STUDIES ON SALT TOLERANCE IN TUBEROSE (*Polianthes tuberosa* L.) cvs. SINGLE AND DOUBLE

BY

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Thesis submitted to the CCS Haryana Agricultural University in partial fulfilment of the requirements for the degree of :

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IN

HORTICULTURE

College of Agriculture
CCS Haryana Agricultural University, Hisar

1993

DEDICATED

TO MY

BELOVED AND REVERED PARENTS

CERTIFICATE I

This is to certify that this thesis entitled "Studies on salt tolerance in tuberose (Polianthes tuberosa L.) cvs. Single and Double" submitted for the degree of M.Sc., in the subject of Horticulture to the CCS Haryana Agricultural University, Hisar is a bonafide research work carried out by Mr. Virender Singh under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

(A. K. GUPTA) 28/7/93
Major Advisor

CERTIFICATE II

This is to certify that this thesis entitled "Studies on salt tolerance in tuberose (*Polianthes tuberosa* L.) cvs. Single and Double" submitted by Mr. Virender Singh to the CCS Haryana Agricultural University, Hisar in partial fulfilment of the requirements for the degree of M.Sc., in the subject of Horticulture has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

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CHAPTER 1

INTRODUCTION

Tuberose (Polianthes tuberosa) is occupying an important position among the cut flower due to its attractive spikes sweet fragrance and high economic value. Its flowers are not only used for extraction of the valuable natural aromatic oil need for the high cost perfume industry but also for making garlands and decoration of table. Tuberose is believed to have originated in Mexico. The name tuberose is derived from 'tuberosa' as this plant being tuberous hyacinth as distinguished from bulbous hyacinth.

Tuberose belongs to the family Amarlyllidaceae. It is estimated that in India it is cultivated in about 20,000 ha and its cultivation is mainly concentrated in the States like in Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra and West Bengal on commercial scale.

It is also grown in Northern States like in Uttar Pradesh, Haryana, Punjab and Rajasthan on small scale. Due to its importance and popularity the demand of flower is increasing day by day. The contribution of Haryana State in the production of this flower is very less because of the presence of sodium salts in toxic limit in the cultivable soil.

It is estimated that in India there is about ~~8~~ 7.044 million ha of salt affected soil at different stage of degradation (Mangal and Singh, 1992). However, the extent of salinity is varying from State to State and incidence is .(in Punjab 16.688, Delhi .016, Haryana .526, West Bengal .850, Gujarat 1.214 and Uttar Pradesh 1.295 m.ha. When the crops are grown on such soil the growth is stunted and flowering and fruiting is reduced. The tolerance to salinity is usually appraised in one of the 3 ways.

1. The ability of the plant to survive in saline condition.
2. The absolute plant growth and yield.
3. The relative growth or yield on saline soil as compared to non saline soil.

The exploitation of the ornamental crop on saline soil has not been made and, therefore, it is not known at upto what salinity level this crop can be grown successfully. Therefore, efforts were made in the present study to identify the comparative tolerance to two commercially grown variety under different salinity level and to find out the physiological basis of salinity tolerance with the following objectives:

1. To study the salt tolerance capacity and to find out nutritional imbalance caused by salinity.
2. To study the effect of various levels of salinity on growth, flowering, physiological and biochemical changes in the plant.

CHAPTER 2

REVIEW OF LITERATURE

The research informations about salt tolerance in ornamental plants in general and seasonal flowers are very scanty. Hence, it was thought worthwhile to review the work done on some other crops similar to garden annuals in nature. The available literature regarding effect of salt stress on plant growth, development and metabolism have been reviewed giving main emphasis on the topic closely related to the subject of present study. Loughridge (1901) was one of the earliest workers who pointed out that different plant species were able to tolerate different salt concentrations. Since then a great deal of research has been conducted and extensively reviewed by many workers (Levitt, 1972; Mass and Haffman, 1977 and Mangal et al., 1989). Salinity tolerance of seasonal flower has received attention in the recent past by Ishida et al. (1978, 1979), Sonnevold and Voigt (1983, 1988) and Sharma and Yamdagni (1989). The work done on salinity tolerance in various crops is reviewed under the following heads:

Physiological basis of salt tolerance

Different views have been putforth to explain the detrimental effects of salts on plant growth. One school of thoughts is of the opinion that reduced growth of plants under saline conditions is caused by osmotic inhibition of water absorption, toxic effect of ion, nutritional imbalance, production of toxic substances within the plant and many other all effects on plant metabolism. According to water relation theory given by Daniels and Russel (1957) it was reported that due to increased osmotic pressure of soil solution, availability of water is decreased. Phillips (1958) felt that "physiological drought" developed under saline media when solution could not penetrate into the cells and only salt entered into the cell, causing an increase osmotic pressure and increased water uptake. Inhibition of plant growth under such conditions is explained by him as being direct toxic effect of salts.

The penetration of both nutritional and non-nutritional salt into plant is mainly limited to roots under saline conditions. However, the permeability of root tissues to regulate the salt tolerance of plant is maintained upto a certain level, beyond which a sort of salt brust occur therefore causing poisoning and ultimately death of the plant. Stroganov (1962) demonstrated that salt poisoning was a result of accumulation of toxic intermediates i.e. accumulation of nitrogenous substances like ammonia and H_2O_2. O'Leary (1971) suggested that resistance of roots to water flow increases in plants grown in salt solution. Pan (1985) found decrease in fresh shoot and root weight when it was grown in nutrient solution with increase in salinity level. Smirnori (1985) experimented on one and two year seedling of Rosa beggeriana to determine salt resistance and found that there was a close relation between height and salt concentration and between seedling dimension and concentration of chloride ions and of SO_4 ion. In irrigated condition it can be grown as plantation crop on soil where salinity is 1.0 - 1.5%. Chow et al. (1990) suggested that higher requirement for shoot growth under high and low salinity conditions and that high concentration of Na^+ in the leaves may help to maintain turgor, but can not substitute for adequate leaf K^+ concentration. Presumably because K^+ is specifically required for protein synthesis.

Malini and Khader (1989) observed in tuberose var. Single that when both NaCl and $CaCl_2$ were added to the irrigation water, plant growth declined even at lowest rate of salt solution and declined increasingly as salt concentrations increased.

Effect on germination

Several evidences are available that some crops are sensitive while others are tolerant to salinity during germination and early seedling growth. The different salinity levels affect germination of seeds differently. Lower levels of salinity causes delayed germination, whereas higher levels cause delay as well as reduced germination percentage (Bhumbla and Singh, 1965; Kumar, 1973; Mohamed and Abdel-Salam, 1974; Unger, 1978; Card et al., 1978; Kumar, 1980; Mangal and Singh, 1985; Mangal et al., 1978; Mangal et al., 1988).

Sonnevold (1988) found the osmotic effects of salt mixture, the specific ion effects of NaCl and the specific salt effects of various salts as Na, K, Ca, and Mg as cations and Cl, NO_3, SO_4 and HCO_3 as anions on performance of a range of vegetable crops and ornamental species. Salinity was found to have positive as well as negative effects on germination (Prisca and O'Leary, 1970; Tur et al., 1980). The effect have been considered to be mainly osmotic at lower levels but appear to be primarily ionic at higher levels of salinity.

Sharma and Yamdagni (1989) observed the effect of salinity of winter annuals at different salinity levels with respect to seed germination and seedling survival. They found that both germination and survival were inhibited with increasing salinity levels and maximum germination was found in the control.

St.-Arnaud and Vincent (1990) found the effect of salinity on germination and growth of Coronilla varia, Lotus corniculatus, Medicaga lupulina, Kachia scoparia and Polygonum aviculase. Seed germination were not affected within salinity range of 50-250 mS/m. High NaCl concentration in the soil adversely affected the growth of Lotus corniculatus and M. lupulina, but germination and growth of P. aviculase were better at high salt concentration.

Kaul et al. (1988) observed the seed germination in guava. The soil artificially salinized with 3 different salts (NaCl, Na_2SO_4 and $CaCl_2$) at 3 ECe levels (6, 9 and 12 dS/m). Increase in salinity level delayed, reduced and inhibited germination. Chloride salts were more injurious than sulphate salts.

Kalliappan and Rajgopal (1970) found that the germination of chilly was greatly reduced above 4000 ppm NaCl and $CaCl_2$ in equal parts but at lower concentration no significant effect was observed. Singh and Mangal (1974) found that NaCl at iso-osmotic concentration inhibited the germination of okra seed of cv. Pusa Sawani more than $NaSO_4$, whereas Jaiswal et al. (1975) found no harmful effects of salinity on germination is peas upto 6 dS/m ECe but above this level germination was significantly reduced. Similar observations were also reported by Malik et al. (1977) and Nand Kishore (1979) in onion and brinjal, respectively.

