EFFECT OF SALINE WATER ON GROWTH, YIELD AND QUALITY OF GREEN GRAM (*Vigna radiata* L.) VARIETIES

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EFFECT OF SALINE WATER ON GROWTH, YIELD AND QUALITY OF GREEN GRAM (*Vigna radiata* L.) VARIETIES

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ABSTRACT

A pot experiment entitled "**Effect of saline water on growth, yield and quality of green gram (*Vigna radiata* L.) varieties**" was carried out during summer season of 2017 in the net house of Micronutrient Research Project (ICAR), Anand Agricultural University, Anand (Gujarat). The experiment was laid out in Factorial Completely Randomized Design with four repetitions. Varying five salt concentrations viz., S_0 (EC_{iw} 0.9 dS m^{-1},Tap water); S_1 (EC_{iw} 1.0 dS m^{-1}); S_2 (EC_{iw} 2.0 dS m^{-1}); S_3 (EC_{iw} 4.0 dS m^{-1}); S_4 (EC_{iw} 6.0 dS m^{-1}) and two green gram varieties *viz.* Meha and GAM 5 were selected in the experiment. The artificially salinized water was used with five different levels *viz.* 0.9 (tap water), 1.0, 2.0, 4.0 and 6.0 dS m^{-1} by using the salts of NaCl, $CaCl_2$, $MgCl_2$, $NaHCO_3$, Na_2SO_4 and $CaCO_3$ by mixing it with R.O. water (0.01 dS m^{-1}). The effect of salt concentrations on germination (7 DAS), plant height at 30, 45 DAS and at harvest, proline content at 15 DAS, protein content of grain, nutrient composition *viz.* N, P, K, S, Na, Fe, Mn, Zn, and Cu in grain and stover and EC, pH, N, P, K, S, Ca, Mg, Na, OC, Fe, Mn, Zn, and Cu in soil after harvesting of green gram were studied.

The results of this investigation showed that yield attributes characters *viz.,* germination percentage, plant height as well as yield of grain and stover were increased upto salinity level S_1 (EC_{iw} 1.0 dS m^{-1}). Beyond this level, drastic reduction in germination percentage, plant height, yield of grain and stover were recorded due to high salt concentration. The reduction in grain and stover yield was 36.47 and 40.96 per cent, respectively at EC_{iw} 2.0 dS m^{-1} as compared to control. Varietal effects on proline content was found significant, in which variety Meha recorded significantly highest proline content of leaves (148.30 µg g^{-1}).The proline content of leaves linearly and significantly increased with increasing salt concentration and significantly highest (241.28 µg g^{-1}) at S_4 level (EC_{iw} 6.0 dS m^{-1}).

Protein content of grain was found significant with respect to salinity levels, wherein significantly highest protein content (21.31%) and lowest (18.39%) were found under S_0 level (EC_{iw} 0.9 dS m^{-1}) and S_2 level (EC_{iw} 2.0 dS m^{-1}), respectively.

N, P, K and S content of grain and stover significantly changed due to salinity levels. Significant reduction in N, P, K and S content were recorded with increased salt concentrations levels. Maximum reduction was observed under salinity level S_4 (EC_{iw} 6.0 dS m^{-1}). Only N and P content of stover differed significantly with salinity levels.

Salinity levels significantly decreased Fe, Zn and Cu contents content in grain and stover as levels of salinity increased. Significantly highest and lowest content of Fe, Zn and Cu were noted under S_4 (EC_{iw} 6.0 dS m^{-1}) and S_0 (EC_{iw} 0.9 dS m^{-1}) respectively. Significantly increased Na and Mn content in grain and stover were observed as salinity levels increased. High level of salinity S_4 (EC_{iw} 6.0 dS m^{-1}) recorded significantly highest Na and Mn content. Fe, Mn, Zn, Cu and Na content in grain and stover did not significantly affected by varieties.

Soil properties after harvest of crop *viz.,* soil pH, available N, P, K, S, Fe, Mn, Zn and Cu status significantly decreased, while improvement in EC, OC, exchangeable Ca, Mg, Na were found with salinity levels.

The overall finding suggested that improvement in macro and micronutrients content in grain and stover of green gram found with irrigation water which has lower salinity level 0.9 dS m^{-1} EC_{iw}. Higher concentration of salt also affected the nutrient status of soil. From the growth and yield point of view, there was a drastic damage to the crop at high salt concentrations above 2.0 dS m^{-1} EC of irrigation water so it is not beneficial for green gram. Higher yield, height and proline content was observed in Meha as compared to GAM 5, so among the both cultivars, Meha had higher relative salt tolerance nature under the saline condition.

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of saline water on growth, yield and quality of green gram (*Vigna radiata* L.) varieties"** submitted by **Mr. TRIVEDI AJITKUMAR MAHENDRABHAIBHAI (Reg. No. 04-2921-2016)** in partial fulfillment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Soil Science and Agricultural Chemistry** of the Anand Agricultural University, Anand is a record of bonafide research work carried out by him under my personal guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place: Anand **(S. B. PATEL)**

Date: /0/2018 Major Guide

DECLARATION

This is to declare that the whole of the research work reported here in the thesis entitled **"Effect of saline water on growth, yield and quality of green gram (*Vigna radiata* L.) varieties"** for the partial fulfillment of the requirement for the degree of **Master of Science (Agriculture)** in **Soil Science and Agricultural Chemistry** by the undersigned is the results of investigation done by me under the direct guidance and supervision of **Dr. S. B. Patel**, Associate Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, A.A.U., Vaso – 387 380 and no part of work has been submitted for any other degree so far.

Place: Anand

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Place: Anand
Dated: /0/2018 ***(Ajitkumar M. Trivedi)***

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LIST OF ABBREVIATION AND SYMBOLS

%	Per cent
@	At the rate of
&	And
^0C	Degree Celsius
≥	Greater than and equal to
µg	Microgram
1^{st}	First
2^{nd}	Second
4^{th}	Fourth
8^{th}	Eighth
12^{th}	Twelfth
16^{th}	Sixteenth
29^{th}	Twenty ninth
AAU	Anand Agricultural University
Anon.	Anonymous
B.A.C.A.	Bansilal Amrutlal College of Agriculture
C. D.	Critical difference
C. V.	Co-efficient of variance
$CaCl_2$	Calcium Chloride
$CaCO_3$	Calcium Carbonate
Cl^-	Chloride
CO_3^{2-}	Carbonate
Cu	Copper
cm	Centimetre
DAP	Di ammonium phosphate

DAS	Days after sowing
DTPA	Diethylene Triamine Penta Acetic Acid
dS m^{-1}	deciSiemens per meter
e. g.	For example
EC	Electrical conductivity
et al.	Et allii; and co-workers
etc.	Etcetera
Fe	Iron
Fig.	Figure
g	Gram
g kg^{-1}	Gram per kilogram
HCO_3^-	Bicarbonate
ha^{-1}	Per hectare
hrs	Hours
hr	Hour
ICAR	Indian Council of Agricultural Research
K	Potassium
K_2O	Potassium oxide
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
M	Million
M	Molar
mL	millileter
mM	Millimolar
mm	Millimeter
meq/L	Mill equivalent per liter

meq/100g	Mill equivalent per 100 gram
mg g^{-1}	Miligram per gram
$MgCl_2$	Magnesium Chloride
Mn	Manganese
mmhos cm^{-1}	Millimhos per centimeter
Max.	Maximum
Mg	Mega gram
mg	Milligram
Min.	Minimum
N	Nitrogen
NO_3^-	Nitrate
NaCl	Sodium Chloride
Na_2SO_4	Sodium Sulphate
$NaHCO_3$	Sodium Bicarbonate
No.	Number
NS	Non significant
O.C.	Organic Carbon
O.D.	Optical density
P	Phosphorus
P_2O_5	Phosphorus pentaoxide
pH	Potential of hydrogen ion
ppm	Parts per million
R.O.	Reverse osmosis
RH	Relative Humidity
CRD	Completely Randomized block design
SE(m)±	Standard Error of mean

SO_4^{2-}	Sulphate
Sr. No.	Serial number
var.	Variety
v/s	Versus
viz.	Namely
Zn	Zinc

CONTENTS

1. INTRODUCTION

In many arid and semi-arid regions, use of saline water for irrigation in the absence of appropriate soil-water-crop management practices, often leads to the builds-up of salinity in the soil profile which adversely affects the crop productivity. Each year approximately 10 million hectares (M ha) of the world's irrigated land is abdoned mainly due to secondary salinization and alkalinization as consequence of adverse effects of irrigation (Prasad *et al.* 2010). Scarcity of good quality water forces the farmers to use available poor quality water for irrigation.

The quality of irrigation water plays a vital role in crop production. Generally, irrigation water from all sources contains dissolved salts in very low concentration. The use of saline water for irrigation adversely affects productivity of soil by influencing the uptake of nutrients and many soil properties. This problem becomes more aggravated when the chloride, sulphate, carbonate and bicarbonate of saline water occur in association with sodium, calcium and magnesium creating the problem of salinization.

Salinity is known to influence physiological, biochemical and morphological changes in plants which reflect on overall performances of the plant. Generally, these changes due to salinity stress may adversely affect the plant growth and metabolism. The use of saline irrigation water has an adverse effect on soil–water–plant relations, occasionally severely restricting the normal physiological activity and productive capacity of the crops. Under high salinity level, the crop growth, leaf surface expansion and primary carbon metabolism of many crops are negatively affected due to osmotic effect, water deficit, nutritional imbalance and oxidative stress. Several crops are sensitive to salinity and the negative effect on growth leads to the decrease in potential profits. For this reason, salinity has been considered as one of the most important factors of irrigation water. Irrigating saline water can also result in salt accumulation in soil, leading to the decrease in yield and deterioration in soil resource.

In nature, usually the soil salinity is caused by excessive chloride, sulphate, carbonate, bicarbonate and other types of soluble salts which create unfavourable condition for plant growth and metabolism. It is generally observed that the crop growth is usually poor in areas where chloride is dominant over sulphate in irrigation water even when composition of water, types of soil, nutrient status, management practices *etc*. are almost identical (Manchanda, 1976; Bandyopadhyay *et al*. 1985; Grattan and Mass, 1985).

Fortunately the agricultural crops, in general, show marked difference in their ability to grow under saline condition and a great variability exists among varieties as well as species level (Epstein, 1972; Mass and Hoffman, 1977). Salinity stress is a serious problem in arid and semi-arid tropics and in the Indo-Gangetic plains in irrigated areas. It is recognized as major constraint in the production of this crop where 50 mM NaCl can cause yield losses ≥70% (Hasanuzzaman *et al*. 2013; Jacoby, 1999). The arable land is continuously transforming into saline (1-3% per year) either due to natural salinity or due to human interference which accounts nearly 20% of the irrigated agricultural land.

Salinity is the concentration of dissolved mineral salts (electrolytes of cations and anions) present in the soil and water. The major cations in saline soil solutions consist of Na^+, Ca^{2+}, Mg^{2+} and K^+ and the major anions are Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-} and NO_3^-. Plants in saline soils not only suffer from high sodium level but also affected by some degree of hypoxia by the action of Na^+ ions because when they occupy the cation exchange complex of clay particles makes the soil more compact thereby hampering soil aeration. According to the USDA Salinity Laboratory, saline soils have the EC_e is ≥4 dS m^{-1}. Sodium ions in saline soils are toxic to plants because of their adverse effects on potassium ion nutrition, cytosolic enzyme activities, photosynthesis and metabolism (Lambridge and Godwin, 2007; Liener, 1975).

Due to global climate change, green gram also encounters the cumulative adverse effects of other environmental factors as insects, pests, high temperature, pod shattering along with salinity causing high yield loss. Salt stress inflicts considerable adverse effects on plant growth, symbiotic association of nodules and soil rhizobia and finally the nitrogen fixation capacity. However, the intensity of adverse and injurious effects of salinity stress depends upon the nature of plant species, concentration and duration of salt stress, plant developmental stage, and mode of salt application to the crop. Salinity is a polygenic trait which adversely affected the biometric, morpho-physiological, biochemical and biophysical characters of green gram.

Soil salinity causes prominent losses of yield in all crops, therefore causing to reduction in crop production (Ashraf, 2009 and Cha-um *et al*. 2011). Reduction in yield due to salinity is due to a number of physiological and biochemical abnormalities in plants grown which have been mentioned in a number of comprehensive reviews on salinity effects and tolerance in plants (Munns and Tester, 2008; Jamil *et al*. 2011 and Krasensky and Jonak, 2012).

Pulses are considered as a principal source of protein in India. These crops are important food crops occupying a unique position in every known system of farming as main, catch, cover, green manure, intercrop and mix crop. Its inclusion in rotation keeps the soil alive and productive. Pulse crops enrich the soil fertility adding organic matter and biological nitrogen fixation mediated by root nodule bacteria *Rhizobium*.

