adjustments (Bernstein, 1961).

With increasing salinity, the concentrations of K in the leaf and stem at maturity decreased. But the decrease was more pronounced in leaf than in stem; at the highest salinity the depression was about 3 times in the leaf and $2\frac{1}{2}$ times in stem as compared with control treatment. This drastic effect was also reported by Heikal (1977) with sunflower, Francois and Bernstein (1964) with safflower, Kaddah and Ghowail (1964) with maize, Bierhueizen and Phloegman (1967) and Rush and Epstein (1976) with tomato leaves, Mehrotra (1971) with some agricultural crops, Hassan et al. (1970) with corn, Nimbalker and Joshi (1975) with sugarcane, Paricha et al. (1975), Muhammad Rashid (1983) and Patricio (1984) with rice and Shuang Cheng (1983) with sunflower. The reduction in K content may be due to the high concentration of Ca in the soil, as reported by Allison (1964), who reviewed that high concentration of Ca may restrict the uptake of K by beans and some carrot varieties.

The amount of N in the leaf and stem of sunflower was found positively correlated with increasing EC value of the substrate. Marked increase in N percentage of different plant parts with increasing salt concentration in the soil was also investigated by Shuang Cheng (1983) and Heikal (1977) with sunflower and safflower and Muhammad Rashid (1983) and Patricio (1984) with rice. Bernstein (1962) and Ansari (1972) have reported increase in N content of plants at high levels of NaCl and Chen et al. (1964) demonstrated that total N increased



in the aerial parts of Citrus seedlings due to translocation from roots. The possibility of increasing N concentrations may be due to salinity restricting plant growth, thus increasing N concentration in plant tissue. Selassie and Wagnet (1981) also proposed that the drastic reduction in plant population under highly saline condition resulted in a greater nutrient supply per plant per unit area.

In general, the uptake and concentration of P in the leaves and stems of sunflower decreased with increasing salinity but the depression was more in the stem than the leaf. The decreases in the uptake of P with increasing EC value in the soil have been reported by Shuang Cheng (1983) with sunflower, Fine and Carson (1954) with small grains, Khalil et al. (1967) and Hassan et al. (1970) with barley and corn, Zhukovskaya (1962) with tomato, Taha et al. (1972) with grapes, guava and Olive plants, Amirova et al. (1975) with rice, Sharma and Lal (1975) with wheat and Arunsiri Kumlung (1983) experimenting with soybean. The decreased P concentration may be due to the negative effect of Cl in saline soil (Pakroo and Kashirad, 1981). Since P is not highly mobile in soil, the depression in uptake of P may have been related to a reduction in root growth caused by soil salinity and an associated decrease in the surface area of roots in contact with P in the soil (Pakroo and Kashirad, 1981; Khalil et al., 1967; Ruf et al., 1963; and Hassan et al., 1970).

A highly significant positive relationship existed between soil salinity and Cl concentration in the plant parts tested. For most plants the internal concentrations of Cl closely reflects the external concentration. Gauch and Wadleigh (1945) reported that there was a linear relationship with a relatively steep slope between the concentration of Cl in root media and in the bean leaves. Similar positive relationship between Cl content in the plant body and the external substrate has been demonstrated by Bernstein (1964) with several crops, Abel and Mackenzie (1964) with soybean, Francois and Bernstein (1964) with safflower, Lessani and Marschner (1978) with various crop species, Mengel and Kirby (1979) and Shuang Cheng (1983) with sunflower, Muhammad Rashid (1983) and Patricio (1984) with rice and Dedeck and Peacock (1985) with turfgrass. In saline soils, Cl can accumulate to high concentration in plants. This ion is particularly effective in osmotic adjustment if it does not have a direct toxic effect on the plants (Mengel and Kirby, 1979). The relatively high uptake and concentration of Cl in the plant body could be directly or indirectly responsible for growth depression, either by depressing the uptake of other anions such as nitrate (Bernal et al., 1974) or by direct osmotic effects of high local concentrations particularly on the leaf margins (Bingham et al., 1968). High Cl concentrations in the shoot, however, are not damaging for crop plants as have been shown in salt-tolerant tomato varieties (Tal, 1971). High tolerance of

the cells for Cl is perhaps caused by a particular compartmentation within the cells (Flowers, 1972). Maas and Hoffman (1977) also stated that most herbaceous plants did not exhibit leaf injury symptoms even though some accumulated Cl to levels as high as those causing injury in weedy species.

The uptake of S by sunflower plant and its accumulation in the leaf and stem at the time of maturity decreased as a linear function of salinity which is in agreement with the findings of Shuang Cheng (1983) working with sunflower, Gauch and Wadleigh (1945) with bean plants and Shevyakova (1973) with cotton. The significant decrease of S in the plant body with increasing EC value of the soil solution may be attributed to the negative effect of Cl on S.