Wannamaker and Pike (1988) evaluated the germination percentage of onion for 8 days at salt concentration with EC ranging from 0 to 5 dS/m. Germination rate was retarded by 1-3 days with increase in salt concentration, but germination percentage after 8 days was not significantly reduced at the EC ranging between 0-25 dS/m. Germination was prevented by EC 45 dS/m for all cultivar except Texas Gran.

Miyamoto (1989) found that onion seed germination exceeded 80% at the salinity of 20 dS/m or a slightly less. A significant increase in seedling mortality was also observed when seedling were sprayed twice after emergence with saline solution of 28 and 39 dS/m.

Effect on vegetative growth

Saline condition prevailing in the soil bring about a general reduction in vegetative growth. The stunting of plants, restricted lateral shoot development, reduction in size and number of leaves, fall in fresh and dry weight of leaves, stem, roots and other plant organs occur in different plants to varying degrees in respect to salinity.

Bernetein et al. (1972) while working on salt tolerance of ornamental shrubs and ground covers found that in artificially salinized plots with NaCl and $CaCl_2$ chloride and sodium injury was more pronounced in sand cultures than in water or soil cultures. Tolerant species like bougain villea, Natal plum and rosemary were affected little if at all by soil salinity of 8 mmhos/cm. Whereas sensitive species like star jasmines, holly and rose were severely damaged or killed even at EC of 4 dS/m.

Skimina (1982) experimented by growing woody and herbaceous ornamental plants to determine their tolerance to 4 levels of saline irrigation water. Out of 118 spp. and cvs. tested, 29 were found very tolerant, 38 moderatelytolerant, 43 sensitive and 8 very sensitive. The very tolerant groups were Araucaria heterophyllus, Asparagus densiflorus a Sprengeri, Hibiscus rosasinensis cvs. President and Brilliant. Ishida et al. (1978, 1979) studied the effects of various concentrations of sea water on the growth of Chrysanthemum morifolium Ramat and Carnation. They reported that the plant height and fresh weight of the flowering plants grown in sand and soil decrease above 250 ppm of Cl in sea water.

Clemens and Campbell (1982) reported that among the Casuarina species, C. glauca was more tolerant than C. decaisneana and C. inophola. The growth rate of lower species was reduced one week after the salt treatment whereas the seedlings of former were little affected.

Sonnevold and Voigt (1983) studied the salt tolerance of some flower crops viz., Carnation, gerbera, anthuriump, chrysanthemum and hippeastrum.

They reported that the salt application had a deleterious effect on the development of all the flower crops used in the investigation. Carnations and chrysanthemum proved to be the least sensitive. Gerberas and hippeastrums showed a medium sensitivity and authurium proved to be the most salt sensitive. Smirnov (1985) experimented to determine salt resistance of one and two years seedling of Rosa beggeriana. Data are tabulated on height/growth in relation to salt concentration in the soil. Close relation were found between height and salt concentration and between seedling dimension and concentration of chloride ions and of sulphate ions. Malini and Khader (1989) observed in tuberose var. Single in pot experiments adding 6000, 8000 or 10000 ppm $CaCl_2$ or NaCl in irrigation water and observed plant height, number of leaves, leaf area and tuber DW at 80 and 145 days after planting. The plants were more tolerant in NaCl than of $CaCl_2$ showing less damage at 8000 ppm NaCl then at 6000 ppm $CaCl_2$. When NaCl and $CaCl_2$ were both added to the irrigation water, plant growth declined even at lower rate of salt concentration i.e. 6000 ppm of each salts and growth rate further declined as the salt concentration increases.

Singh and Mangal (1974) and Malik (1974) observed the height of plant, number and length of leaves and root growth in onion crop was greatly reduced above the salinity of 7.5 mmhos/cm. Similar results have been reported by Jaiswal et al. (1975) in peas.

Shannon et al. (1983) observed the response of lettuce to salinity in green house. They found that fresh weight of lettuce plants declined as salinity increased while the root weight was not affected as much as the leaf weight. Climax cultivar of lettuce showed a greater tolerance to salinity than Calmer (Cramer et al., 1982).

Pan (1985) found that when spinach was grown in nutrient solution at low salinity or gradually increasing salinity levels of 50 to 300 mM NaCl. There was a slight decrease in shoot fresh weight at levels above 100 mM. At 300 mM the increase in fresh weight of root and the cotyledon was inhibited.

Hashim et al. (1991) observed the effect in two tomato cultivars i.e. salt sensitive cv. E-6203 and tolerant cv. Edkawy were grown in solution culture with 0 and 25 mM NaCl added from the 2 leaf stage. The major ions found in sea water were also added in appropriate proportions. Dry weight accumulation in all plant part and leaf canopy expansion were increasingly inhibited by increasing NaCl concentration in both cultivars. High salinity increased leaf succulence in E-6203 but not in Edkawy.

Effect on flowering

Very little information on the effects of salt on flowering is available.

Hughes (1976) reported that in roses, presence of small quantity i.e. 1 me/L of HCO_3, Na or Cl ions with salinity levels above 1330 mmhos/cm reduced the cut flower yield by more than 15%. The most toxic ion was HCO_3 and concentration above 2 me/L could reduce production by as much as 20%. Chlorosis in the petels was a major symptom and it was associated with the presence of HCO_3. Similarly, Hughes and Hanan (1977) in roses reported that with increasing $NaHCO_3$ salinity levels there was a progressive reduction in yield and flower stem length whereas flower weight was only slightly affected. Ishida et al. (1978, 1979, 1979) evaluated the effect of various concentration of sea water on flowering of chrysenthenum,carnation and roses. They observed that flowering of both chrysanthenum and carnation were markedly delayed above 2000 ppm Cl in irrigation water whereas in case of 'Sunlight' roses the flowering was delayed and cut flower production was significantly reduced at 1000 ppm sea water concentration. Kurzmann et al. (1985) found that when Elatior begonias cv. Schwabenland were grown in peat substrate with 0.5 g Flory Grain per litre of substrate as a basal treatment followed by 8-18 liquid feed supplying N @ 100, 250, 500, 750, 1000 or 1250 mg/ plant. The optimal rate was 250 mg which produced the earliest and most prolific flowers whereas 750 mg reduced the growth and flowering. A salt level of 1.5 - 2 gm/lit. of substrate was critical higher levels causing salt damage. Devitt and Morris (1988) observed when ten species of annuals were grown in green house and irrigated with water of EC 0.8, 3.0 or 4.5 dS/m. All the 10 species differed in their response to salinity. The relative number of flower and their relative maximum flower diameter at harvest decreased significantly. Cosmos bipinnatus cv. Sunny Gold were found very sensitive. Petunia hybrida cv. White Coscade and Challenger White and Dianthus chinensis cv. Princess White were the only species rated very tolerant.

Malini and Khader (1989) observed the effect of different salinity on flowering of tuberose cv. Single. He studied the response to days to flowering at salinity levels 6000, 8000 or 10000 ppm NaCl or $CaCl_2$ added to the irrigation water either separately or in combination. Flowering in control occured at 122 days but it was delayed to 165 days at highest salinity levels i.e. 10000 ppm.

Singh and Mangal (1974) also observed a decline in number of flowers per plant with both chloride and sulphate salinity at 6 and 8 mmhos/cm in okra. Similar results were also reported by Howie and Lloyd (1991) when they irrigated 24 years old plants of Washington Navas Orange with 5-20 mol

$NaCl/m^3$ for 5 years and observed its effect on flowering and fruit set. They observed reduction in flowering under high salinity levels.

Effect on mineral composition

The saline conditions of soil may be due to the excess of cations Na^+, K^+, Ca^+ and Mg^+ and the anions Cl^{-1}, SO_4, NO_3 and HCO_3. Growth is checked under saline conditions by total ion activity in the soil solution as well as by the relative contribution of the each ion. Under NaCl salinization, the uptake of Ca, Mg, K, P and N is reduced and accumulation of Cl occurs (Mangal, 1974; Hanna et al., 1978; Hajji, 1979). Divate and Pandey (1981) studied the salt tolerance of various grape cultivars and found that salt treatments increased leaf N, P, Na, Cl and decreased leaf K. The increase or decreased of ions were proportional to the salt concentration. Similar results were reported in different crop plants (Storey and Jones, 1977; Cevda et al., 1979).