Green gram (*Vigna radiata L.*); commonly known as "mung" or "mungbean", is one of the most important and extensively cultivated pulse crop of the Indian sub-continent. Green gram is native of India and central Asia and grown in these regions since prehistoric times. It is widely cultivated throughout the Asia, including India, Pakistan, Bangladesh, Sri lanka, Thailand, Laos, Cambodina, Indonesia, Malaysia and South China. The cultivation of green gram is mainly confined to the states *viz*. Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Uttar Pradesh Rajasthan, Tamilnadu and Orrisa covering 4.40, 2.30, 5.28, 6.71, 0.72, 10.60, 1.71 and 2.55 lakh hectares, respectively. (Anon., 2014)

In Gujarat, green gram is mainly grown in the districts of Kutch, Banaskantha, Mahesana and Panchmahal in *kharif* season under inadequate and erratic rainfall. However, it is grown on large area during summer season in Kheda, Baroda and Panchmahal districts. With the availability of irrigation water through Narmada project, area under green gram crop will be increased in middle and north Gujarat. Green gram matures in 65 to 70 days and due to photo and thermo insensitivity, it can be grown during *kharif*, *rabi* and summer seasons. The yield level of summer green gram is higher as compared to *kharif* crop because of minimum biotic and abiotic stresses (Anon., 2004). Because of short duration of the crop and adjustability under different cropping systems or situations, green gram has enormous potential for the future, which needs to be capitalized.

Green gram is rich in protein as it contains about 24 per cent protein which is almost three times more than that of cereals. Legume crops are not only used as human diet but also for improving soil fertility through biological nitrogen fixation. Its seed is more palatable, nutritive, digestible and non-flatulent than other pulses grown in country. Green gram is primarily consumed in the form of *dhal.* Green pods are also used as vegetable and haulms as green fodder. Its seeds contain 24% protein, 1.2% fat and 62% carbohydrates. The lysine, methionine and cystine are 436, 75 and 55 mg g^{-1}, respectively. It is rich in vitamin A (Reddy, 2013).

In order to generate location specific information on "**Effect of saline water on growth, yield and quality of green gram (*Vigna radiata* L.) varieties"** the present study was conducted during summer, 2017 in the net house at Model Laboratory of Micronutrient Research Project (ICAR), A.A.U., Anand with following specific objectives.

OBJECTIVES:

1. To evaluate the effect of salt concentration on growth, quality and yield of green gram varieties
2. To study the effect of saline water on the content of nutrients in soil and plant
3. To study the relative salt tolerance nature of green gram varieties

2. REVIEW OF LITERATURE

Salinity is one of the most important factors limiting the crop production. The crop response, in general, show marked difference in their ability to grow under saline conditions and great variability exists at varietal as well as species level (Dhawan *et al*. 1987; Epstein, 1972; Mass and Hoffman, 1977). Pulse crops show very widely diversified responses towards salinity, not in varieties and strains but different stages of growth of the same crop may exhibit different tolerance. An understanding of relationship between salinity levels of irrigation water and crop responses in different types of soil and management practices to be adopted to minimize adverse effect is required. An attempt has been made to review the available literature on the related aspects and presented in this chapter under followings headings.

2.1 Effect of salt concentration on the germination

2.2 Effect of salt concentration on the plant growth and yield

2.3 Effect of salt concentration on the proline content

2.4 Effect of salt concentration on the nutrient composition

2.1 EFFECT OF SALT CONCENTRATION ON THE GERMINATION OF THE CROP

Maliwal and Paliwal (1982) tested 8 varieties of gram and 6 varieties of linseed at five levels of salinity (EC of 3, 6, 9, 12 and 18 dS m^{-1}) in Hogland solution in sand culture. Varieties showed significance difference in relation to duration and percentage of germination. The variety G-24 of gram and K-2 of linseed were found most salt tolerance up to 9 dS m^{-1}.

Kumar and Malik (1983) tested six cultivars of Indian mustard with salinity levels of 2.1 (control), 4, 8, 12 and 16 dS m^{-1} during 1978-79, 79-80 and observed average seed germination of 31.2 and 11.7 per cent at 16 dS m^{-1} in 1st and 2nd year, respectively. The variety T-59 recorded the highest germination of 57.5 and 45.6 per cent and lowest of 53.1 and 38.3 per cent was with the variety Prakash in both the years, respectively. In another study, Kumar and Kumar (1985) indicated 88.8 and 32.7 per cent germination of mustard at salinity level 2.1 and 16 dS m^{-1}, respectively. The highest (61.2%) and the lowest (51.5%) germination were found with variety *viz*. Appress pod and T-6342, respectively.

Kumar and Dauley (1995) tested 46 strains of castor on saline soils with ECe control (0.2), 12.5 and 16.6 dS m^{-1}. They noticed that seedling emergence was delayed and depressed with rise in salinity levels. The emergence to the extent of 2.2, 2.6 and 10.4 per cent observed at ECe 16.6 dS m^{-1} as against 52.5, 60.0 and 65.2 per cent in control at 8^{th}, 12^{th} and 16^{th} day of sowing, respectively.

An experiment was conducted by Kaymakanova M. (2009) to study the effect of salinity on germination and seed physiology in bean in which three bean cultivars (*Phaseolus vulgaris* L.) treated with NaCl and Na_2SO_4 was investigated. Result showed that all treated cultivars registered decrease in the percentage of germination, seedlings growth and respiration rate.

Mudgal *et al.* (2009) observed the changes in growth and metabolic profile of Chickpea under salt stress. From ten genotypes of chickpea, three cultivars were screened in saline soils; two of them are kabuli (PUSA-1053, PUSA-939) and one desi types (BG-256). Saline water of varying concentrations (0, 4, 8, 12, 16 dS m^{-1}) NaCl, Na_2SO_4, $CaCl_2$ were supplied to the seedlings. Results showed that salinity reduced germination in all the three cultivars.

A laboratory experiment was conducted by Sabah and Hana (2010) in petri dishes to find out the effect of different salt concentration levels (0, 50, 100, 150 and 200 mMol/L) of sodium chloride on the seeds germination and growth of mungbean plant. They showed that the increase in salinity concentration cause a decrease in seeds germination percentage and growth of the crop.

Ahmed *et al*. (2012) studied the impact of salinity on seed germination and early seedling growth of three sorghum cultivars in which salinity stress through sodium chloride (NaCl) at the levels of 0 (as control), 2, 4, 8 and 16 dS m^{-1} and three sorghum (*Sorghum bicolor* L. Moench) cultivars (Arfagadamak, Wad Ahmed and Butana) were tested. Seed germination percentage, seedling root dry weight and seedling shoot dry weight were measured. Low level of salinity (2 dS m^{-1}) increased seed germination percentage, while the high levels (4, 8 and 16 dS m^{-1}) inhibited the seed germination significantly.

Dutta and Bera (2013) studied the effect of different salinity levels on germination, seedling growth and vigour and chlorophyll contents of five mungbean [*Vigna radiata* (L.) Wilczek] cultivars *viz.* Pusa Baisakhi, PS-7, B-105, Pusa-105 and Suniana. The percentage of germination, seedling growth parameters and seedling vigour index were found to decrease under salinity stress. Salinity caused reduction in chlorophyll contents, chlorophyll a/b ratio and chlorophyll stability index. Among the five cultivars studied, Pusa Baisakhi showed better growth performance and comparatively higher tolerance to salinity.

Panuccio *et al.* (2014) studied the effect of saline water on seed germination and early seedling growth of the halophyte quinoa. They evaluated the effects of sea water and different salts on seed germination, seedling emergence and the antioxidative pathway of quinoa. Seeds were germinated in petri dishes and seedlings grown in pots with sea water solutions (25, 50, 75 and 100%) and NaCl, $CaCl_2$, KCl and $MgCl_2$ individually, at the concentrations in which they are present in sea water. Results demonstrated that all salts, at lower concentrations, increased the germination rate but not the germination percentages, compared with control (pure water).

2.2 EFFECT OF SALT CONCENTRATION ON THE PLANT GROWTH AND YIELD

Bhumbla and Singh (1965) tested germination of barley, wheat, sugarbeet, gram, berseem and mustard crops at EC levels of 2, 4, 8, 12 and 16 dS m^{-1}. Barley was the most tolerant followed by wheat, sugarbeet, berseem, mustard and gram.

Reddy (1982) observed injury to mungbean cultivars with irrigation water containing electrical conductivity of 4 dS m^{-1}.

Singh *et al.* (1999) reported that salinity had no adverse effect on capsicum, normal growth occurring upto 4 mmhos cm^{-1}, but above this level a progressive decrease in growth was noted. The highest yield (156 g/plant) was obtained at 2 mmhos cm^{-1}, while the control yielded 149.5 g/plant.

Francois and West (2004) reported that the yield of celery cv. Tall Utah 52-70R was reduced by 6.2 per cent for each unit increase in soil salinity beyond 1.8 dS m^{-1}. The petiole length, width and thickness were significantly reduced with increasing salinity but petiole pith development remained unaffected.

Meloni *et al.* (2004) studied the effects of salt stress on growth and nitrate reduction in *Prosopis Alba*. 17 days old seedlings were subjected to three salt treatments by adding NaCl to the growth medium in 50 mmol L^{-1} increments every 24 h until the final concentrations of 0, 300 and 600 mmol L^{-1} were reached. Only the highest NaCl concentration affected all of the considered parameters. Thus, 600 mmol L^{-1} NaCl caused a significant reduction in root and shoot growth, but an increase in the root/shoot ratio. Leaf relative water content, nitrate content and nitrate reductase activity in leaves and roots were also decreased.

Magda and Kramany (2005) studied the effect of salinity stress on yield characteristics. Soil salinity caused reduction in flowering and severe yield loss in many crop plants including legumes *viz*., soybean, mungbean, wheat, barley, bean, rice and cotton.

Jaoguin *et al.* (2007) observed that seed yield of soybean was reduced when EC and ESP was more than 1.71 dS m^{-1} and 10.51 per cent, respectively. At EC and ESP of 4.43 dS m^{-1} and 22.7 per cent, a reduction of 50 per cent in yield was recorded.

To evaluate the effects of different level of Na salinity (0, 3, 6 and 9 dS m^{-1}) on growth, yield and yield component of Kabuli (Hashem and Jam) and Desi (Kaka and Pirooz) chickpea cultivars, an experiment was conducted by Sohrabi *et al.* (2008). Seeds of four chickpea cultivars were grown under 0, 3, 6 and 9 dS m^{-1} levels of salinity until maturity. Salinity reduced the plant growth, flower, pod and seed number and seed weight. As increase in salinity, the undesirable effect of Na^+ was more pronounced and reached the highest value at 9 dS m^{-1} in all cultivars.

Ahmed (2009) conducted an experiment with 5 mungbean accessions/genotypes with the aim of ascertaining the effect of salt stress on the yield and its component. The decrease in seed yield per plant under salt stress was more pronounced, associated with a reduced number of seed per pod and 100 seed weight. Consequently salt stress was more effective at vegetative, flowering and seed filling stages rather than seed development stage in all the five accessions/genotypes. Delayed maturity due to salt stress pushes the plant also be desiccation stress causing shrivelled seeds.

Mahmood *et al.* (2009) studied the effect of salinity on growth, yield and yield components in basmati rice germplasm in which salt tolerance of 4 commercial varieties and 17 breeding lines of Basmati rice (*Oryza sativa* L.) was assessed at early growth stage and at maturity in field plots artificially salinzed with NaCl and $CaCl_2$ (1:1 by weight). Result showed that on an average plant height, number of tillers per plant, panicle length, number of grains per panicle, shoot dry weight, grain straw ratio, grain yield per plant, K content of shoot and K/Na ratio were reduced linearly while grain sterility and Na content of shoot were increased with increasing soil salinity.

Panda and Khan (2009) observed the growth, oxidative damage and antioxidant responses in green gram (*Vigna radiata* L.) under short-term salinity stress and its recovery. They investigated spatio-temporal differences under short-term NaCl-salinity (0, 50, 100, 150 mM L^{-1}) on the growth, water relations, ionic composition, proline and antioxidants of 12 days old roots, stem and leaves of green gram. Fresh and dry weight, relative water content and K^+ ion decreased, whereas, Na^+ ion and Na^+/K^+ ratio increased significantly in roots, stem and leaves.

Kumar *et al.* (2012) conducted an experiment to study the effect of salinity on germination, growth, yield and yield attributes of wheat. Eight genotypes of wheat are selected with varying in their salt tolerance level to evaluate the effect of salinity on germination, growth, and yield related parameters. They observed that lower salinity (3 dS m^{-1}) did not affect the germination, growth and yield attributing parameters. Higher salinity levels reduced germination, growth and yield attributing parameters.

Sehrawat *et al*. (2013) stated that high salt accumulation resulted in decreased osmotic potential of soil solution eliciting water stress in plants and further interactions of the salts with mineral nutrition caused nutrient imbalance and deficiencies, oxidative stress or even pathology eventually lead to plant death as a result of physiological changes, metabolic damage and growth arrest.