The moisture percentage in the seeds of sunflower cultivars decreased significantly with rising salinity in the soil. A similar decrease in the moisture percentage of the seeds in relation to increasing electrical conductivity of the soil was found by Asaliev (1976), Prokoflov, and Khalodov (1967) quoted by Asaliev (1976) with sunflower seed and Hassan et al. (1970) with barley grains. The decreased water content with regard to added salts in the soil has also been investigated in other plant tissues. For instance, Heikal (1977) demonstrated marked decrease in the leaf water content of sunflower and Meiri et al. (1971) observed a remarkable decrease in water content in chloride salinated bean plants and also Wilson et al.

(1970) in the young leaf tissue of Glycine spp. during salt treatment. The reduction in water content of sunflower and safflower is associated with a decrease in dry matter content and this is due to a real reduction in the rate of water uptake, as was measured directly by Hayward and Spurr (1943) for corn under saline treatment. Also, Janes (1966) noted a reduction in water absorption with increasing osmotic pressure of the soil solution.

Calculation performed for the oil content in sunflower seed showed that on account of the increase in the level of salinity of the soil, a regular decrease in oil formation in the seeds of all the test cultivars took place. Similar decrease in the oil concentration with increasing salinity has been observed by Asaliev (1976), Muhammad and Makhdum (1973)/^{and} Shuang Cheng (1983) working with sunflower and Abel and Mackenzie (1964) with safflower. The decreased oil content in the seeds of plants growing on such soils could be due to the hastening of flower maturity which resulted in a short period and thus the process of the oil formation was completed earlier than the full maturation of the seeds.

Fatty acid composition of the oil of sunflower seeds in different cultivars revealed insignificant relationship with rising salinity in the soil. Nevertheless a changing pattern of these acids was followed in some of the cultivars tested. Increasing salinity caused palmitic acid to decrease in Shams

but H01 and Noor were unaffected. Stearic and Oleic acids were increased at the expense of Linoleic acid in Shams and Noor while H01 was unaffected. The effect of salinity on linolenic acid was also insignificant. The insignificant effect of increasing electrical conductivity of the salts on the oil composition of sunflower seed is in agreement with the findings of Yermanos et al., 1964, Werkhoven et al., 1966 and Makhdum, 1973.

SUMMARY AND CONCLUSIONS

Oke
 Sunflower cultivars were put to test the various growth parameters and yield components under saline conditions produced artificially in petri plates in the laboratory and glazed pots in the open atmosphere. Increasing salinity of the salts of NaCl , CaCl_2 , MgCl_2 , Na_2SO_4 and their mixture affected germination of all the cultivars in petri plates and pots but to different degrees. The germination was delayed by 7 days in petri plates and about 10 days in the pots. Final emergence, plumule length and radicle length were depressed most with NaCl and MgCl_2 and the least with Na_2SO_4 ; mixture salts had intermediate effect. Similarly plant height and flower diameter was reduced with each increment of the salts. However, plants were not affected with CaCl_2 and Na_2SO_4 upto 5.0 mmhos/cm salinity. Transplanting plants at the cotyledonary stage into the saline medium were not as stunted as were the plants at primary leaf stage. Flower diameter got reduced according to the intensity of the salts in the soil and the effect was more pronounced in NaCl , CaCl_2 and MgCl_2 salinity than Na_2SO_4 or mixture salts.

Blooming and maturity in sunflower cultivars growing on saline soil generally reached earlier than those on nonsaline soil. At the highest level of salinity plants bloomed 4-10 days earlier on such soils. Earlier maturity resulted in decrement of the dry matter production of the stem, leaf, seed and oil of this plant

More drastic reduction in the yield components occurred with NaCl and $MgCl_2$ than the other salts in the soil. With regard to these parameters H01 showed comparatively better performance than Shams and Noor.

Increasing electrical conductivity of the soil solutions also affected the uptake and accumulation of various elements in the aerial portions of this plant. In general, the concentrations of Na^+ , Ca^{++} , N and Cl^- in the leaf and stem were increased, but to different degrees. On the other hand, the increase in these elements was associated with a decrease in the contents of Mg, K, P and S in different cultivars of this plant.

The effect of salinity on refractive index, specific gravity, acid value, iodine value and saponification value of the oil of sunflower seed was not significant. Palmitic, stearic, oleic, linolenic and linoleic acids of the oil, although changed with rising salinity, but the effect was not significant in all the cultivars tested.

From the results it can be concluded that sunflower is a moderately tolerant plant to salinity (below 7.5 mmhos/cm) without appreciably losing its yield components. It is, therefore, suggested that large areas of Pakistan which are in the process of salinization and which are lying just barren may be covered with this crop economically.