Kaul (1981) reported that with increase in salinity, N content in leaves of guava increased and P, K, Ca and Mg were decreased.Contrary to this Makhuja et al. (1980) observed an increase in Ca and Mg and reduction in N content above 7.5 mmhos/cm of salinity. However, increase in Na, SO_4 and Cl content at all the concentration was reported by Joolka (1976), Jindal (1974), Sepaskhah and Maftoun (1982), Ishida et al. (1978), Singh (1981) and Divate and Pandey (1981) while working with chrysanthemums, roses and grapes reported a decrease in K content with increased salinity. Sharma et al. (1989) assessed the performance of garden annuals under 4 salinity levels (3, 6, 9 or 12 mmhos/cm) and found that plant N and P content generally increased with increasing salinity levels whereas the K content decreased.

Bhivare and Nimbalkar (1986) while working on French bean found that N, K, Cu, Zn were decreased by salinity while content of Na and Fe were increased. There was little effect on P content and effect on Ca, Mg and Mn were variable. Shimose and Hayashi (1985) found that when the crop were grown in constantly renewed sand culture watered with solution containing 0-60 meq/lit. Na_2SO_4 or NaCl. The uptake of K, Ca and Mg by the crop decreased with rising salt concentration and this effect was more pronounced in plants receiving Na_2SO_4.

Pinkau and Lappas (1987) studied that sprinkler irrigation with sweet water caused only minor changes in the mineral content (P, Ca, K, Mg, Na and Cl) at harvest and Na and Cl content after storage of the two crops compared with those of unirrigated controls. Sprinkler irrigation with Baltic Sea Water caused a substantial rise in Na and Cl and minor increase in the content of other mineral.

Effect on physiological and biochemical parameters

a) Water potential/relaive water content

The problem of water supply and water exchange of plants growing on saline soil has been studied inadequately. Relative water technique formerly known as relative turgidity was described by weatherley and has been widely accepted as a reproducable and meaningful index of plant water status. Meiri et al. (1971) reported that chloride salinity induced succulence character due to increased hydration of tissues, whereas sulphate salinization causes as apparent dehydration of tissues and organs and thus reduced succulence. However, water supply under sulphate salinity was ensured by an intensive development of root system and water conducting system in root and stem. Plants from chloride salinity have a higher suction force in their leaves and a higher osmotic pressure in their cell sap than plants from sulphate type of salinity. Ram (1979) observed that plants in conditions of chloride salinity has more relative water content as compared to plants growing in salinity due to sulphates. Desai and Singh (1982) observed that percentage inter-water deficit (100-relative water content) of salt treated plants was significantly affected by the type of salt and it was also seen that increased concentration of the salts also significantly increased the internal water deficit. Divate and Pandey (1979) also reported that the percentage of internal water deficit induced in all grape cultivars was higher than that of untreated controls except with the chloride treatments applied alone.

Ahmad et al. (1985) found in Neem when grown on coastal sand using 10-30% dilution of saline water EC 4.5-14 dS/m for irrigation. Plant irrigated with saline water showed an increase in moisture content. Bhivare and Nimbalkar (1986) studied on the seedling of Phaseolus vulgaris cv. Vaghya grown in pots. They found that at concentration of 2.5 and 5.0 dS/m of Na_2SO_4 growth and dry matter were stimulated but inhibited by all other treatment. Leaf thickness and moisture content were increased by salinity.

Gangwar and Varshney (1986) found that the water potential and osmotic potential in leaves of 2 pea cvs. were investigated in relation to different concentration of NaCl, $CaCl_2$, Na_2CO_3 and $NaHCO_3$. Both leaf water potential and leaf osmotic potential were adversely affected by increasing EC of soil solution.

Neumann et al. (1989) studied the effect of 50 or 100 mM NaCl on bean seedlings. At 50 mM NaCl caused a significant reduction in leaf turgor at 24 h, adaptive decrease in leaf osmotic potential were more than compensated by parallel decrease in xylem tension potential and the leaf apoplastic solute potential, resulting in a decreased leaf water potential.

Sharma et al. (1989) observed decline in relative water content and leaf water potential with increase in soil EC and observed increase in leaf diffusive resistance.

b) Chlorophyll content

The adverse effect of salt stress on plant causes marked changes in the metabolism of plastidal and soluble pigments (Strogonov et al., 1970). The changes in the pigment concentration depend upon the specific nature of the ion, plant species and stage of plant growth and development. Chlorophyll content of the leaves decreased under saline conditions in number of plants (Lapina and Popov, 1970; Prisco and O'Leary, 1972; Kumar, 1973; Sheoran, 1975; Reddy and Das, 1978; Verma, 1978; Masih et al., 1981). This may be due to the decrease in the ratio of metabolism caused by high concentration of chloride.

Tesu et al. (1977) and Persera and Albuzio (1978) reported an increase in chlorophyll content in wheat leaves under salt stress. Similar increase in chlorophyll content under salt stress were reported by Sheoran (1975) in moong and chickpea. This increased amount of chlorophyll may be due to the accumulation of various compound necessary for its synthesis. Divate and Pandey (1981) found an increase in the chlorophyll content under saline conditions which may be due to the increased bud strength of the chlorophyll protein-lipid complex (Gupta and Nauriyal, 1973). Lapina and Popov (1970) noticed concurrent changes in the structure of chloroplast i.e. increase in the transparency of protein stroma and disorientation of lamella system. Mehta (1982) in grain also reported decrease in chlorophyll content with increased salinity. Doring and Ludders (1986) observed in pomegranate cutting were treated with different salt at 40, 60, 80 meq/lit. for 3 months.

Reduced chlorophyll content in leaves appeared 4 weeks after the start of treatment and before any visible damage occured. The strongest effect was with the salt at 60 meq/lit. which led to the lowest chlorophyll content and rate of photosynthesis. Bhivare and Nimbalkar (1986) studied in French bean. They found that leaf thickness and moisture content were increased by salinity. Chlorophyll content was increased by Na_2SO_4 and decreased by NaCl. Similar result was reported by Ahmed et al. (1986). They found that plant irrigated with saline water showed decreased in chlorophyll content. Attalla (1990) found that the leaves of all the seedlings of hybrid citrus in the 1000 and 2000 ppm treatment had lower content of chlorophyll.

Sinel'Nikova (1990) observed in tomato during 1983-85 under saline condition content of chlorophyll 'a' and 'b' and total chlorophyll content rose under saline conditions in the resistant variety. Mangal and Singh (1973) reported that the highest concentration (8 mmhos/cm) of both salts (NaCl and Na_2SO_4) markedly reduced the chlorophyll 'a' and 'b' contents in leaves and fruits. The chlorophyll 'a' being the most effective and Na_2SO_4 being more injurious salt.

CHAPTER 3

MATERIALS AND METHODS

The present investigation on salt tolerance studies in tuberose (Polianthes tuberosa) cv. Single and Double was carried out in the screen house of Department of Horticulture, College of Agriculture, CCS Haryana Agricultural University, Hisar during the year 1992-93. Details of the experiment is given as follows.

Two types of salinity i.e. chloride dominated (70 Cl : 30 SO_4) and sulphate dominated (SO_4 70 : Cl 30) was used in six concentrations (0, 2, 4, 6, 8 and 10 dS/m ECe) developed by using five salts (NaCl, $MgCl_2$, $CaCl_2$, Na_2SO_4 and $MgSO_4$) in appropriate ratios was used. There were two cultivars (Single and Double) were grown in both types of salinity under different concentrations of salinity. There were 24 treatments combination (2 cultivars x 2 types of salinity x 6 salinity concentrations) which were replicated 4 time in C.R.D. The experiment was conducted in earthen pots of 25 cm diameter filled with soil which was analysed before planting. The experimental soil had the following chemical characteristics.

Various chemical characteristics of the experimental soil

Texture	=	Sandy soil
Saturation percentage	=	30
pH	=	8.4
Electrical conductivity	=	0.058 dS/m ECe
Organic carbon	=	0.3%
Available phosphorus	=	18 kg/ha
Available potash	=	109 kg/ha
Available nitrogen	=	200 kg/ha

Five kg well sieved soil was filled in 12" size earthen pots which were lined with thick polythene bag to avoid the losses of leaching. Each pot (96 pots) was planted with 2 bulb of tuberose of desired varieties on 1st week of April. The pots were saturated @ 1.2 litre salt solution of different concentrations of both types of salinity. After two days, soil of each pot was sampled to know their actual electrical conductivity. The values are given as under:

Showing the desired and actually obtained value of ECe (dS/m)

Desired ECe (dS/m)	Observed ECe (dS/m)	
	At the start of experiment	At the end of experiment
0.05 (Control)	0.06	0.06
2	1.9	2.0
4	4.1	4.2
6	6.0	6.2
8	7.8	8.1
10	10.1	10.2

Irrigation and cultural practices

All the pots were irrigated with canal water @ 200 ml water/pot in equal amount when plant showed wilting in the morning and soil was brought to field capacity after each irrigation. Irrigation water was applied alternatively at surface and through plastic tubes from bottom of the pot to prevent leaching and accumulation of salts below the root zone.