Ghosh *et al*. (2014) studied the physiological and biochemical responses to increasing NaCl concentrations, along with low concentrations of gibberellic acid, either alone or in their combination, in mungbean seedlings. In the test seedlings, the root-shoot elongation, biomass production and the chlorophyll content were significantly decreased with increasing NaCl concentration.

Sreejith *et al*. (2014) studied the effect of salt stress on seed germination and seedling growth in which they used different concentrations of salt, (sodium chloride - 50 mM, 150 mM and 250 mM). Salt stress responses were determined by assessing seedling vigour, growth, dry and fresh weight, water uptake, pigment degradation, amount of free amino acid and total protein content. The results showed that the stress adaptability was higher in seedlings when exposed to different concentrations of salt after completing its initial stages of germination in normal water. They observed lower salt concentration (50 mM) has a stimulatory effect on the growth of green gram seedlings.

Pot culture experiment was planned by Sharma and Dhanda (2015) to study mitigation of saline stress on mungbean by $CaCl_2$ treatment. It was observed that in the presence of individual NaCl and $CaCl_2$ treatment, the growth of plant was reduced with its some major changes in important stress related physiological contents (chlorophyll and carotenoids). In contrast combined treatment of NaCl and $CaCl_2$ reduced saline stress in these plants, increased their growth and yield.

Nivedita *et al.* (2016) tested biochemical response of *Solanum Melongena* to salinity stress in relation to stress factors. The experiment was conducted on 60 days old plants. Four replicates were taken wherein two of the replicates were subjected to 25 mM NaCl and other two to 50 mM NaCl on every third day for duration of 10 days. The stress was found to reduce the dry and fresh weight and relative water content of the leaf tissue respectively.

Hasan *et al.* (2017) tested the screening of salt tolerance capability of wheat genotypes under salt stress condition. To screen salt tolerance wheat genotypes, germination and seedling growth characters were used as screening criteria. 33 wheat genotypes were tested under 5 different salt concentrations (0, 5, 10, 15 and 20 dS m^{-1}). The results of the experiment revealed that various germination and seedling growth parameters of the wheat genotypes varied significantly under salt stress. A marked reduction of germination rate, shoot and root length, shoot and root dry weight, relative water content, water retention capacity and vigour index was observed with the increasing of salt concentration for most of the wheat genotypes.

Prakash (2017) conducted an experiment to study the effect of saline on germination and seedling attributes, four cultivated varieties of green gram were subjected with five levels of salinity *viz*., 0, 4, 8 and 12 dS m^{-1}. Genotypic variation was observed for germination and seedling characters among the varieties. The results revealed that with increase in salinity levels, greater reduction was observed for all the parameters. Germination per cent, seedling length, shoot, root and total dry matter production, seed vigour and salt tolerance index were found reduced in all the varieties studied with more reduction at higher salinity (12 dS m^{-1}) level rather than other lower salinity levels and shoot root ratio was found increased with increase in salinity.

2.3 EFFECT OF SALT CONCENTRATION ON THE PROLINE CONTENT

Sudhakar *et al.* (1993) reported the influence of NaCl or Na_2SO_4 on glutamate, proline and glycine betaine contents, proline dehydrogenase and proline oxidase in green gram seedlings. The levels of glutamate decreased. Consequently, proline accumulated substantially in roots and shoots of stressed seedlings; glycine betaine content increased in the tissues.

Khatkar and Kuhad (2000) measured the soluble sugars, proline, total chlorophyll contents and electrolyte leakage in two wheat (*Triticum aestivum* L.) cultivars KRL 1-4 and HD 2009 at different growth stages [crown root initiation (CRI), flowering and soft dough] under short term salinity (NaCl, $CaCl_2$ and Na_2SO_4). The results showed that proline and sugar concentration increased in both cultivars under salinity with a maximum increase at CRI.

Misra and Gupta (2005) studied the effect of salt stress on free proline accumulation and chlorophyll contents in two cultivars of green gram (T-44 and SML-32, salt tolerant and salt sensitive, respectively) under the conditions of absence as well as in the presence of various levels of salinity. Salt stress resulted in a significant accumulation of free proline in shoots of both the cultivars of green gram. The magnitude of increase in free proline accumulation was higher in the sensitive cultivar than in the tolerant cultivar.

Lutts *et al*. (2007) investigated the salt-stress effects on osmotic adjustment, ion and proline concentrations as well as proline metabolizing enzyme activities were studied in two rice (*Oryza sativa* L.) cultivars differing in salinity resistance: I Kong Pao (IKP; salt-sensitive) and Nona Bokra (salt-resistant). The salt-sensitive cultivar exposed to 50 and 100 mM NaCl in nutritive solution for 3 and 10 days accumulated higher levels of sodium and proline than the salt-resistant cultivar and displayed lower levels of osmotic adjustment.

Jampeetong and Brix (2009) investigated the effects of NaCl salinity on growth, morphology and photosynthesis of *Salvinia natans* (L.). All were investigated by growing plants in a growth chamber at NaCl concentrations of 0, 50, 100 and 150 mM. The contents of proline in the plant tissue increased at high salinity, but concentrations were very low (<0.1 mmol g^{-1} FW), indicating a limited capacity of S. natans to synthesize proline as a compatible compound.

Amirjani (2010) studied the salinity sensitivity of soybean in which the plants were exposed to 0, 50, 100 and 200 mM NaCl. Increasing salinity level to 50, 100 and 200 mM resulted in a reduction of plant height and fresh weight. Consequently, proline content was increased in soybean under 50 to 200 mM NaCl.

Nazarbeygi *et al.* (2011) observed the response of canola to different levels of salinity. In their experiment the seedlings were placed in the different salt medium (0, 75, 100 and 150 mM) as salinity treatments. After 20 days the contents of a- and b-chlorophylls and proline were tested in the plant roots and leaves. Results showed that salinity stress had significant effect on increase of a and b chlorophylls and content of proline ($p<0.01$). Salinity induced significant increase of proline content in leaf and root ($p<0.01$).

An experiment was conducted by Saady *et al.* (2012) to investigate selected physiological characteristics like germination stress, proline and chlorophyll content under salinity stress, 8 Omani fenugreek accessions were exposed to 0, 4, 6, 8, 10 dS m^{-1} NaCl for 8 days. All accessions showed salt tolerance at germination and seedling growth at low level of salinity. But germination was delayed as NaCl concentration increased and 10 dS m^{-1} NaCl showed very poor germination rate. The accessions were then transferred to pots under same salt concentration to analyze the proline and chlorophyll content. The presence of NaCl in soil significantly influenced both proline and chlorophyll content and they both correlated positively.

Huang *et al.* (2013) noticed proline accumulation profiles in roots, stems and leaves of Jerusalem artichoke (*Helianthus tuberosus* L.) under NaCl stress. The result showed that Jerusalem artichoke plantlets were observed to accumulate proline in roots, stems and leaves during salt stress which is mainly through the Glu pathway.

Kaur and Gupta (2018) observed the influence of proline and ascorbic acid on physiological parameters in seeds subjected to different levels of salt stress in tomato. Different treatments (hydration, different concentrations of proline 5mM, 10mM and ascorbic acid 1mM, 4mM) were given to seeds at 25mM, 50mM and 75mM NaCl concentrations. The results showed that proline 10mM and ascorbic acid 4mM were more effective than proline 5mM and ascorbic acid 1mM respectively. All the seed treatments increased the physiological parameters (percent germination, seedling length, seedling biomass, speed of germination, vigour indexes I and II) of seedlings as compared to control at different salinity levels.

2.4 EFFECT OF SALT CONCENTRATION ON THE NUTRIENT COMPOSITION

Paliwal and Maliwal (1980) conducted a green house study in quartz sand (free from nutrients) using china clay pots on the growth and chemical composition of some crops viz. pearlmillet, sorghum, blackgram and green gram at different salinity levels (3, 6, 9, 12 and 18 dS m^{-1}). The content of N and P in plant decreased with increase in salinity, except blackgram, where N uptake increased.

Fageria (1985) evaluated rice cultivars with EC of 0.29, 4, 10 and 15 dS m^{-1} of saturation extract developed by NaCl. The concentration of Zn, Cu and Mn increased with salinity, while significant varietal differences were observed.

Kabir *et al*. (2004) reported that salinity disturbs mungbean plant growth by creating nutrient imbalance and disturbance in plant water relations. In this study, mungbean plant (var. BARI mung 3) was grown in pot at three levels of K *viz*. 14, 40 and 60 kg ha^{-1} under 0 and 75 mM NaCl saline conditions. Result showed that salinity decreased the uptake of N, P, K and Ca, while increased Na uptake several fold. Mg accumulation was unchanged due to salinity. K doses had no significant influence on nutrient uptake by mungbean plant, though the uptake of most of the nutrients showed an increasing tendency with increased levels of K application.

Lal and Bhardwaj (2004) found that content of K and Zn in peas decreased from 3.219 to 2.167 and 0.277 to 0.311%, while content of Ca and Na increased from 1.700 to 2.641 and 0.133 to 0.503% at 4 and 8 dS m^{-1}, respectively.

Hirpara *et al*. (2005) reported that salinisation of soil affects mineral accumulation of *Butea monosperma* Taub (Fabaceae). Sodium chloride (NaCl) was added to the soil and salinity was maintained at 0.3, 1.9, 3.9, 6.2, 8.2, 10.2, 12.2 and 13.8 dS m^{-1}. Results showed that sodium content significantly increased in leaves and stems and there was no effective mechanism to block Na transfer to shoot tissues. Potassium content also significantly increased in tissues; however, Na was transferred to the tissues in greater proportion than K. Nitrogen and phosphorus contents significantly decreased in all tissues in response to salinisation of soil.

Sinha *et al.* (2007) studied the effects of soil salinity and soil water regime on growth and chemical composition of *Sorghum helepense* L. With a view to evaluating its potential as a forage crop in saline soils, the experiment was conducted under controlled conditions using pot- culture with three levels of soil salinity (EC 0.5, 5.0, 10.0 dS m^{-1}) and three soil water regimes (60%, 40% and 20% of water holding capacity of soil). The results showed an increase in the concentration of certain nutrients (N, Ca, and Mg) in the plants in response to salinity, which along with increase root: shoot ratio was inferred as an adaptive feature for the plant for persistence under saline condition.

Bhatt *et al*. (2008) conducted a greenhouse experiment to assess the effects of soil salinity on emergence, growth, water content, proline content and mineral accumulation of seedlings of *Ziziphus mauritiana* Lam. (Rhamnaceae). Sodium chloride (NaCl) was added to the soil to maintain electric conductivity at 0.3, 3.9, 6.0, 7.9, 10.0 and 11.9 dS m^{-1}. Results showed that nitrogen, phosphorus, calcium and magnesium content in seedling organs significantly decreased as soil salinity increased.

Mass *et al*. (2012) investigated the influence of salinity on the uptake of Fe, Mn, and Zn by plants during the period of rapid vegetative growth. Tomato (*Lycopersicon esculentum* L.), soybean (*Glycine max* L.) and squash (*Cucurbita pepo*) were grown in the greenhouse in half-strength Hoagland‘s solution salinized with 0, 25, 50, 75 and 100 meq NaCl/liter. Concentrations of Fe and Zn increased in the roots and tops of each species with increasing ambient levels of NaCl. Manganese concentrations increased in tomato and soybean tops but decreased in squash tops. Concentrations of Mn in the roots of tomato and squash were reduced at all salt levels, but they increased in the 100 meq/litre treatment in soybean.

Prapagar *et al.* (2015) designed a study to assess the plant nutrient availability of manure treated soil at different soil salinity levels. Cow dung and paddy straw were chosen as organic amendments and applied at the rate of 10 tons/ha. Manure decomposition and nutrient availability studied at three salinity levels namely 1500, 2000 and 2500 ppm. Treatments were incubated at 25°C for 42 days. With increasing salt concentration nutrient availability was significantly decreased in manure amended soil. Application of cow dung to soil had shown highest available N (0.223%) and P content (110.14 ppm) at 1500 ppm salt concentration. Highest available K content (158.33 ppm) was observed from paddy straw treated soil at 1500 ppm salt concentration.

3. MATERIALS AND METHODS

A pot experiment was conducted during summer season of 2017 in the net house at Model Laboratory, Micronutrient Research Project (ICAR), Anand Agricultural University, Anand to carry out the study on "**Effect of saline water on growth, yield and quality of green gram (*Vigna radiata* L.) varieties**". The details of materials used, procedure followed and methods adopted for conducting present investigation are described in this chapter.

3.1 LOCATION OF EXPERIMENTAL SITE

Anand district is located approximately between 22° 6' to 22° 43' North latitude and 72° 2' to 73° 12' East longitude. The geological formation of the Anand district is made up of Inceptisols, Entisols, Vertisols and Aridisols type of soil orders with medium black to loamy sand (Goradu) soil type of soil texture.