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Climatic Data for the year 1992

Months	Temperature		Humidity	Rainfall (mm)
	Maxi.	Mini.		
January	63.3 F ^o 17.7 C ^o	36.7 F ^o 2.6 C ^o	82.1	39.35
Feb.	61.4 F ^o 16.3 C ^o	40.9 F ^o 4.9 F ^o	76	23.86
March	67.0 F ^o 19.4 C ^o	50.00 F ^o 10.0 C ^o	80	92.19
April.	82.0 F ^o 27.8 C ^o	58.0 F ^o 14.4 C ^o	72	16.00
May	91.1 F ^o 22.8 C ^o	66.5 F ^o 19.2 C ^o	69.8	5.59
June	106.1 F ^o 41.2 C ^o	77.7 F ^o 27.4 C ^o	84.3	0.00
July	100.3 F ^o 37.9 F ^o	77.4 F ^o 25.2 C ^o	76.0	10.9
Aug.	90.0 F ^o 32.2 C ^o	74.5 F ^o 33.6 C ^o	89.0	123.9
Oct.	85.9 F ^o 30.0 C ^o	58.4 F ^o 14.7 C ^o	00.00	4.27
Sept.	92.2 F ^o 33.4 C ^o	67.5 F ^o 19.7 C ^o	73.6	9.14
Nov.	75.1 F ^o 23.9 C ^o	46.0 F ^o 7.8 C ^o	63.0	55.12
Dec.	15.0C ^o	4.1 C ^o	75.6	22.96

Data for the year, 1993				
Months.	Temperature.		Humidity.	Ranfall (mm)
	Maxi.	Mini.		
Jan.	62.2 F ^o 16.3 C ^o	35.7 F ^o 2.1 C ^o	63	37.6
Feb.	66.08 F ^o 18.9 C ^o	39.17 F ^o 3.9 C ^o	65.	38.61
March.	68.11 F ^o 20.1 C ^o	42.48 F ^o 5.8 C ^o	62.3	70.37
April	76.16 F ^o 24.5 C ^o	12.2 F ^o	68	178.37
June	99.68 F ^o 37.3 C ^o	71.32 F ^o 22.2 C ^o	50	10.16
May.	91.65 F ^o 33.0 C ^o	67.77 F ^o 19.9 C ^o	46	17.52
July.			69.86	43.69
Aug.	96.0 F ^o	71.83 F ^o		18.90
Sept.	94.6 F ^o	71.45 F ^o	71.71	1.02
Oct.	90.4 F ^o	56.96 F ^o	63.18	4.35
Nov.	77.68 F ^o 25.4 C ^o	42.68 F ^o 23.7 C ^o	63.6	13.72
Dec.	66.57 F ^o 19.2 C ^o	34.57 F ^o 1.4 C ^o	67.5	0

Climatic Data for the year 1994

Months	Temperature		Humidity	Rainfall (mm)
	Maxi.	Mini		
January	66.11 F ^o 19.9 C ^o	32.2 F ^o 0.1 C ^o	69.1	3.56
February	67.04 F ^o 19.5 C ^o	33.56 F ^o 0.9 C ^o	71.0	19.05
March	70.5 F ^o 21.5 C ^o	45.8 F ^o 7.8 C ^o	56.0	70.97
April	90.9 F ^o 32.7 C ^o	54.2 F ^o 12.3 C ^o	64.9	33.62
May	92.66 F ^o	65.33 F ^o	40.00	0.00
June	103.90 F ^o	75.90 F ^o	62.36	3.55
July	113.33 F ^o	77.11 F ^o	54.36	82.16
August	94.3 F ^o	77.55 F ^o	54.55	12.11.
September	94.00 F ^o	70.99 F ^o	74.68	12.5
October	84.73 F ^o	54.91 F ^o	49.52	10.4
November	82.23 F ^o	44.66 F ^o	79.09	2.79
December	65.9 F ^o	33.15 F ^o	92.25	92.25

Climatic Data for the year 1985

Months	Temperature		Humidity	Rainfall (mm)
	Maxi.	Mini		
January	63.4 F° 17.44 C°	37.3 19.65 F°	89.0	25.4
February	68.22 F° 36.22 C°	41.0 F° 5.0 C°	86.5	7.5
March	78.76 F° 25.97 C°	49.8 F° 9.88 C°	89.44	14.81
April	94.15 F° 28.97 C°	60.92 F° 16.06 C°	61.96	16. mm
May	95.56 F° 35.31 C°	67.48 F° 19.71 C°	31.84	28.96
June	104.0 F° 40.00 C°	73.5 F° 23.06 C°	28.8	0.00
July	93.92 F° 34.4 C°	78.14 F° 25.63 C°	71.92	15.24
August	92.0 F° 33.33 C°	76.31 F° 24.62 C°	76.77	52.04
September	92.52 F° 33.62 C°	71.32 F° 22.12 C°	65.0	5.08
October	84.61 F°	56.07 F°	58.57	5.08
November	77.13 F° 25.07 C°	46.13 F° 7.85 C°	73.95	18.12
December	63.8 °F 17.7 °C	~~64.4 °F~~ 36.7 °F 2.6 °C	~~89.44~~ 82.1	39.35