A fertilizer mixture containing KNO_3 - 10.200 gm, $Ca(NO_3)_2$ - 4.92 gm, $NH_4H_2PO_4$ - 2.30 gm and $MgSO_4$ - 4.90 gm was dissolved in 10 litres water and applied @ 200 ml/pot at an interval of 90 and 120 days after planting. Uniformity in other cultural practices like hoeing, weeding etc. was maintained throughout the experiment as per recommendations.

Observations

The following observations were recorded during the course of experiment.

A. Growth and flowering

1. **Days taken for sprouting of bulb:** Days taken for the sprouting of bulb were recorded from the date of planting to days taken for sprouting.

2. **Survival percentage:** After 60 days of sprouting of all the bulb, number of surviving plants were counted and expressed as survival percentage of the plants.

3. **Number of leaves:** Total number of leaves per plant were counted at an interval of 90 days and 120 days after planting.

4. **Height of the plant:** The height of the plant was measured from the base of the plant to the top exposed leaf of the stem at an interval of 60 and 90 days after planting.

5. **Days to initiation of spike:** Total number of days taken for initiation of spike were counted after planting.

6. **Length of spike:** Length of spike of plant was recorded in centimeter with the help of a meter scale after the opening of last flower in each spike.

7. **Number of florite per spike:** Total number of florites per spike were counted.

8. **Days to opening first florite:** Days taken for the opening of first florite were recorded from the date of planting.

9. Duration of flowering: Duration of flowering was calculated from the date of first appearance of flower to the date of last flower open.

B. Plant chemical analysis

For chemical analysis of plant, leaf samples were taken for all the four replications. The leaves were then thoroughly washed with distilled water to remove any contamination and dried in oven at 60°C till the dry weight became constant. Then dried samples were finally ground and stored in small polythene bags. Different nutrients from these samples were determined according to the procedure as given below:

Nitrogen	Linder (1944)
Phosphorus	Jackson (1973)
Potassium	Flame photometer
Calcium and Magnesium	Cheng and Bray (1951)
Chloride	Chhabra et al. (1976)
Sulphate	A.O.A.C. (1950)

C. Physiological and biochemical studies

1. Relative water content: The relative water content was calculated by the following formula:

$$R.W.C. = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - dry weight}} \times 100$$

2. Chlorophyll content: The chlorophyll content in the leaves was determined by the formula given by Arnon (1949).

Chlorophyll 'a' = 10.3 x A 663 - 0.918 x A 645

Chlorophyll 'b' = 19.7 x A 645 - 3.87 x A 663

CHAPTER 4

EXPERIMENTAL RESULTS

1. Days taken for sprouting of bulb

It is evident from the data presented in Table 1 that the sprouting of tuberose bulb was significantly affected by different levels of salinity as well as with treatments. It was noted that the bulbs sprouted earliest in control whereas it was delayed with the increase in levels of salinity. This trend was followed in both the varieties and both the treatments. The number of days taken for sprouting of bulb ranged from 18.2 to 41.7 days in control and highest concentration of salinity respectively in single tuberose. Similarly in double tuberose it ranged from 22.5 to 35.3 days. It is clear from the data that type of salinity also played an important role in sprouting. In both varieties the sprouting of bulbs in chloride dominated salinity was delayed in comparison with sulphate dominated salinity (Table 1).

2. Survival percentage

Data on survival percentage of two tuberose cultivars planted at various salinity levels are presented in Table 2. The survival percentage of both the varieties decreased with increase in salinity levels which reached upto 68.75 and 87.75 in single and double respectively at highest concentration i.e. 10 dS/m. However, cent per cent survival percentage was noted upto 6 dS/m salinity levels in both the treatments in single variety and upto 8 dS/m salinity levels of both treatments in double variety. But cent per cent survival percentage was observed in sulphate dominated salinity in double variety even at highest salinity levels i.e. 10 dS/m. In single variety from control to 6 dS/m sprouting was cent per cent but it decreased significantly with increase in salinity i.e. at 8 and 10 dS/m in both the treatments i.e. 81.25 and 68.75 per cent, respectively. Whereas in double variety survival

Table 1. Effect of various levels of salinity on number of days taken for sprouting of bulbs

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	19.5	17.0	18.2	22.7	22.2	22.5	20.3
2.0	22.2	21.5	21.8	26.2	24.0	25.1	23.5
4.0	25.7	25.7	25.7	27.7	25.0	26.3	26.0
6.0	32.0	30.0	31.0	30.5	30.2	30.3	30.6
8.0	39.7	32.5	36.1	33.2	31.5	32.3	34.2
10.0	48.7	34.7	41.7	35.0	35.7	35.3	38.5
Mean	31.3	26.9	29.1	29.2	28.1	28.6	28.9

C.D. at 5%

i) Variety = N.S. ii) Salinity type = 1.73 iii) Salinity level = 3.01

N.S. = Non significant

Table 2. Effect of various levels of salinity on survival percentage of plants of tuberose

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
4.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
6.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
8.0	75.00	87.50	81.25	100.00	100.00	100.00	90.62
10.0	62.50	75.00	68.75	75.00	100.00	87.75	78.12
Mean	89.58	93.75	91.66	98.83	100.00	97.95	94.79

C.D. at 5%

i) Variety = 6.00 ii) Salinity type = N.S. iii) Salinity level = 8.66

N.S. = Non significant

percentage was cent per cent in sulphate dominated salinity and it significantly decreased at 10 dS/m in chloride dominated salinity. Thus from the above table it is clear that single variety is more sensitive to both type of salinity as compared to double variety which is sensitive to chloride dominated salinity only (Table 2).

3. Growth parameter

3.1 Number of leaves

Total number of leaves retained by plants of both varieties of tuberose under varying levels of salinity was counted after 60 and 90 days from date of planting and the data are presented in Tables 3 and 4.

The perusal of the data reveals that total number of leaves of both the variety decreased with the increase in the salinity levels of both the treatments. At 60 days of planting total number of leaves ranged from 6.5 to 12.2 in single and 6.2 to 12.5 in double respectively between control and highest level of salinity i.e.10 dS/m.It was also noted that total number of leaves were more in sulphate dominated salinity in comparison to chloride dominated salinity.

The trend regarding the number of leaves after 90 days of planting (Table 4) was some what similar to that 60 days of planting. It was found thattotal number of leaves decreased significantly at 10 dS/m. In both varieties maximum number of leaves per plant were recorded in sulphate dominated salts particularly at lower concentration i.e. in control 21.00 and 25.25 respectively (Tables 3 and 4).

3.2 Height of the plant

The data on the effect of salinity level on plant height are given in Tables 5 and 6 after 60 and 90 days of planting of bulbs. It is clear that

Table 3. Effect of various levels of salinity on number of leaves per plant (60 days after planting)

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	11.75	12.75	12.25	11.25	13.75	12.50	12.37
2.0	11.50	11.50	11.50	10.25	11.75	11.00	11.25
4.0	9.50	9.75	9.62	9.50	10.25	9.87	9.75
6.0	8.25	8.50	8.37	8.75	9.50	9.12	8.75
8.0	7.50	7.75	7.62	7.50	8.25	7.87	7.75
10.0	6.50	6.50	6.50	6.00	6.50	6.25	6.37
Mean	9.00	9.45	9.31	8.87	10.00	9.43	9.35

C.D. at 5%

i) Variety = N.S. ii) Salinity type = 0.74 iii) Salinity level = 1.28

N.S. = Non significant

Table 4. Effect of various levels of salinity on number of leaves/plant (after 90 days of planting)

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	18.75	21.00	19.87	21.75	25.25	23.50	21.68
2.0	16.75	20.00	18.37	19.00	22.25	20.62	19.50
4.0	15.75	18.50	17.12	17.75	18.75	18.25	17.68
6.0	14.75	16.50	15.62	16.75	16.75	16.75	16.18
8.0	13.00	15.00	14.00	15.50	15.00	15.25	14.62
10.0	11.00	11.00	11.00	14.50	13.50	14.00	12.50
Mean	15.00	17.00	16.00	17.54	18.54	18.06	17.02