3.2 CLIMATE AND WEATHER CONDITION

The climate of the region is typically semi-arid characterized with extremes of the temperature both during summer and winter. The average rainfall of this region is about 625-1000 mm, which is mostly received between July and September (Monsoon season) and mean annual temperature is about 27°C. The observation on temperature, bright sun shine, relative humidity, rainfall and wind velocity recorded at college meteorological observatory during the period of experimentation are presented in the Table 3.1.

3.3 COLLECTION AND PREPARATION OF SOIL SAMPLE

A composite bulk soil sample was collected from a plough layer (0-15 cm depth) of constructional site of Department Soil Science and Agricultural Chemistry, B.A.C.A., A.A.U., Anand. The soil sample was air dried, powdered with wooden mortar and was passed through a 2 mm sieve and mixed thoroughly. This soil was used for conducting the present investigation.

3.4 DESCRIPTION OF SOIL UNDER STUDY

The soils were analyzed for their physico-chemical properties (Table 3.2). The soil collected from constructional site of Department Soil Science and Agricultural Chemistry, B.A.C.A., A.A.U., Anand was of Typic Ustochrepts, having loamy sand soil texture, slightly alkaline in reaction (pH-9.07). Where organic carbon content and available N were low in status, while available S, Zn, Fe and Mn were medium in soil, whereas available K_2O, P_2O_5 and Cu contents were high in soil.

Table 3.1 Meteorological data recorded during crop season for the year 2017 (weakly mean)

Month and year	Std. Met. Week	Date	Temp (°C)		Bright Sun Shine (hrs day^{-1})	Mean R.H. (%)	Wind velocity (km hr^{-1})	Rainfall
			Max	Min				
March, 2017	13	26-1	40.8	20.8	10.0	41.8	3.7	0.0
April, 2017	14	02-08	37.3	20.6	10.0	58.8	6.5	0.0
	15	09-15	41.2	18.8	10.4	29.1	3.7	0.0
	16	16-22	40.5	22.8	10.6	46.9	6.4	0.0
	17	23-29	37.5	21.7	10.6	54.8	5.8	0.0
	18	30-06	40.5	22.9	10.4	49.2	4.6	0.0
May, 2017	19	07-13	41.6	24.8	11.2	52.5	5.2	0.0
	20	14-20	41.1	25.0	10.7	50.1	6.2	0.0
	21	21-27	40.1	25.6	11.1	57.5	6.5	3.4
	22	28-03	39.0	28.0	9.7	63.2	8.2	0.0
June, 2017	23	04-10	39.0	27.4	9.0	63.9	8.4	2.0

Table 3.2 Initial physico-chemical properties of the soil used for pot study

Sr. No	Characteristics		Method	Reference
A. Mechanical analysis				
1	Coarse sand (%)	3.45	International pipette method	Piper (1966)
2	Fine sand (%)	75.49		
3	Silt (%)	13.05		
4	Clay (%)	6.75		
5	Texture	Loamy sand	USDA Method	

B. Chemical analysis				
1	pH	9.07	Potentiometric (1:2.5) Soil: water suspension	Jackson (1973)
2	EC (dS m^{-1})	0.14	Conductometric (1:2.5) Soil: water suspension	
3	Organic carbon (g kg^{-1})	4.2	Walkley and Black wet oxidation method	Jackson (1973)
4	Available N (kg ha^{-1})	196	Alkaline permanganate method	Subbiah and Asija (1956)
5	Available P_2O_5 (kg ha^{-1})	62.10	Olsen's method	Olsen *et al.* (1954)
6	Available K_2O (kg ha^{-1})	325.3	Neutral Normal Ammonium acetate method	Jackson (1973)
7	Available S (ppm)	11.97	Turbidometric method	Williams and Steinbergs (1959)
8	Exchangeable Ca^{2+} (meq/100g)	2.92	Versenate titration method	Chang and Bray (1951)
9	Exchangeable Mg^{2+} (meq/100g)	1.22		
10	Exchangeable Na^{+} (meq/100g)	1.79	Flame photometric	Richards (1954)
11	DTPA- Zn (mg kg^{-1})	0.83	Atomic Absorption Spectrophotometric (AAS) method	Lindsay and Norvell (1978)
12	DTPA- Fe (mg kg^{-1})	6.6		
13	DTPA- Mn (mg kg^{-1})	7.85		
14	DTPA- Cu (mg kg^{-1})	0.91		

Table 3.3 Analysis of tap water (water soluble) used for pot study

pH	**EC (dS m^{-1})**	**Ca^{2+} meq L^{-1}**	**Mg^{2+} meq L^{-1}**	**Na^{+} meq L^{-1}**	**CO_3^{-} meq L^{-1}**	**HCO_3^{-} meq L^{-1}**	**Cl^{-} meq L^{-1}**	**SO_4^{2-} meq L^{-1}**
7.7	0.9	0.8	3.7	1.6	0.8	9.6	5.6	0.3

3.5 FILLING OF POTS

Soil was filled in cylindrical earthen pots (20 cm diameter and 28 cm height). Each pot had 10 kg of soil. At the time of filling the pots, the broken pieces of stone were placed on the bottom hole to allow free drainage. The recommended dose of N and P_2O_5 were added by applying DAP and urea. For counting the fertilizer quantity, the weight of hectare furrow slice (15 cm depth) is used as a base which is 22, 44, 000 kg per hectare.

3.6 POT CULTURE STUDY

A pot experiment was conducted to study the effect of saline water on growth, yield and quality of green gram (*Vigna radiata* L.) varieties grown on a loamy sand soil. The details of the treatments were as under (Table 3.4).

Table 3.4 Experimental details

	Treatment details	
	Varieties	**Symbol**
	Meha	V_1
	GAM 5	V_2
	Salinity levels	
	Tap water (EC 0.9 dS m^{-1})	S_0
	EC 1.0 dS m^{-1}	S_1
	EC 2.0 dS m^{-1}	S_2
	EC 4.0 dS m^{-1}	S_3
	EC 6.0 dS m^{-1}	S_4
(ii)	**Experimental design**	CRD (factorial)
(iii)	**Repetition**	Four (04)
(iv)	**Treatment combination**	2 (V) × 5 (S) = 10
(v)	**Total no. of pots**	10 × 4 = 40 pots
(vi)	**Pot capacity**	10 kg soil pot^{-1}
(vii)	**Recommended fertilizer dose**	20-40-0 kg NPK ha^{-1}
(viii)	**Type of Soil**	Loamy sand
(ix)	**Crop and Variety**	Green gram (*Vigna radiata* L.), Meha and GAM 5
(x)	**Date of sowing**	29/03/2017
(xi)	**Date of harvesting**	04/06/2017

Table 3.5 Treatment combinations

Sr. No	Treatment Combination	Sr. No	Treatment Combination
1	V_1S_0	**6**	V_2S_0
2	V_1S_1	**7**	V_2S_1
3	V_1S_2	**8**	V_2S_2
4	V_1S_3	**9**	V_2S_3
5	V_1S_4	**10**	V_2S_4

3.7 ARTIFICIAL SALINIZATION OF WATER

The desired salinity in water was artificially prepared by dissolving required amount of $NaHCO_3$, NaCl, Na_2SO_4, $CaCl_2$, $CaCO_3$ and $MgCl_2$ in R.O. water (EC 0.01 dS m^{-1}). The tap water was used for the control and other pots were irrigated 7 times with water of varying EC as treatment during experiment. The composition of prepared water is given in Table 3.6.

Table 3.6 Composition of saline water

EC (dS m^{-1})	Ionic constitution (g/100 mL of R.O. water)					
	NaCl	$NaHCO_3$	Na_2SO_4	$CaCl_2$	$CaCO_3$	$MgCl_2$
6.0	0.05	0.11	0.11	0.11	0.11	0.11

By this composition, 50 L saline water of 6 dS m^{-1} was prepared and other saline water were prepared by dissolving it with R.O. water. 21 L of water was prepared per each respective treatment (4.0, 2.0 and 1.0 dS m^{-1}).

3. 8 AGRONOMICAL OPERATIONS

3.8.1 Fertilizer Application

DAP and urea was applied as per the recommended dose of the green gram (20:40:00 kg NPK ha^{-1}). As per the weight of hectare furrow slice mentioned above, the quantity of both the fertilizers were counted and applied with the irrigation water and mixed well with the soil (10 kg) of each pot.

3.8.2 Sowing

The green gram, seeds of variety Meha and GAM 5 both were treated with thirum @ 3 g kg^{-1} seed to control seed borne diseases. 8 treated seed per pot were sown on 29th March, 2017 and after germination, only five plants per pot were maintained. The crop was harvested on 4th June, 2017.

3.8.3 Irrigation

Measured volume (2.5 liter) of water was applied to each pot according to plan of experiment. Besides one pre sowing irrigation, six subsequent irrigations were given.

3.9 TREATMENTS EVALUATION

The effect of treatments was evaluated in term of growth and yield parameters.

3.9.1 Yield and Yield Attributes

3.9.1.1 Germination percentage (7 DAS)

$$\text{Germination \%} = \frac{\text{No.of seeds germinated}}{\text{Total no.of seeds sown}} \times 100$$

3.9.1.2 Plant height

The height of plant was measured at 30, 45 DAS and at harvest from base of the plant to tip of main shoot by meter scale.

3.9.1.3 Grain yield

Living plants of each pot were harvested at maturity and tied up and kept on threshing floor for sun drying. After complete sun drying the produce of each pot was weighed for recording biological yield. After threshing, winnowing and clearing, the produce of each pot was weighted separately and the weight recorded as grain yield in g per pot.

3.9.1.4 Stover yield

The weight of harvested material after picking the pods and weight of pod husk were added together and recorded as stover yield of green gram in g per pot.

3.10 ESTIMATION OF PROLINE

The proline content was analysed at pre-flowering, siliquae initiation and grain filling stages. Proline was estimated as per method described by Bates *et al*. (1973) The leaf tissue was ground in 3 per cent sulfosalicylic acid (10 mL) and filtered with whatman No. 2 filter paper. Five mL of filtrate was recorded with 5 mL of acid ninhydrin (1.25 g ninhydrin in 30 mL glacial acetic acid and 20 mL of 6 M phosphoric acid) add 5 mL of glacial acetic acid in a test tube for one hour at 100°C and reaction terminated in an ice bath. The reaction mixture was extracted with 5 mL toluene and the colour intensity was measured at 520 nm on spectrophotometer. The proline concentration was determined from a standard curve and calculated on fresh weight basis as follows:

$$\mu g \text{ proline/ g fresh weight} = \frac{\text{O.D.} \times \ \mu g \text{ proline/mL} \times \text{mL toluene} \times 10/5}{\text{fresh weight of material (g)}}$$

Where,

µg proline/mL = from standard curve

10 mL = sulfosalicylic acid extract

5 mL = aliquot

3.11 PLANT ANALYSIS

The plant samples were first air dried in the open sun and then oven dried at 65°C until the attainment of constant weight. The oven dried plant samples were ground with the help of a stainless steel grinder for subsequent analysis.

3.11.1 Nutrient Content

For estimation of nitrogen, phosphorus, potassium, sulphur, iron, manganese, copper and zinc content in representative samples of grain and straw taken at the time of threshing were ground to fine powder. Nutrient content in grain and straw were estimated by using standard methods given in Table 3.7.

Table 3.7 Methods for plant chemical analysis

Sr. No	Determination	Methods	Reference
1.	Nitrogen	Kjeldahl's Method	Jackson, 1973
2.	Phosphorus	Vanadomolybdo phosphoric acid yellow colour	
3.	Potassium	Flame photometric	
4.	Sulphur	Turbidometric method	Williams and Steinbergs (1959)
4.	Iron, Manganese, Zinc, Copper	Atomic Absorption Spectrophotometry	Lindsay and Norvell (1978)
5.	Protein	Kjeldahl's Method	Jackson, 1973
6.	Proline	Spectrophotometry	Bates *et al.*(1973)

3.12 SOIL ANALYSIS

To know the nutrient status of the soil, samples were collected from the pots after harvest of green gram crop. These samples were air dried, ground and passed through 2.0 mm sieve and then analysed for their nutrient content by adopting the methods indicated in Table 3.2.

3.13 STATISTICAL ANALYSIS

The statistical analysis of the data on plant height, grain yield and stover yield, content of N, P, K, S, Na, Fe, Mn, Zn and Cu in grain and stover were analysed by using 6 treatment combination while germination percentage and proline content were analysed by using 10 treatment combination and soil analysis for pH, EC, available N, P, K, S, OC, Ca, Mg, Na, Fe, Mn, Zn and Cu were done by using 10 treatment combination through statistical method of analysis of variance. To compare the treatment difference, the critical difference (CD) at 5 per cent level of significance was calculated as per method described by Steel and Torrie (1982) wherever 'F' test came out significant.

4. RESULTS AND DISCUSSION

The chapter embodies the results of the pot study entitled **"Effect of saline water on growth, yield and quality of two green gram (*Vigna radiata* L.) varieties"** was carried out during summer season of 2017 in the net house of Micronutrient Research Project (ICAR), Anand Agricultural University, Anand (Gujarat). The data pertaining to growth parameter, yield, nutrients content (N, P, K, S, Na, Fe, Mn, Zn and Cu) in grain and stover, quality parameters (proline content in fresh weight of leaves and protein content in grain) as well as soil chemical parameters after harvest (EC, pH, N, P, K, S, Ca, Mg, Na, OC, Fe, Mn, Zn, and Cu) have been presented in the tables and also illustrated graphically, wherever necessary along with statistical inferences in this chapter. The results obtained in the present investigation are discussed here under following heads.

4.1 Effect of salt concentrations on germination percentage of green gram varieties

4.2 Effect of salt concentrations on the proline content of green gram varieties

4.3 Effect of salt concentrations on the plant growth and yield of green gram varieties

4.4 Effect of salt concentrations on the nutrient content of green gram varieties

4.5 Effect of salt concentrations on the chemical properties of soil after harvesting

4.1 EFFECT OF SALT CONCENTRATIONS ON GERMINATION PERCENTAGE OF GREEN GRAM VARIETIES

The mean data on germination percentage at 7 DAS of green gram varieties as influenced by different concentration and varieties are presented in Table 4.1 and graphically shown in Fig. 4.1.

It is revealed from the data that varieties did not bring out any significant influence on germination percentage, but salinity levels had significant effect on germination percentage of two green gram varieties.

Though the varieties did not differ significantly, variety V_1 (Meha) recorded the higher germination (77.5%) as compared to V_2 (GAM 5), indicating GAM 5 showed more sensitivity towards salts.

Decreasing trend in germination percentage was observed with increasing the salinity levels. The significantly higher germination percentage (98.4%) was found under S_0 level (EC_{iw} 0.9 dS m^{-1}) as compared to other levels and it was at par with S_1 level (EC_{iw} 1.0 dS m^{-1}). Significantly lowest germination percentage (48.4%) was observed at higher salinity level (S_4). The germination percentage was decreased to the tune of 38.10 and 50.81 per cent at EC_{iw} 4.0 and 6.0 dS m^{-1}, respectively over control. The germination percentage was decreased with increasing salt concentration (Fig. 4.1).

With regards to interaction effect between varieties and salinity levels, non significant result was observed.

Table 4.1 Effect of salt concentrations on the germination percentage (7 DAS) of green gram varieties

Sr. No.	Treatments	Germination (%)
A. Varieties (V)		
V_1	**Meha**	77.5
V_2	**GAM 5**	73.1
	S.Em. ±	1.75
	C.D. at 5%	NS
B. Salinity Levels (S)		
S_0	**Tap water (EC 0.9 dS m^{-1})**	98.4
S_1	**EC 1.0 dS m^{-1}**	92.2
S_2	**EC 2.0 dS m^{-1}**	76.6
S_3	**EC 4.0 dS m^{-1}**	60.9
S_4	**EC 6.0 dS m^{-1}**	48.4
	S.Em. ±	2.77
	C.D. at 5%	8.07
C. S × V Interaction		
	S.Em.±	3.91
	C.D. at 5%	NS
	C.V. %	10.39

The greater reduction in germination at higher levels of S_3 and S_4 could be due the specific ion effect (Hassen, 1999), or to the limited water supply as a result of low osmotic potential (Dutt, 1976). The negative effect of salinity during germination was due to the toxic and osmotic effects of salt ions especially sodium and chloride (Khan *et al*., 1999; Tester and Davenport, 2003). These results are in accordance with Al – Zubaydi *et al*., (1992); Nasir, (2002); Al-Seedi, (2004).

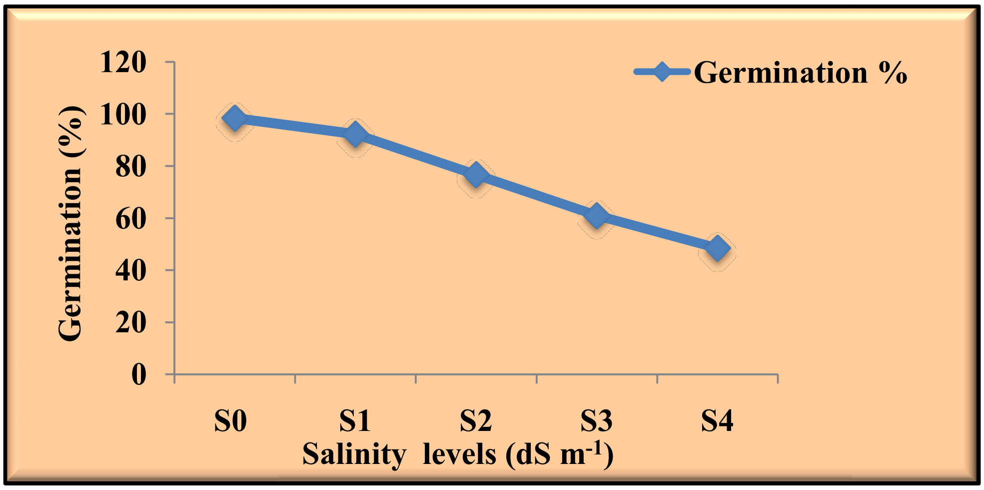

Fig.4.1: Effect of salt concentrations on germination (%) of green gram varieties

4.2 EFFECT OF SALT CONCENTRATIONS ON THE PROLINE CONTENT OF GREEN GRAM VARIETIES

The results of the effect of different varieties and salt concentrations on proline content of leaves after 15 DAS are given in Table 4.2 and graphically shown in Fig. 4.2.

It is observed from the data presented in Table 4.2 that the varietal and salinity levels effect were found significant, while interaction effect of variety and salinity levels was found non significant for proline content .

Data showed that the varietal effects on proline content found significant, where the variety V_1 (Meha) recorded significantly highest proline (148.30 µg g^{-1}) content (Table 4.2).

With respect of salinity levels effect, positive relationship with proline content was noted (Table 4.2). The proline content of leaves linearly and significantly increased with increasing salt concentration (Fig 4.2). It was ranged from 50.17 to 241.28 µg g^{-1} of fresh weight of leaves. It was significantly highest at S_4 level (EC_{iw} 6.0 dS m^{-1}) which was 241.28 µg g^{-1}.

The overall proline accumulation increased with increasing salt concentration (Fig. 4.2). The higher accumulation of proline may be due to enhanced activities of ornithine aminotransferase (OAT) and pyrroline-5-carboxylate reductase (P-5-CR), the enzyme involved in proline biosynthesis as well as due to inhibition of proline oxidase and proline dehydrogenase (PDH), proline catabolising enzymes. Accumulation of proline with increasing salt concentration and varietal difference observed in the present study fairly agree with results by Misra and Gupta, (2005) for the green gram crop. Similar results have been reported by Khatkar and Kuhad, (2000) for wheat; Saady *et al*., (2012) for fenugreek and Amirjani, (2010) for soybean crop.

Table 4.2 Effect of salt concentrations on proline content (15 DAS) of fresh weight of leaves of green gram varieties

Sr. No.	Treatments	Proline (µg g^{-1})
A. Varieties (V)		
V_1	**Meha**	148.30
V_2	**GAM 5**	144.82
	S.Em. ±	0.96
	C.D. at 5%	2.80
B. Salinity Levels (S)		
S_0	**Tap water (EC 0.9 dS m^{-1})**	50.17
S_1	**EC 1.0 dS m^{-1}**	83.50
S_2	**EC 2.0 dS m^{-1}**	161.97
S_3	**EC 4.0 dS m^{-1}**	195.89
S_4	**EC 6.0 dS m^{-1}**	241.28
	S.Em. ±	1.52
	C.D. at 5%	4.43
C. S × V Interaction		
	S.Em.±	2.15
	C.D. at 5%	NS
	C.V. %	2.93

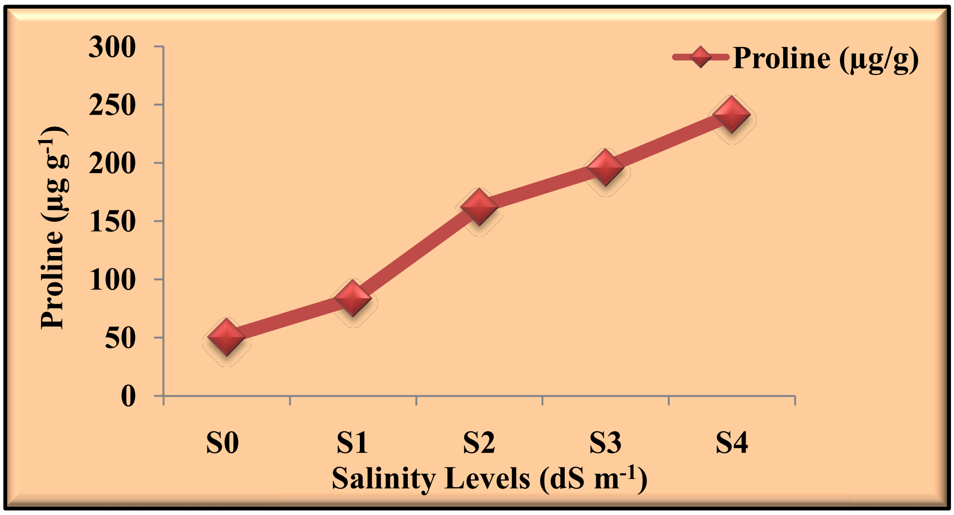

Fig.4.2: Effect of salt concentrations on proline content (µg g^{-1}) of fresh weight of leaves of green gram varieties

In the statistical analysis of above two parameters *viz*. germination percentage and proline content, 10 treatment combinations were used. After 20 DAS, the green gram plants with the EC 4.0 and 6.0 dS m^{-1} couldn't survive which is might be due to high salt concentration and low nutrient and water availability. At this stage, plants didn't tolerate the salt stress and they wilted. Remaining parameters *viz*. plant height, yield, protein content, nutrient content in grain and stover were analysed by using 6 treatment combinations. Further, the statistical analysis of soil parameters was done by 10 treatment combinations.

4.3 EFFECT OF SALT CONCENTRATIONS ON THE PLANT GROWTH, PROTEIN CONTENT AND YIELD OF GREEN GRAM VARIETIES

4.3.1 Effect on Plant Height

The data on plant height at different growth stages i.e. at 30, 45 DAS and at harvest as influenced by varieties and salt concentration are presented in Table 4.3 and graphically shown in Fig. 4.3.

Plant height at different growth stages i.e. at 30, 45 DAS and at harvest were significantly altered by varieties and salinity levels while interaction effect between varieties and salinity levels was non significant with respect to plant height at 30, 45 DAS and at harvest.

Analysis of data given in Table 4.3, it is revealed that the varietal effect was found significant under saline condition at different growth stages i.e. at 30, 45 DAS and at harvest. The significantly highest plant height (15.01, 37.04 and 60.23 cm at

30, 45 DAS and at harvest, respectively) was recorded under V_1 (Meha). In general, lower plant height was found at all the growth stages in V_2 (GAM 5).

The data revealed that the effect of salt concentration on plant height at different growth stages i.e. at 30, 45 DAS and at harvest was found significant. At S_1 level (EC_{iw} 1.0 dS m^{-1}) it was recorded significantly highest plant height of 16.28 and 41.19 cm at 30, 45 DAS, respectively while it was significantly higher (68.10 cm) at harvest which was at par with level S_0 (EC_{iw} 0.9 dS m^{-1}). As salinity levels increases from S_1 level (EC_{iw} 1.0 dS m^{-1}) to S_2 level (EC_{iw} 2.0 dS m^{-1}), there were drastically reduction in plant height at all stages of growth. The reduction in plant height at 30, 45 DAS and at harvest at S_2 level (EC_{iw} 2.0 dS m^{-1}) was noted 7.80, 28.32 and 34.83 per cent over S_0 level (Tap water). The plant height tended to decrease with increase in salt concentration after S_1 level which was graphically shown in Fig. 4.3.

The data presented in Table 4.3 indicated that interaction effect of varieties and salinity levels was found non significant with respect to plant height at 30, 45 DAS and at harvest.