C.D. at 5%

i) Variety = 1.15 ii) Salinity type = 1.15 iii) Salinity level = 1.99

Table 5. Effect of various levels of salinity on the height (cm) of plant (60 days after planting)

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	32.10	31.85	31.97	27.98	30.41	29.20	30.58
2.0	25.06	26.30	25.68	26.86	25.36	26.11	25.89
4.0	21.50	23.55	22.52	21.50	23.67	22.58	22.55
6.0	19.43	17.62	18.53	17.23	19.30	18.26	18.40
8.0	16.37	15.85	16.11	15.41	16.36	15.88	16.00
10.0	8.68	8.85	8.76	10.97	11.43	11.20	9.98
Mean	20.52	20.67	20.59	19.99	21.09	20.54	20.56

C.D. at 5%

i) Variety = N.S. ii) Salinity type = N.S. iii) Salinity level = 2.17

N.S. = Non significant

Table 6. Effect of various levels of salinity on the height (cm) of plant (90 days after planting)

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	51.50	45.25	48.37	42.50	40.62	41.56	44.96
2.0	45.87	40.62	43.25	39.75	36.75	38.25	40.75
4.0	41.02	39.12	40.07	36.37	35.37	35.87	37.97
6.0	38.00	37.50	37.75	34.50	33.06	33.78	35.76
8.0	35.56	34.40	34.98	32.87	31.37	32.12	33.55
10.0	30.50	26.87	28.68	28.00	25.12	26.56	27.62
Mean	40.41	37.29	38.85	35.66	33.71	34.69	36.76

C.D. at 5%

i) Variety = 1.45 ii) Salinity type = 1.45 iii) Salinity level = 2.52

with increase in each successive levels of salinity from control to highest concentration of salinity, height of the plant reduced significantly. Maximum height was found in control i.e. 31.97 cm and 29.20 cm in single and double tuberose respectively whereas minimum height of the plant was found at highest salinity level i.e. 8.76 cm and 11.20 cm in single and double variety. It is clear from the Table 5 that height of the plant was more adversely affected by chloride dominant salinity as compared to sulphate dominant salinity (Table 5).

Similarly after 90 days planting it was noticed that with increase in the successive level of salinity from control to 10 dS/m, height of the plant reduced significantly. Height of the plant reduced significantly with their respective lower levels i.e. 4 to 6 dS/m. But the values at 4 and 6 dS/m were at par. Similarly height decrease significantly with increase in salinity from 8 to 10 dS/m. Maximum height was found in control i.e. 48.37 cm and 41.56 cm in single and double varieties respectively and minimum height of the plant was recorded 28.68 cm and 26.56 cm in single and double was found at height salinity level. It is clear from the Table 6 that overall increase in height of the plant was more in sulphate dominant salinity as compared to chloride dominant salinity (Table 6).

4. Flowering studies

4.1 Number of days taken for spike initiation

It is evident from the data presented in Table 7 that days taken for spike initiation in both the variety was significantly affected by different levels of salinity levels and treatments. With the increase in each successive level of salinity from control to 10 dS/m, number of days taken for spike initiation increased significantly. However, minimum number of days taken for

Table 7. Effect of various levels of salinity on the number of days taken for initiation of spike

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	76.0	89.7	82.8	87.0	88.5	87.7	85.3
2.0	85.7	93.7	89.7	91.5	91.5	91.5	90.6
4.0	88.0	101.7	94.8	96.0	94.5	95.2	95.0
6.0	93.7	104.0	98.8	98.2	95.7	97.0	97.9
8.0	105.2	107.5	106.3	101.2	104.2	102.7	104.5
10.0	116.7	112.5	114.6	111.5	115.7	113.6	114.1
Mean	94.2	101.5	97.8	97.5	98.3	97.9	97.9

C.D. at 5%

i) Variety = N.S. ii) Salinity type = 1.49 iii) Salinity level = 1.49

N.S. = Non significant

spike initiation was noted in control i.e. 82.8 days and 87.7 in single and double, respectively whereas maximum number of days taken was noted 114.6 days and 113.6 days in single and double, respectively. The initiation of spike was also affected by chloride and sulphate mixture. In single variety spikes emerged a few days earlier in sulphated mixture in comparison to chloride dominated salinity whereas it was reverse in case of double variety (Table 7).

4.2 Length of spike

The data on the effect of salinity on the length of spike is given in Table 8. From the table it is clear that with the increase in the salinity levels, length of the spike reduced significantly. In variety single maximum length of spike was recorded in control i.e. 97.87 cm and minimum 29.50 cm in highest concentration of salinity levels. Similarly in double variety maximum length i.e. 64.50 cm was found in control and minimum length i.e. 44.50 cm was found at 10 dS/m salinity level. The effect of treatments was also observed and it was found that in both the treatments length of the spike was significantly reduced with increase in the salinity level from control to highest concentration of salinity levels in both variety. The plants grown under chloride mixture were able to produce spikes having more length in comparison to plants grown under sulphate dominated salts. It was also noted that single variety could attain spikes with better length than double.

4.3 Number of days required for opening of first flower

The data presented in Table 9 reveal that increased salinity levels, in general, delayed the opening of first flower. It was found that with the increase in successive levels of salinity from control to 10 dS/m, number of days taken for opening of first flower increased significantly. It was noted that firstly flower opened in the control and delayed with the increase in the level

Table 8. Effect of various levels of salinity on the length (cm) of spike

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	98.75	97.00	97.87	64.00	65.00	64.50	81.18
2.0	89.75	80.25	85.00	60.50	62.50	61.50	73.25
4.0	83.50	78.25	80.87	58.00	60.75	59.37	70.12
6.0	71.00	70.50	70.75	56.50	59.00	57.75	64.25
8.0	58.00	65.00	61.50	52.50	43.25	47.87	54.68
10.0	30.00	28.75	29.50	50.25	38.75	44.50	37.00
Mean	71.87	69.95	70.91	56.95	54.87	55.91	63.41

C.D. at 5%

i) Variety = 0.93 ii) Salinity type = 0.93 iii) Salinity level = 1.61

Table 9. Effect of various levels of salinity on the number of days taken for opening of 1st floret

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	110.5	114.7	112.6	120.0	117.5	118.7	115.6
2.0	117.2	122.5	119.8	123.2	123.2	123.2	121.5
4.0	120.0	126.7	123.7	134.7	127.2	131.0	127.1
6.0	124.0	133.2	128.6	137.7	129.5	133.6	131.1
8.0	136.2	139.0	137.6	140.7	142.2	141.5	139.5
10.0	143.5	146.0	144.7	150.0	157.5	153.7	149.2
Mean	125.2	130.3	128.8	134.4	132.8	133.6	130.7

C.D. at 5%

i) Variety = 1.37 ii) Salinity type = 1.37 iii) Salinity level = 2.38

of salinity. This trend was followed in both the varieties and both the treatment. The number of days taken for opening of first flower ranged from 112.6 to 144.7 days in single. Similarly in double tuberose it ranged from 118.7 to 153.7 days. It is clear from the data that flower opening was affected by treatments also. In both the varieties opening of first flower in sulphate dominated salinity, delayed in comparison with chloride dominated salinity. While comparing the performance of varieties in relation to response of sulphate and chloride salts it was noted that in single variety chloride dominated salts flowering opening was enhanced whereas it was delayed in double variety.

4.4 Number of flowers per spike

The data in Table 10 reveal that with the increase in salinity levels from control to highest concentration of salinity level number of flower per spike decreased significantly. It was noted that maximum flowers were noted in the control and it decreased with the increase in the level of salinity. This trend was followed in both the varieties and both the treatments. The maximum number of flower ranged from 36.12 to 14.12 in control and highest salinity level in single tuberose. Similarly in double tuberose it ranged fro 24.75 to 11.75. It was also noted that treatment also affected the number of flower per spike. Minimum number of flowers were found in chloride dominated salinity in comparison with sulphate dominated salinity (Table 10).