The highest salt concentrations have shown clear depressing effect on plants of green gram. The suppressive effect could be related to the increased osmotic potential i.e. increased osmotic pressure at saline root medium (Bernstein, 1975). Adverse effect of salinity on the plant height might be due to fewer uptakes of water and nutrients from the growing media due to higher concentration of salts present in the root zone, which may causes imbalances in osmotic pressure. (Kumar *et al*., 2012)

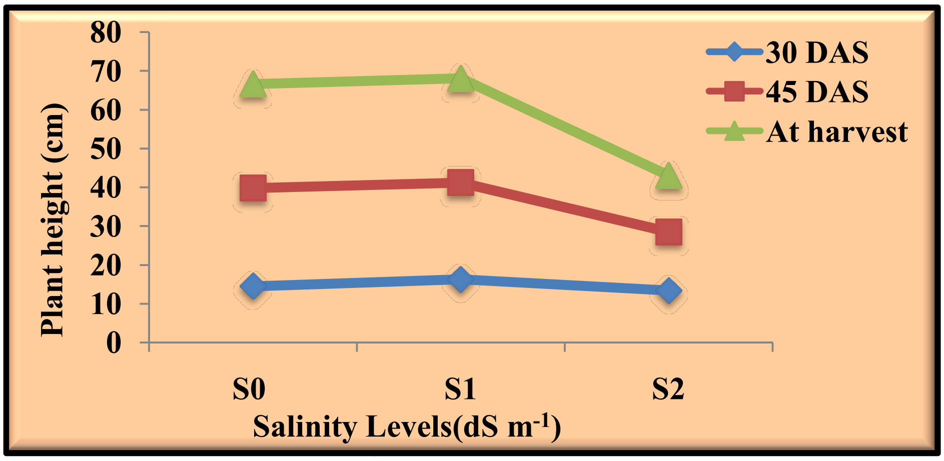

Fig.4.3: Effect of salt concentrations on plant height (cm) of green gram varieties at 30 and 45 DAS and at harvest

Table 4.3 Effect of salt concentrations on the plant height (cm) at different stages of green gram varieties

Sr. No.	Treatments	30 DAS	45 DAS	At harvest
A. Varieties (V)				
V_1	**Meha**	15.01	37.04	60.23
V_2	**GAM 5**	14.39	35.99	58.27
	S.Em. ±	0.15	0.34	0.54
	C.D. at 5%	0.45	1.00	1.58
B. Salinity Levels (S)				
S_0	**Tap water (EC 0.9 dS m^{-1})**	14.48	39.82	66.60
S_1	**EC 1.0 dS m^{-1}**	16.28	41.19	68.10
S_2	**EC 2.0 dS m^{-1}**	13.35	28.54	43.05
	S.Em. ±	0.19	0.42	0.66
	C.D. at 5%	0.45	1.23	1.94
C. S × V Interaction				
	S.Em.±	0.26	0.59	0.94
	C.D. at 5%	NS	NS	NS
	C.V. %	3.60	3.26	3.17

4.3.2 Effect on Yield

Data pertaining to grain and stover yield of green gram as influenced by varieties and salinity levels are summarized in Table 4.4 and also graphically depicted in Fig. 4.4.

The results presented in Table 4.4 revealed that varieties and salinity levels produced significant effect on grain and stover yield of green gram, while interaction effect on grain and stover yield was found non significant.

The data also revealed that the varietal effect on grain and stover yield was found significant. Among genotypes tested for salt tolerance, variety V_1 (Meha) gave significantly highest grain and stover yield (6.53 and 23.92 g pot^{-1}).

In case of salinity levels, significantly highest grain (7.30 g pot^{-1}) and stover yield (28.66 g pot^{-1}) was found under S_1 level (EC_{iw} 1.0 dS m^{-1}). The grain and stover yield decreased with increasing salt concentration after at S_1 level which was graphically shown in Fig. 4.4. The reduction in grain and stover yield was 36.47 and 40.96 per cent, respectively at EC_{iw} 2.0 dS m^{-1} as compared to control.

Detrimental effect of higher salt concentration on grain and stover yield of green gram varieties on plants may be due to (i) increase in osmotic pressure of soil solution (ii) toxic effects excreted by the excess salts. The other possible explanation for reduction in yield may be due to lower photosynthesis because of disturbed carbohydrates and nitrogen metabolism leading to the poor conversion of certain metabolites (Strongonov, 1964). The effect of salt concentration and varietal difference observed are in conformity with Kaymakanova, (2009); Prakash, (2017); Sohrabi *et al*., (2008) and Kumar *et al*., (2012).

Table 4.4 Effect of salt concentrations on the yield (g pot^{-1}) of green gram varieties

Sr. No.	Treatments	Grain	Stover
A. Varieties (V)			
V_1	**Meha**	6.53	23.92
V_2	**GAM 5**	6.11	22.68
	S.Em. ±	0.10	0.39
	C.D. at 5%	0.29	1.13
B. Salinity Levels (S)			
S_0	**Tap water (EC 0.9 dS m^{-1})**	7.13	25.93
S_1	**EC 1.0 dS m^{-1}**	7.30	28.66
S_2	**EC 2.0 dS m^{-1}**	4.53	15.31
	S.Em. ±	0.12	0.47
	C.D. at 5%	0.35	1.38
C. S × V Interaction			
	S.Em.±	0.17	0.67
	C.D. at 5%	NS	NS
	C.V. %	5.39	5.75

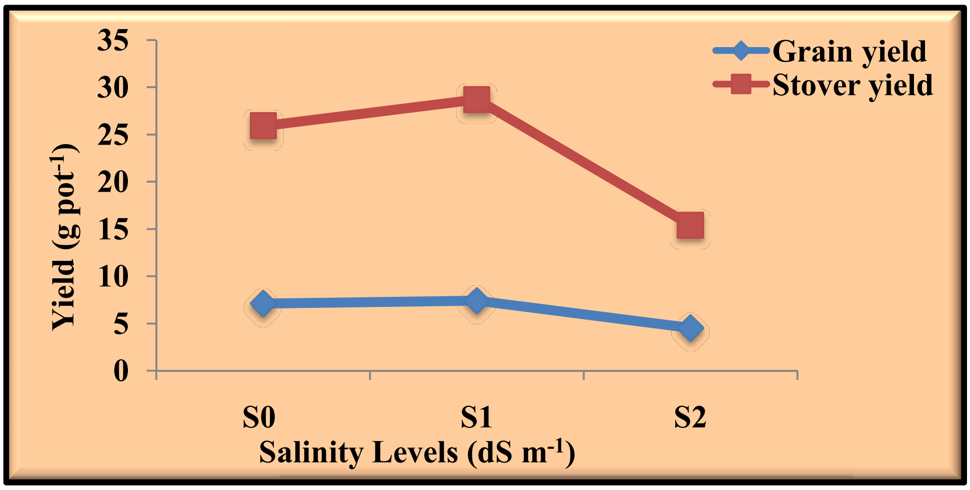

Fig.4.4: Effect of salt concentrations on yield (g pot^{-1}) of green gram varieties

4.3.3 Effect on Protein

The data on protein content of green gram as influenced by different varieties and salt concentrations are given in Table 4.5.

The data revealed that the varietal effect and interaction effect on protein content was found non significant, while salinity levels had significant effect on protein content.

Though results are non significant, Meha variety recorded higher protein content (20.14%) than GAM 5 (19.97%).

Regarding various salt concentration effect, the protein content was found significant. The significantly highest protein content (21.31%) and lowest (18.39%) were found under S_0 level (EC_{iw} 0.9 dS m^{-1}) and S_2 level (EC_{iw} 2.0 dS m^{-1}), respectively.

The protein content decreased with increasing salt concentration which is shown in Fig. 4.5. It was may be due to proteins are surrounded by the salt ions of opposite net charge and these results in decreasing electrostatic free energy of the protein and increasing the activity of the solvent, which in turn, leads to increasing solubility while at high salt concentration, the abundance of the salt ions decreases the solvating power of the salt ions and solubility of the protein decreased.

Similar results for protein content had also been reported by Sreejith *et al*., (2014); Gloria and Lilia, (2010); Soussi *et al*., (2001); Kumari and Vishnuvardhan Z., (2015) and Rajakumar, (2013).

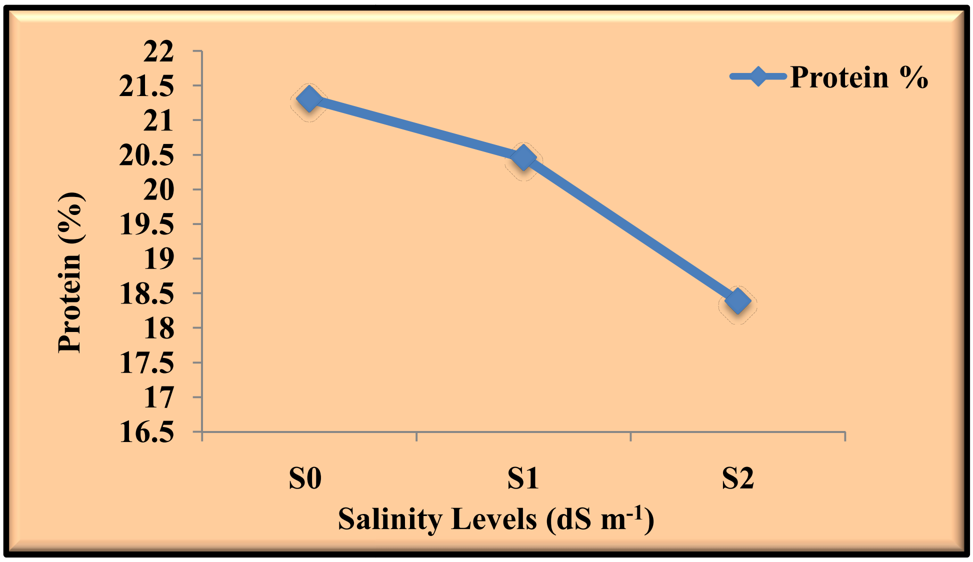

Fig.4.5: Effect of salt concentrations on protein content (%) of green gram varieties

Table 4.5 Effect of salt concentrations on protein content (%) of green gram varieties

Sr. No.	Treatments	Protein
A. Varieties (V)		
V_1	**Meha**	20.14
V_2	**GAM 5**	19.97
	S.Em. ±	0.11
	C.D. at 5%	NS
B. Salinity Levels (S)		
S_0	**Tap water (EC 0.9 dS m^{-1})**	21.31
S_1	**EC 1.0 dS m^{-1}**	20.46
S_2	**EC 2.0 dS m^{-1}**	18.39
	S.Em. ±	0.14
	C.D. at 5%	0.41
C. S × V Interaction		
	S.Em.±	0.20
	C.D. at 5%	NS
	C.V. %	1.96

4.4 EFFECT OF SALT CONCENTRATIONS ON NUTRIENT CONTENT OF GREEN GRAM VARIETIES

4.4.1 Effect of Salt Concentrations on Nitrogen Content in Grain and Stover

The mean data regarding nitrogen content in grain and stover as influenced by varieties and salt concentration are presented in Table 4.6.

The data in Table 4.6 revealed that varieties (Meha and GAM 5) had non significant effect on nitrogen content in grain, while significant difference was observed in nitrogen content of stover in which V_1 (Meha) recorded significantly highest nitrogen content (0.59%). The interaction effect on nitrogen content in grain and stover of green gram was found non significant.

The effect of salt concentration on nitrogen content in grain and stover was found significant. As salinity level increased, significant reduction in nitrogen content of grain and stover was recorded. There was a progressive decrease in accumulation of nitrogen with increase in the salt concentration (Fig. 4.6). The maximum reduction in nitrogen content for grain and stover were observed 13.78 and 34.78 per cent under salinity level of S_2 level (EC_{iw} 2.0 dS m^{-1}) as compared to control.

This decrease could be due to low absorption of nitrogen by the plant roots in the presence of higher salinity. This confirms the finding of earlier works, Kabir *et al*., (2004) for green gram and Tejera *et al*., (2005) for common bean plants and Lal and Bhardwaj, (2004) for pea.