4.5 Duration of flowering

It is apparent from the data in Table 11 that different salinity levels affected the duration of flowering. From the above table it was noted that with the increase in each successive levels of salinity from control to 10 dS/m duration of flowering reduced significantly. Similarly treatments also affected

Table 10. Effect of various levels of salinity on total number of flowers/spike

Salinity levels (dS/m) ECe	Single			Double			Salinity levels mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	41.75	30.50	36.12	25.25	24.25	24.75	30.43
2.0	35.75	27.50	31.62	23.00	21.50	22.25	26.93
4.0	30.25	22.50	26.37	20.75	20.25	20.50	23.43
6.0	24.00	20.75	22.37	18.50	19.00	18.75	20.56
8.0	17.50	18.75	18.12	17.75	17.50	17.62	17.87
10.0	14.00	14.25	14.12	10.75	12.75	11.75	12.93
Mean	27.20	22.37	24.79	19.33	19.20	19.27	22.02

C.D. at 5%

i) Variety = 0.63 ii) Salinity type = 0.63 iii) Salinity level = 1.09

Table 11. Effect of various levels of salinity on duration of flowering (days)

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	12.5	17.5	15.1	16.2	17.2	16.7	15.9
2.0	10.7	15.2	13.0	14.5	16.0	15.2	14.1
4.0	9.7	13.2	11.5	13.5	15.0	14.2	12.8
6.0	8.7	11.2	10.0	12.7	13.7	13.2	11.6
8.0	7.5	9.0	8.2	12.0	12.5	12.2	10.2
10.0	6.2	6.0	6.1	10.7	10.0	10.3	8.2
Mean	9.2	12.0	10.6	13.2	14.0	13.6	12.1

C.D.at 5%

i) Variety = 0.50 ii) Salinity type = 0.50 iii) Salinity level = 0.86

the duration of flowering. Maximum duration of flowering ranged between 6.1 to 15.1 days in single and 10.3 to 16.7 days in double. Similar trend was also found in both the treatments and in both the varieties. Duration of flowering was longer in sulphate dominated salinity than the chloride dominated salinity (Table 11).

5. Mineral composition

5.1 Nitrogen content

Results of effect of various salinity levels and treatments on nitrogen content in two varieties of tuberose are presented in Table 12. It is obvious from the data in above table that with increase in the salinity levels, the nitrogen content in the leaves decreased significantly. Similar results were found in varieties and treatments also. Maximum nitrogen content 1.54% and 1.68% and minimum nitrogen content 1.00% and 1.16% was noted in single and double, respectively. It is also clear that nitrogen content decreased significantly with increase in salinity level in both the treatments and varieties. Though other interaction between variety and treatment, variety and salinity level, treatment and salinity level were found highly significant (Table 12).

5.2 Phosphorus content

Data pertaining to phosphorus content in leaves of various tuberose varieties as affected by various salinity levels and treatments are presented in Table 13. A perusal of data in Table 13 reveal that with increase in each successive level of salinity levels from control to highest salt concentration leaf phosphorus content of various tuberose varieties decreased significantly over control and with respect to their lower level of salinity. There was a progressive decrease in phosphorus content of leaves with increasing levels of salinity and maximum reduction was observed at 10 dS/m of salinity in

Table 12. Effect of various levels of salinity on nitrogen content (per cent) in leaves of tuberose

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	1.50	1.58	1.54	1.57	1.80	1.68	1.61
2.0	1.47	1.40	1.43	1.50	1.43	1.46	1.45
4.0	1.28	1.33	1.30	1.45	1.41	1.43	1.37
6.0	1.19	1.29	1.24	1.33	1.30	1.31	1.27
8.0	1.14	1.21	1.17	1.28	1.21	1.25	1.21
10.0	1.01	1.00	1.00	1.16	1.15	1.16	1.08
Mean	1.26	1.30	1.28	1.38	1.38	1.38	1.33

C.D.at 5%

i) Variety = 0.01 ii) Salinity type = 0.01 iii) Salinity level = 0.03

Table 13. Effect of various levels of salinity on phosphorus content (per cent) in leaves of tuberose

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	0.31	0.30	0.30	0.20	0.21	0.20	0.25
2.0	0.28	0.29	0.29	0.17	0.17	0.17	0.23
4.0	0.26	0.28	0.27	0.15	0.15	0.15	0.21
6.0	0.24	0.23	0.24	0.14	0.14	0.14	0.19
8.0	0.23	0.20	0.21	0.14	0.12	0.13	0.17
10.0	0.20	0.12	0.16	0.12	0.10	0.11	0.14
Mean	0.25	0.24	0.24	0.15	0.15	0.15	0.19

C.D. at 5%

i) Variety = 0.01 ii) Salinity type = N.S. iii) Salinity level = 0.02

N.S. = Non significant

both the varieties and treatments. Phosphorus content was decreased significantly in both the variety and treatment, more phosphorus content was found in control i.e. 0.30% in single as compared to double i.e. 0.20%. Phosphorus accumulation in leaves not at all affected as it is clear from the table that in both the salts the values are same (Table 13).

5.3 Potassium content

The effect of various salinity levels on the potassium content in leaves of tuberose is presented in Table 14. From the table it is very clear that potassium content in leaves was significantly affected by different levels of salinity and varieties. Moreover, it is obvious fromthe data that with the increase in salinity levels from control to highest concentration of salinity level there was a significant decrease in potassium content of tuberose leaves. Similarly in the variety also there was a significant decrease in potassium content with increasing salinity level from control to 10 dS/m. In single tuberose potassium content ranged from 4.79% to 3.70% in control and 10 dS/m respectively whereas in double tuberose it ranged from 4.47% to 3.71%. The table also indicate that potassium content in leaves was more affected by chloride type of salinity in comparison to sulphate type of salinity (Table 14).

5.4 Calcium content

The data concerning per cent calcium content has been given in Table 15. It is obvious from the data that with the increase in salinity levels calcium content increased significantly upto 6 dS/m over control then it decreased significantly at higher level i.e. at 8 and 10 dS/m. There was a significant increase in calcium content with increasing salinity from control to 6 dS/m, but with further increase in salinity depletion in calcium content occured. This trend was followed in both the varieties. Almost similar trend

Table 14. Effect of various levels of salinity on potassium content (per cent) in leaves of tuberose

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	4.81	4.76	4.79	4.66	4.28	4.47	4.63
2.0	4.49	4.59	4.54	4.48	4.27	4.37	4.46
4.0	4.22	4.56	4.39	4.42	4.17	4.29	4.34
6.0	4.16	4.10	4.13	4.09	4.16	4.12	4.13
8.0	4.10	3.97	4.03	3.89	4.07	3.98	4.01
10.0	3.53	3.86	3.70	3.64	3.78	3.71	3.70
Mean	4.22	4.30	4.26	4.19	4.12	4.16	4.20

C.D. at 5%

i) Variety = 0.08 ii) Salinity type = N.S. iii) Salinity level = 0.14

N.S. = Non significant

Table 15. Effect of various levels of salinity on calcium content (per cent) in leaves of tuberose

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	2.00	1.72	1.86	1.50	1.70	1.60	1.73
2.0	2.07	1.82	1.95	2.00	1.72	1.86	1.90
4.0	2.10	1.90	2.00	2.12	1.77	1.95	1.97
6.0	2.17	2.10	2.13	2.25	1.87	2.06	2.10
8.0	1.90	1.95	1.92	1.75	1.67	1.71	1.81
10.0	1.72	1.62	1.67	1.65	1.50	1.57	1.62
Mean	1.99	1.85	1.92	1.87	1.70	1.79	1.85

C.D. at 5%

i) Variety = 0.05 ii) Salinity type = 0.05 iii) Salinity level = 0.01

was observed in both the treatments also. Maximum calcium content was found at 6 dS/m i.e. 2.13% and 2.06% in single and double respectively and minimum calcium content was found at 10 dS/m. It is clear from the table that less calcium content was found in sulphate dominant salinity as compared to chloride dominant salinity in single whereas it was reverse in double variety (Table 15).

5.5 Magnesium content

Magnesium content in the leaves of tuberose grown in various salinity levels is presented in Table 16. Data pertaining to magnesium content given in Table 16 reveal that there was a significant decrease in the magnesium content with increasing salinity from control to 10 dS/m over control but concentrations of 4 dS/m and 6 dS/m were more or less equally effective. With further increase from 6 to 10 dS/m there was significant decrease in magnesium content. But in both variety and treatment there was significant decrease in magnesium content with increasing salinity. Maximum magnesium content was found in control in both the varieties and minimum was found at 10 dS/m. Less magnesium content was found in chloride dominated salinity as compared to sulphate dominated salinity in both the varieties (Table 16).

5.6 Chloride content

The data pertaining to chloride content given in Table 17 express that with increase in salinity level from control to 10 dS/m there was significant increase in chloride content over the control. When salinity levels increase from control to 4 dS/m there was significant increase in chloride content whereas the values at 4 to 6 dS/m were at par. Further increase from 6 to 10 dS/m there was significant increase in chloride content. It is clear from the table that there was a significant increase in the chloride content in

Table 16: Effect of various levels of salinity on magnesium content (per cent) in leaves of tuberose

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	1.10	1.08	1.00	0.96	1.20	1.08	1.09
2.0	0.90	1.05	0.97	0.92	1.01	0.96	0.97
4.0	0.74	1.01	0.88	0.90	0.98	0.94	0.91
6.0	0.69	0.96	0.83	0.87	0.95	0.91	0.87
8.0	0.62	0.87	0.74	0.78	0.92	0.85	0.80
10.0	0.57	0.61	0.59	0.67	0.89	0.78	0.69
Mean	0.77	0.93	0.85	0.85	0.99	0.92	0.88

C.D. at 5%

i) Variety = 0.02 ii) Salinity type = 0.02 iii) Salinity level = 0.05

Table 17. Effect of various levels of salinity on chloride content (per cent) in leaves of tuberose

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	1.85	1.41	1.63	1.52	1.08	1.30	1.46
2.0	1.94	1.76	1.85	1.61	1.12	1.36	1.60
4.0	2.03	1.85	1.94	1.82	1.50	1.66	1.80
6.0	2.08	1.86	1.97	1.82	1.50	1.68	1.82
8.0	2.31	2.02	2.16	1.97	1.63	1.80	1.98
10.0	2.58	2.08	2.33	2.16	1.91	2.03	2.18
Mean	2.13	1.83	1.98	1.81	1.46	1.63	1.80

C.D. at 5%

i) Variety = 0.07 iii) Salinity type = 0.07 iii) Salinity level = 0.13

both the varieties and both the treatments with increasing salinity from control to 10 dS/m. Maximum chloride content i.e. 2.33% and 2.03% was found at 10 dS/m in single and double tuberose respectively. Minimum chloride content recorded in normal soil (control) 1.63 and 1.30 in single and double, respectively (Table 17).

5.7 Sulphate content

It is evident from the data presented in Table 18 that sulphate content in tuberose leaves increased significantly with the increase in salinity levels from control to 10 dS/m and it ranged from 1.69 to 3.49% in single and 1.44 to 2.87% in double variety. The sulphate content in sulphate dominated mixture was noted much in comparison to chloride dominated mixture in both the varieties (Table 18).

6. Physiological study

6.1 Relative water content

The data pertaining to relative water content of both the varieties of tuberose is presented in Table 19. The data reveal that the relative water content increased upto 4 dS/m but further increase in the salinity caused decrease in relative water content which reduced upto 90.74%. Similarly relative water content in both the variety and both the treatment the values were at par (Table 19).

7. Biochemical parameters

7.1 Chlorophyll 'a' content

Chlorophyll 'a' content in leaves affected by different salinity levels and treatments was estimated and data are presented in Table 20.

From the table it is clear that with the increase in salinity levels from control to highest concentration of salinity chlorophyll 'a' content

Table 18. Effect of various levels of salinity on sulphate content (per cent) in leaves of tuberose

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl.	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	1.38	2.00	1.69	1.28	1.60	1.44	1.56
2.0	1.56	2.85	2.20	1.38	1.85	1.61	1.90
4.0	1.68	2.89	2.28	1.43	2.05	1.74	2.01
6.0	1.90	3.18	2.54	1.45	2.09	1.77	2.15
8.0	2.43	3.27	2.85	1.80	2.39	2.09	2.47
10.0	2.63	4.36	3.49	3.02	2.72	2.87	3.18
Mean	1.93	3.09	2.50	1.72	2.11	1.92	2.21

C.D. at 5%

i) Variety = 0.14 ii) Salinity type = 0.14 iii) Salinity level = 0.25

Table 19. Effect of various levels of salinity on relative water content (per cent) of leaves of tuberose

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	92.30	94.15	93.22	90.22	92.46	91.34	92.28
2.0	93.26	94.71	93.98	91.33	92.97	92.15	93.07
4.0	93.93	95.07	94.50	94.20	93.89	94.04	94.27
6.0	93.25	94.17	93.71	93.04	92.58	92.81	93.26
8.0	92.17	93.10	92.64	92.47	91.85	92.16	92.40
10.0	89.19	91.06	90.13	91.83	90.89	91.36	90.74
Mean	92.35	93.71	93.03	92.18	92.44	92.31	92.67

C.D. at 5%

i) Variety = N.S.   ii) Salinity type = 1.43   iii) Salinity level = N.S.

N.S. = Non significant

Table 20. Effect of various levels of salinity on chlorophyll 'a' content (mg/g) in leaves of tuberose

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	25.32	26.40	25.86	25.95	26.45	26.20	26.03
2.0	20.67	24.60	22.63	22.64	23.52	23.08	22.86
4.0	16.30	21.67	18.99	18.09	17.57	17.79	18.39
6.0	15.70	21.14	18.42	16.91	15.79	16.35	17.39
8.0	15.50	17.60	16.55	12.94	14.48	13.71	15.13
10.0	13.37	16.33	14.85	10.87	12.02	11.44	13.15
Mean	17.81	21.29	19.55	17.89	18.30	18.10	18.82

C.D. at 5%

i) Variety = 0.39 ii) Salinity type = 0.39 iii) Salinity level = 0.69

decreased significantly. Similar trend was found in both the treatments and variety. Maximum reduction in the chlorophyll 'a' content was 14.85 mg/g and 11.44 mg/g in single and double varieties, respectively. Lesser chlorophyll 'a' content was found in chloride dominated salinity as compared to sulphate dominated salinity in both the varieties (Table 20).

7.2 Chlorophyll 'b' content

Data pertaining to chlorophyll 'b' content in the leaves of tuberose as affected by various levels of salinity are presented in Table 21. From the table it is evident that with the increase in each successive level of salinity from control to 10 dS/m chlorophyll 'b' content decreased significantly over control and each respective lower level of salinity. Similarly treatments also affected the chlorophyll 'b' content. It was found that chlorophyll 'b' content decreased significantly in both variety and treatment with increasing salinity. The chlorophyll 'b' content ranged from 56.29 mg/g to 125.58 mg/g in highest salinity and control respectively in single table. Similarly in double tuberose it ranged from 59.90 and 86.71 mg/g. It is also clear from the table that more chlorophyll 'b' content was found in single tuberose in comparison to double tuberose (Table 21).

Table 21. Effect of various levels of salinity on chlorophyll 'b' content (mg/g) in leaves of tuberose

Salinity levels (dS/m) ECe	Single			Double			Salinity level mean
	Cl	SO_4	Mean	Cl	SO_4	Mean	
0.05 (Control)	125.23	125.92	125.58	86.57	86.86	86.71	106.15
2.0	110.74	114.87	112.80	69.48	80.91	75.20	94.00
4.0	109.63	100.84	105.23	66.13	72.67	69.40	87.31
6.0	97.19	89.31	93.25	64.56	71.62	68.09	80.67
8.0	69.53	73.62	71.57	60.85	69.86	65.35	68.46
10.0	51.97	60.61	56.29	52.41	67.38	59.90	58.09
Mean	95.05	94.19	94.12	66.67	74.88	70.77	82.44

C.D. at 5%

i) Variety = 0.75 ii) Salinity type = 0.75 iii) Salinity level = 1.30

CHAPTER 5

DISCUSSION

The present investigation entitled "Studies on salt tolerance in tuberose (Polianthes tuberosa L.) cvs. Single and Doube" was carried out and various results obtained have been presented in Chapter 5. These results and significant interactions are discussed below in light of each parameters recorded under these studies.

Number of days taken for sprouting

As per the findings, chloride salinity was more injurious and sprouting was significantly delayed with increase in levels of salinity in both the varieties. The delay in sprouting of bulbs may be because of one or combination of the various physiological factors like osmotic effect specific ion or alteration in enzyme activities. Kurian and Iyenger (1967), Iyenger et al. (1967) and Sharma and Yamdagni (1989) reported poor germination in many flowering annuals with increasing in salinity levels. The present findings are similar to the findings of Mangal et al. (1988) and Mangal et al. (1990), Mangal and Singh (1985) where they have reported reduced and delayed sprouting/germination in several vegetable crops and similar results are also observed by Kaul et al. (1988) in guava.