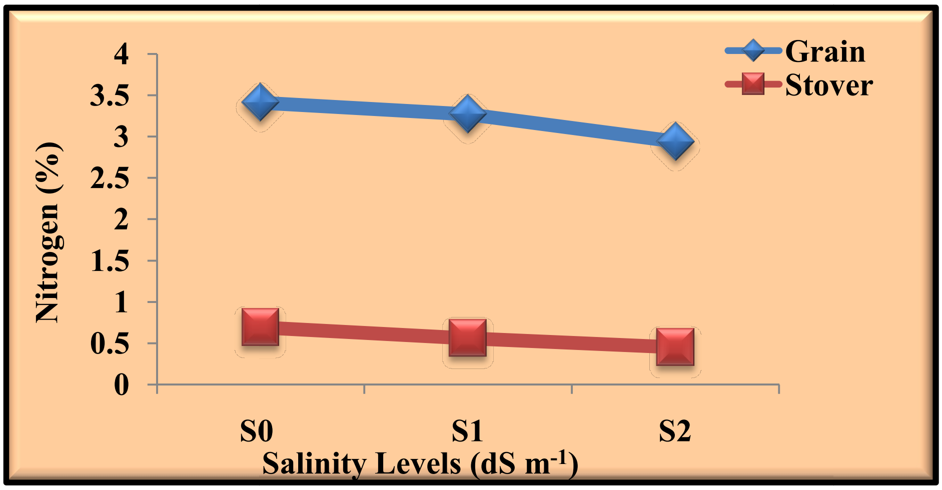

Fig.4.6: Effect of salt concentrations on nitrogen content (%) of green gram varieties

Table 4.6 Effect of salt concentrations on nitrogen content (%) of green gram varieties

Sr. No.	Treatments	Grain	Stover
A. Varieties (V)			
V_1	**Meha**	3.22	0.59
V_2	**GAM 5**	3.19	0.54
	S.Em. ±	0.04	0.01
	C.D. at 5%	NS	0.03
B. Salinity Levels (S)			
S_0	**Tap water (EC 0.9 dS m^{-1})**	3.41	0.69
S_1	**EC 1.0 dS m^{-1}**	3.27	0.56
S_2	**EC 2.0 dS m^{-1}**	2.94	0.45
	S.Em. ±	0.05	0.01
	C.D. at 5%	0.14	0.04
C. S × V Interaction			
	S.Em.±	0.07	0.02
	C.D. at 5%	NS	NS
	C.V. %	4.28	6.14

4.4.2 Effect of Salt Concentrations on Phosphorous Content in Grain and Stover

The mean data regarding phosphorous content in grain and stover as influenced by varieties and salt concentration are summarized in Table 4.7.

Phosphorous content in grain did not differ due to varieties, but it was significantly differ for stover and it was significantly highest (0.143%) in V_1 (Meha).

The effect of salt concentration on phosphorous content in grain and stover was found significant. The results indicated that it was significantly highest (0.35 & 0.153%) in grain and stover, respectively) at S_0 level (EC_{iw} 0.9 dS m^{-1}). The reduction in phosphorous content in grain and stover was 8.57 and 18.95 per cent, respectively at EC_{iw} 2.0 dS m^{-1} as compared to control.

The interaction effect on phosphorous content in grain and stover was found non significant.

There was a progressive decrease in accumulation of phosphorous with increase in the salt concentration (Fig. 4.7). The decrease in phosphorous content might be due to the decreased mobility of phosphorous caused through the increased presence of high sodium salts. These findings are in conformity with Kabir *et al.*, (2004) for green gram; Lal and singh, (1974) on wheat and Arshad Ullah *et al.*, (2016) for green gram.

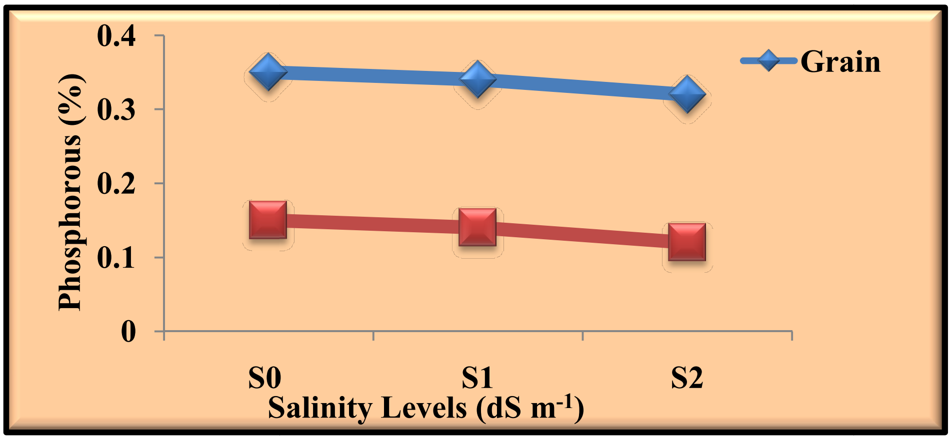

Fig.4.7: Effect of salt concentrations on phosphorous content (%) of green gram varieties

Table 4.7 Effect of salt concentrations on phosphorous content (%) of green gram varieties

Sr. No.	Treatments	Grain	Stover
	A. Varieties (V)		
V_1	**Meha**	0.34	0.143
V_2	**GAM 5**	0.33	0.136
	S.Em. ±	0.003	0.002
	C.D. at 5%	NS	0.006
	B. Salinity Levels (S)		
S_0	**Tap water (EC 0.9 dS m^{-1})**	0.35	0.153
S_1	**EC 1.0 dS m^{-1}**	0.34	0.141
S_2	**EC 2.0 dS m^{-1}**	0.32	0.124
	S.Em. ±	0.004	0.002
	C.D. at 5%	0.009	0.007
	C. S × V Interaction		
	S.Em.±	0.006	0.004
	C.D. at 5%	NS	NS
	C.V. %	3.40	5.04

4.4.3 Effect of Salt Concentrations on Potassium Content in Grain and Stover

The mean data regarding potassium content in grain and stover as influenced by varieties and salt concentration are presented in Table 4.8.

With respect to potassium content in grain and stover, non significant effect was observed due to varietal effect as well as interaction effect of varieties and salt concentration.

The effect of salt concentration on potassium content in grain and stover was found significant. The results indicate that it was significantly highest (0.59 & 0.44% in grain and stover, respectively) at S_0 level (EC_{iw} 0.9 dS m^{-1}).

There was a progressive decrease in accumulation of potassium with increase in the salt concentration (Fig. 4.8). The reduction in potassium content in grain and stover was 13.56 and 54.55 per cent, respectively at EC_{iw} 2.0 dS m^{-1} as compared to control.

The reduction in potassium content in grain and stover with increasing salt concentration is might be due to (i) high levels of sodium inhibit K^+ activity in the soil solution, resulting in a reduction of K^+ availability. (ii) Sodium not only interferes with K^+ translocation from root to shoot, but also competes with K^+ for uptake sites at the plasma membrane, resulting in lower K^+ uptake.

These findings are in conformity with Deepika and Hans, (2014) for cluster bean; Mishra and Dwivedi, (2004) for green gram and Patel *et al*., (2010) for cowpea.

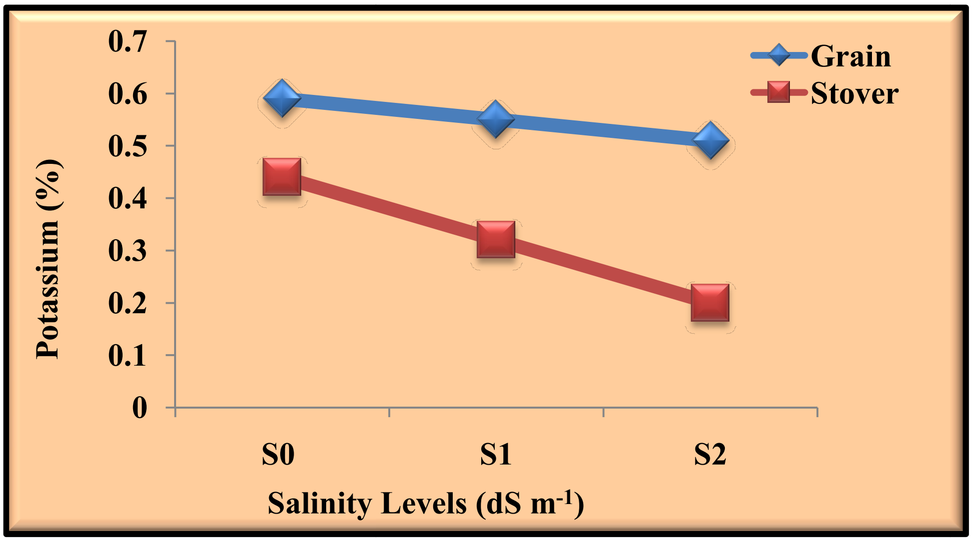

Fig.4.8: Effect of salt concentrations on potassium content (%) of green gram varieties

Table 4.8 Effect of salt concentrations on potassium content (%) of green gram varieties

Sr. No.	Treatments	Grain	Stover
A. Varieties (V)			
V_1	**Meha**	0.56	0.31
V_2	**GAM 5**	0.54	0.33
	S.Em. ±	0.01	0.01
	C.D. at 5%	NS	NS
B. Salinity Levels (S)			
S_0	**Tap water (EC 0.9 dS m^{-1})**	0.59	0.44
S_1	**EC 1.0 dS m^{-1}**	0.55	0.32
S_2	**EC 2.0 dS m^{-1}**	0.51	0.20
	S.Em. ±	0.01	0.01
	C.D. at 5%	0.03	0.02
C. S × V Interaction			
	S.Em.±	0.02	0.01
	C.D. at 5%	NS	NS
	C.V. %	5.97	5.53

4.4.4 Effect of Salt Concentrations on Sodium Content in Grain and Stover

The mean data regarding sodium content in grain and stover as influenced by varieties and salt concentration are presented in Table 4.9.

It is apparent from Table 4.9 that varieties V_1 (Meha) and V_2 (GAM 5) did not show any significant effect on sodium content in grain and stover, while the effect of salt concentration on sodium content in grain and stover was found significant. The interaction effect of varieties and salt concentrations did not show any significant effect.

Significantly increased in sodium content in grain and stover were observed with the salinity levels. The results indicate that it was significantly highest (0.11 & 0.38% in grain and stover, respectively) at S_2 level (EC_{iw} 2.0 dS m^{-1}). There was a progressive increase in accumulation of sodium with increase in the salt concentration

(Fig. 4.9). Increase in sodium content in grain and stover was 37.5 and 35.71 per cent, respectively at EC_{iw} 2.0 dS m^{-1} as compared to control.

The highest salt concentrations have shown clear depressing effect on plants of green gram. This might be due to increase in cell wall permeability with salt and also with age because of cell wall degradation. With increase in the salt concentration, Na content increased in grain as well as in stover. Similar relationship have also been reported by Lal and singh, (1974) for wheat; Patel, (2010) for cow pea and Tejera *et al.*, (2005) for common bean plants.

Table 4.9 Effect of salt concentrations on sodium content (%) of green gram varieties

Sr. No.	Treatments	Grain	Stover
A. Varieties (V)			
V_1	**Meha**	0.09	0.34
V_2	**GAM 5**	0.09	0.34
	S.Em. ±	0.001	0.002
	C.D. at 5%	NS	NS
B. Salinity Levels (S)			
S_0	**Tap water (EC 0.9 dS m^{-1})**	0.08	0.28
S_1	**EC 1.0 dS m^{-1}**	0.09	0.35
S_2	**EC 2.0 dS m^{-1}**	0.11	0.38
	S.Em. ±	0.002	0.004
	C.D. at 5%	0.005	0.011
C. S × V Interaction			
	S.Em.±	0.002	0.005
	C.D. at 5%	NS	NS
	C.V. %	6.06	4.06

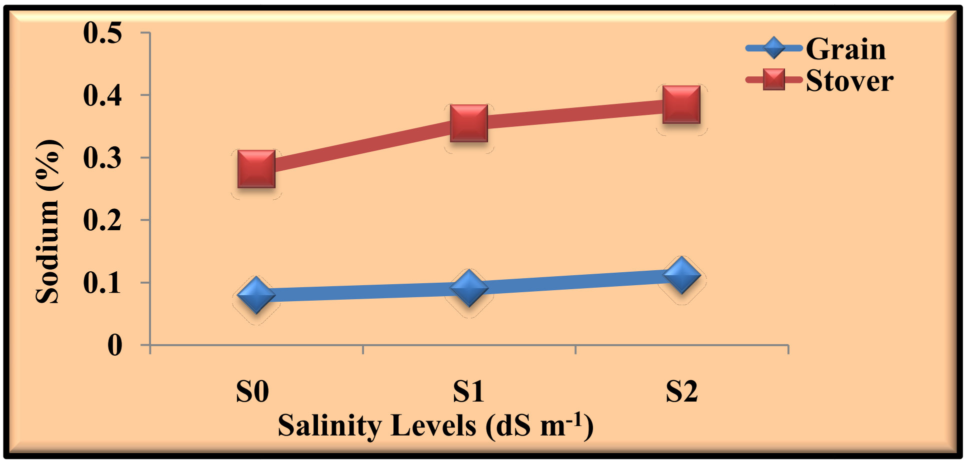

Fig.4.9: Effect of salt concentrations on sodium content (%) of green gram varieties

4.4.5 Effect of Salt Concentrations on Sulphur Content in Grain and Stover

The mean data of sulphur content in grain and stover as influenced by varieties and salt concentrations are presented in Table 4.10.

The data in Table 4.10 revealed that varietal effect was found non significant for sulphur content in grain and stover, while sulphur content in grain was found significant with respect to salinity levels. Regarding interaction effect, it was also found non significant.

Sulphur content in grain was significantly highest (0.63%) at S_0 level (EC_{iw} 0.9 dS m^{-1}). As salinity levels increased, reduction in sulphur content recorded and lowest content (0.41%) was found under higher salinity levels (S_2). There was a progressive decrease in accumulation of sulphur with increase in the salt concentration (Fig. 4.10). The reduction in sulphur content in grain was 34.92 per cent at EC_{iw} 2.0 dS m^{-1} as compared to control.