Survival percentage

The survival percentage of both the varieties was recorded after 60 days of planting of bulbs and it was noted that in both the varieties survival percentage showed a declining trend with the increase in salinity level which reduced upto 68.75% and 87.75% in single and double variety respectively at 10 dS/m (Table 2). The most acceptable reason for poor survival of plants under salt affected soil may be nutrient hunger, moisture stress and toxic effects which might have caused unfavourable conditions for the plants to survive. These findings are in accordance with the findings of Harivandi et al. (1982). Similar report have been reported by Mehta (1981) in ber and Joolka (1976) in citrus in which the establishment of plant was reduced with increasing levels of salinity and sodicity.

Vegetative growth

The present studies (Tables 3 to 6) indicated that growth parameter such as plant height and number of leaves/plant were decreased with increase in salinity levels. Reduction was more pronounced in chloride dominated salinity as compared to sulphate dominated. Single type variety was more sensitive to salinity as compared to double variety. The causes of poor vegetative growth may be easily associated with the osmotic effect, toxic effect, specific ion effect and physiological water stress (Mangal and Singh, 1993). The present findings are similar to the findings of Ishida et al. (1978, 1979) in carnation and chrysanthemum crops.

Flowering

From the present investigation it is clear that various salinity levels caused delay in initiation of spike, reduction in spike length, delay in flower opening and reduction in number of flower/spike and duration of flowering with the increase in levels of salinity in both the varieties and the effects were more adverse under chloride dominated salinity (Tables 7 to 11). The present findings are similar to the findings of Malini and Khader (1989) in single tuberose, Devitt and Morris (1987) in annuals, Kurzmann et al. (1985) in begonias and Yaren et al. (1969) in rose.

Mineral composition

Various salinity levels also affect the levels of mineral content such as N, P, K, Ca, Mg, Cl and SO_4 in leaves. It was observed that the N, P, K and Mg content in leaves reduced with the increase in salinity levels but other nutrient such as Ca, Cl and SO_4 increased in leaves with increase in salinity level (Tables 12 to 18). The probable reason for poor content of N, P, K and Mg under saline soils is the domination of plant media by chloride and sulphate ions which hinder in the absorption of these major nutrients causing their deficiency or low content in plant. Higher concentrations of Ca, SO_4 and Cl under saline media may be only because of their more availability and absorption in higher quantity due to specific ion effects. Present findings are in confirmity with the findings of Mangal (1971), Hanna et al. (1978), Hajji (1979), Divate and Pandey (1981) and Sharma et al. (1989).

Relative water content

The data collected to study the effect of various salinity level on relative water content in leaves indicate that relative water content increased upto 4 dS/m but further increase in salinity caused decrease in relative water content which reduced upto 90.74% at 10 dS/m ECe (Table 19). The probable reason for lower water content in leaves may be that there is a high diffusive resistance in cells at higher salinity level causing low availability of water. Another theory for low water content can be the osmotic effect which hinders in water absorption by plants under saline media. These findings are similar with the findings of Nieman (1962), Divate (1974), Divate and Pandey (1979), Desai and Singh (1982) and Sharma et al. (1989) in several crops plants.

Chlorophyll content

The present investigation indicate that increase in salinity levels decreased in chlorophyll 'a' and 'b' content (Tables 20 and 21). Chloride salinity was more toxic in this case also and single variety was affected more adversely. The possible reason may be the nutritional deficiency or imbalance of nutrient or water stress. It may also be due to the reduction of nitrogen and Mg in the leaves which are constituent of chlorophyll molecules.

The results are in confirmity with the findings of Nieman (1962), Bhambota and Kanwar (1970), Mangal and Singh (1973), Masih et al. (1981) and Ahmed et al. (1985) in several crop plants.

CHAPTER 6

SUMMARY AND CONCLUSION

The present investigation entitled "Studies on salt tolerance in tuberose (Polianthes tuberosa L.) cvs. single and double" was conducted in the screen house of Department of Horticulture, CCS Haryana Agricultural University, Hisar during 1992-93. There were six levels of salinity viz., control, 2,4, 6, 8 and 10 dS/m ECe, two types of salinity (SO_4 and Cl dominated) and two varieties (single and double). The effect of these factors were noted on sprouting, growth, flowering, mineral composition and chlorophyll content. The results achieved are summarised as under:

It was found that the sprouting of bulbs and survival of the plant decreased significantly above 6 dS/m ECe salinity level in both types of salinity. However, double variety is comparatively less effective. Similar trend was also noticed regarding plant height and leaves/plant. Spike emergence and length of spike was also affected by type and levels of salinity. Emergence was delayed by 5 to 30 days depending on salinity levels (4-10 dS/m ECe), whereas length was reduced by almost 40 cm at 10 dS/m ECe as comapred to control (0.05 ECe). Sulphate dominated salinity had less harmful effects compared to chloride dominated salinity. Varietal effect with respect to flowering characters was also noticed. The number of flower/spike also decreased with the increase in the levels of salinity in both the varieties and both the salinity types.

The pattern of various levels of salinity on duration of flowering on plant was quite different and it was decreased with the increase in the levels of salinity (6.1 and 10.3 days at highest levels of salinity) and (15.1 and 16.7 days in control). It was also observed that duration of flowering was longer in sulphate dominated salinity than chloride dominated one.

The mineral composition of leaves was also affected by various levels of salinity. N, P, K and Mg content in leaves decreased with the increase in salinity levels. However, other minerals like Ca, Cl and SO_4 increased significantly with the increase in salinity levels except that Ca content decrease when ECe levels exceeded 6 dS/m. The relative water content was increased upto 4 dS/m ECe which was gradually decreased at higher concentration. Various levels of salinity also affected the chlorophyll content in the leaves and both chlorophyll 'a' and 'b' decreased with the increase in salinity levels. Decrease in chlorophyll was more pronounced in chloride dominated salinity. Based on these studies it can be concluded that:

i) Double varieties are more suitable for saline conditions as compared to single varieties.

ii) The double variety can be grown upto 10 dS/m ECe in sulphate dominated soil whereas single variety can be grown upto 6 dS/m ECe.

iii) Salinity levels and types adversely affect sprouting, plant height and flowering behaviour in both the varieties. Adverse effects were more pronounced under higher salinity levels.

iv) There were declining trend in N, P, K and Mg contents in the plant with increasing levels of salinity in both the varieties. Declining trend was more prevalent in chloride dominated salinity. The contents of Cl and SO_4 increased under saline media.

v) Chlorophyll 'a' and 'b' content in leaves decreased with the increase in salinity levels, thus affecting rate of photosynthesis.

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APPENDIX

APPENDIX I

Meteorological data (weekly) during the period of study

Week From	Week To	Max. temp. °C	Min. temp. °C	Relative humidity (%) M	Relative humidity (%) E	Rainfall (mm)
15.3.92	21.3.92	27.3	10.1	83	37	0.0
22.3.92	28.3.92	28.8	11.6	77	44	0.0
29.3.92	4.4.92	28.0	12.0	81	38	3.3
5.4.92	11.4.92	31.6	14.2	79	38	0.0
12.4.92	18.4.92	32.9	14.1	79	51	0.0
19.4.92	25.4.92	36.4	15.7	70	44	0.0
26.4.92	2.5.92	36.7	18.4	58	19	0.0
3.5.92	9.5.92	36.4	20.1	61	25	12.8
10.5.92	16.5.92	39.4	21.5	54	16	0.0
17.5.92	23.5.92	40.0	21.4	44	15	0.0
24.5.92	30.5.92	39.5	22.9	52	22	0.0
31.5.92	6.6.92	37.7	19.9	64	23	21.4
7.6.92	13.6.92	42.7	25.2	57	23	0.0
14.6.92	20.6.92	42.1	26.4	58	26	0.0
21.6.92	27.6.92	41.7	27.9	61	34	2.5
28.6.92	4.7.92	37.0	24.9	71	52	35.8
5.7.92	11.7.92	36.1	25.4	77	53	19.6
12.7.92	18.7.92	36.8	24.5	78	51	6.6
19.7.92	25.7.92	34.5	24.6	84	80	7.5
26.7.92	1.8.92	33.0	24.8	86	68	60.4
2.8.92	8.8.92	33.9	24.9	83	65	8.1
9.8.92	15.8.92	32.7	24.3	93	74	36.7
16.8.92	22.8.92	33.1	24.9	94	77	106.2
23.8.92	29.8.92	33.9	25.1	84	62	14.2
30.8.92	5.9.92	35.3	25.3	83	54	0.0
6.9.92	12.9.92	32.5	24.0	88	81	50.4
13.9.92	19.9.92	32.5	21.9	87	54	10.3
20.9.92	26.9.92	33.7	19.5	83	41	0.0
27.9.92	3.10.92	34.9	16.6	66	34	0.0