The reason for the reduction in sulphur content in grain is might be due to the presence of excess sodium may induce unavailability of sulphur. When the concentration of soluble salts increased to a high level, it produced toxic effect directly to the plants and plant couldn't survive under high salty condition. Similar results were also reported by Tejera *et al.*, (2005); Patel *et al.*, (2010) and Hakkwan *et al.*, (2016).

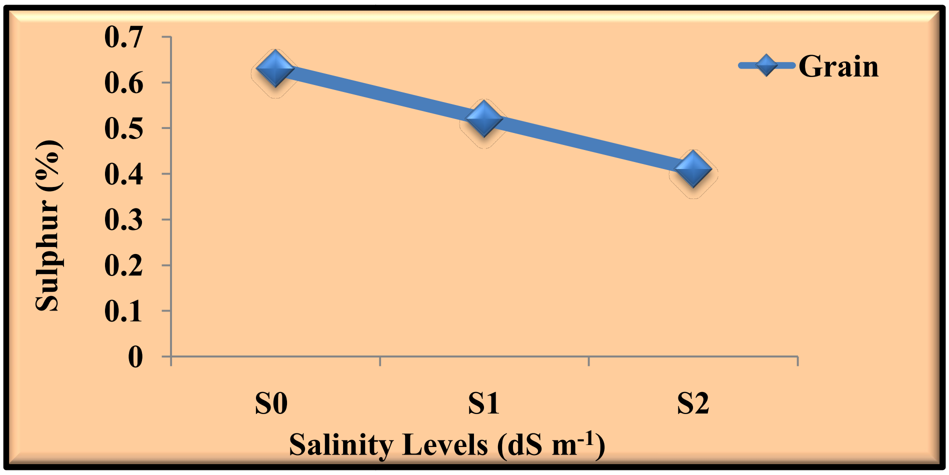

Fig.4.10: Effect of salt concentrations on sulphur content (%) of green gram varieties

Table 4.10 Effect of salt concentrations on sulphur content (%) of green gram varieties

Sr. No.	Treatments	Grain	Stover
A. Varieties (V)			
V_1	Meha	0.53	0.45
V_2	GAM 5	0.51	0.46
	S.Em. ±	0.01	0.01
	C.D. at 5%	NS	NS
B. Salinity Levels (S)			
S_0	Tap water (EC 0.9 dS m^{-1})	0.63	0.47
S_1	EC 1.0 dS m^{-1}	0.52	0.46
S_2	EC 2.0 dS m^{-1}	0.41	0.44
	S.Em. ±	0.01	0.01
	C.D. at 5%	0.04	NS
C. S × V Interaction			
	S.Em.±	0.02	0.01
	C.D. at 5%	NS	NS
	C.V. %	6.72	6.53

4.4.6 Effect of Salt Concentrations on Micronutrient Content in Grain and Stover

4.4.6.1 Iron and manganese

The data on Fe and Mn content in grain and stover of green gram as influenced by different varieties and salt concentrations are given in Table 4.11.

The data revealed that the varietal effect and interaction effect on Fe and Mn content in grain and stover were found non significant, while salinity levels had significant effect on Fe and Mn content in grain and stover. Though V_1 (Meha) variety recorded more Fe and Zn content in grain and stover, but failed to reach to the level of significance.

The effect of salinity levels on Fe and Mn content in grain and stover was found significant. The results indicate that it was significantly highest (45.50 & 261.70 mg kg^{-1} in grain and stover) for Fe at S_0 level (EC_{iw} 0.9 dS m^{-1}) and (23.0 & 66.99 mg kg^{-1} in grain and stover) for Mn at S_2 level (EC_{iw} 2.0 dS m^{-1}).

The overall accumulation of Fe decreased and Mn increased with increasing salt concentration (Fig. 4.11). The reduction in Fe content in grain and stover was 44.50 and 12.50 per cent and the increase in Mn 89.39 and 292.49 per cent in grain and stover, respectively at EC_{iw} 2.0 dS m^{-1} as compared to control. Similar results were reported by Bhatt *et al*., (2008) who noted that contents of Fe decreased and Mn increased in the grain and stover with increasing levels of salt concentration this is might be due to Mn is important for photosynthetic reaction as part of water-splitting enzyme of photosystem-II so Increase in Mn content at the high salt concentration level might be the requirement of this plant for survival in saline soils.

4.4.6.2 Zinc and copper

The mean data regarding Zn and Cu content in grain and stover as influenced by varieties and salt concentration are presented in Table 4.12.

The data in Table 4.12 revealed that varietal and interaction effect were found non significant on Zn and Cu content in grain and stover of both the varieties.

Though results are non significant, Meha variety recorded numerically higher Zn and Cu content in grain and stover. Various salinity levels had significant effect on Zn and Cu content in grain and stover of green gram.

Significantly highest Zn content in grain (31.82 mg kg^{-1}) and stover (17.01 mg kg^{-1}) and for Cu content in grain (11.33 mg kg^{-1}) and stover (20.86 mg kg^{-1}) were found at S_0 level (EC_{iw} 0.9 dS m^{-1}).

The overall accumulation decreased with increasing salt concentration (Fig. 4.12). The reduction in Zn content in grain and stover was 44.50 and 12.50 per cent and in case of Cu it was 74.52 and 47.20 per cent in grain and stover, respectively at EC_{iw} 2.0 dS m^{-1} as compared to control. Similar results were reported by Bhatt *et al.*, (2008) who noted that contents of Zn and Cu in the grain and stover were decreased significantly in with increasing levels of salt concentration. This possibly might be due to added salts increase the concentration of sodium, calcium and magnesium in the soil medium. Generally, the adverse effect of these salts may reduce the availability of copper and zinc.

Table 4.11 Effect of salt concentrations on iron and manganese content (mg kg^{-1}) of green gram varieties

Sr. No.	Treatments	Fe		Mn	
		Grain	**Stover**	**Grain**	**Stover**
A. Varieties (V)					
V_1	**Meha**	36.50	249.35	14.61	51.94
V_2	**GAM 5**	35.71	242.04	14.37	50.63
	S.Em. ±	0.63	3.96	0.23	0.85
	C.D. at 5%	NS	NS	NS	NS
B. Salinity Levels (S)					
S_0	**Tap water (EC 0.9 dS m^{-1})**	45.50	261.70	5.86	35.37
S_1	**EC 1.0 dS m^{-1}**	37.56	246.42	14.60	51.49
S_2	**EC 2.0 dS m^{-1}**	25.25	228.98	23.00	66.99
	S.Em. ±	0.77	4.84	0.29	1.05
	C.D. at 5%	2.24	14.14	0.83	3.05
C. S × V Interaction					
	S.Em.±	1.08	6.85	0.40	1.48
	C.D. at 5%	NS	NS	NS	NS
	C.V. %	6.00	5.58	5.57	5.77

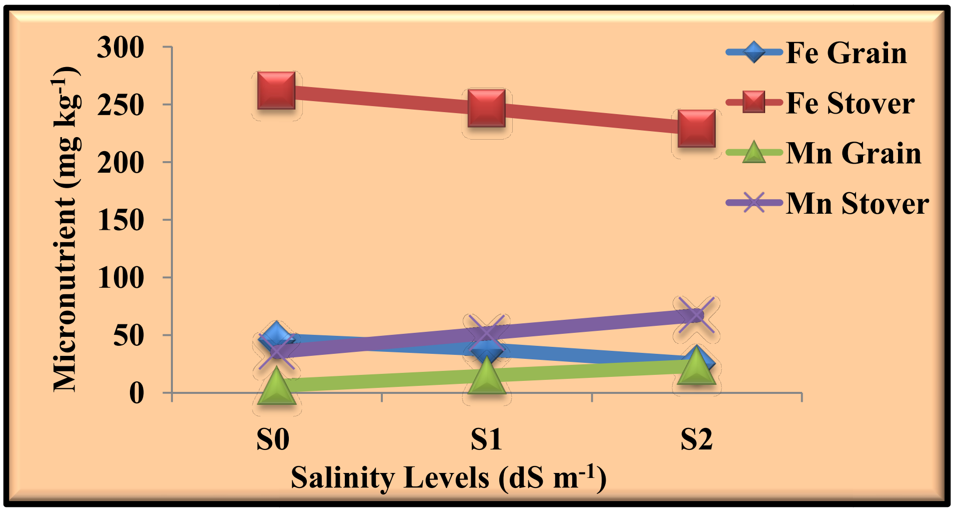

Fig.4.11: Effect of salt concentrations on micronutrient (Fe & Mn) content (mg kg^{-1}) of green gram varieties

Table 4.12 Effect of salt concentrations on zinc and copper content (mg kg^{-1}) of green gram varieties

Sr. No.	Treatments	Zn		Cu	
		Grain	Stover	Grain	Stover
A. Varieties (V)					
V_1	Meha	20.45	13.08	8.79	14.23
V_2	GAM 5	19.69	12.85	8.38	13.67
	S.Em. ±	0.28	0.23	0.15	0.24
	C.D. at 5%	NS	NS	NS	NS
B. Salinity Levels (S)					
S_0	Tap water (EC 0.9 dS m^{-1})	31.82	17.01	11.33	20.86
S_1	EC 1.0 dS m^{-1}	17.45	11.59	8.55	12.21
S_2	EC 2.0 dS m^{-1}	10.95	10.30	5.87	8.79
	S.Em. ±	0.34	0.28	0.19	0.29
	C.D. at 5%	0.99	0.81	0.54	0.84
C. S × V Interaction					
	S.Em.±	0.48	0.39	0.26	0.41
	C.D. at 5%	NS	NS	NS	NS
	C.V. %	4.78	6.06	6.12	5.86

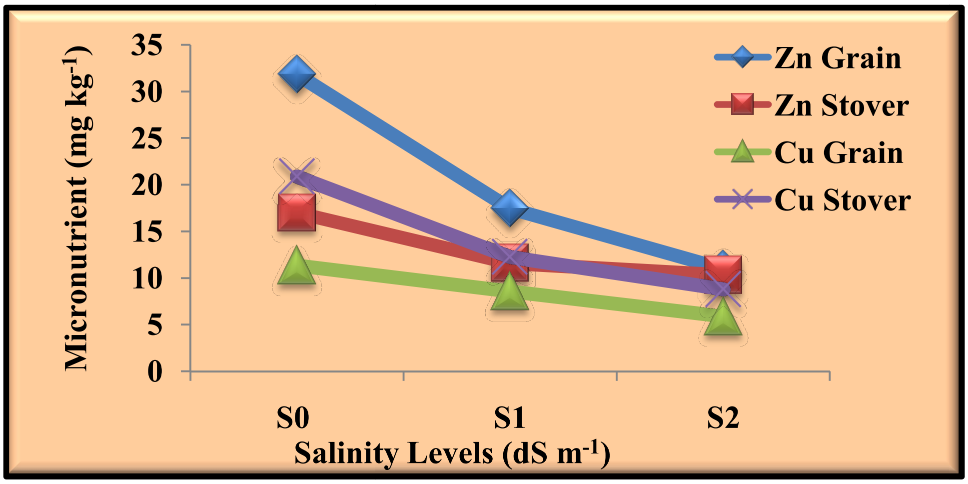

Fig.4.12: Effect of salt concentrations on micronutrient (Zn & Cu) content (mg kg^{-1}) of green gram varieties

4.5 EFFECT OF SALT CONCENTRATIONS ON CHEMICAL PROPERTIES OF SOIL AFTER HARVESTING

4.5.1 Effect on Soil pH, EC and Organic Carbon

The data on soil pH and EC and organic carbon of soil after harvest of the crop as influenced by varieties and salt concentration are summarized in Table 4.13.

4.5.1.1 Effect on soil pH

It is apparent from Table 4.13 that soil pH did not change significantly due to varieties and salinity levels.

The data on pH of soil after harvest of the crop were more or less the same in both varieties and it was observed in the range of 8.80 to 8.90.

With respect to salinity levels effect, though results are not differing significantly, decreasing trend in soil pH was observed as salinity levels increased.

Results presented in Table 4.13 indicated that interaction effect between varieties and salinity levels was found non significant for soil pH.

4.5.1.2 Effect on soil EC

The data on electrical conductivity of soil did not alter due to both varieties, but it was significantly changed with salinity levels. The results indicated that it was significantly highest (0.23 dS m^{-1}) at S_4 level (EC_{iw} 6.0 dS m^{-1}).

The EC of soil increased in the ranged from 0.13 (S_0) to 0.23 dS m^{-1} (S_4) and it was increased of 1.77 times than control.

Soil EC increased with increasing salt concentration (Fig. 4.13). High accumulation of salts like Na, Ca and Mg increases the EC of soil. Similar results were reported by Hakkwan *et al*., (2016) who noted that as the salinity of irrigation water increased, EC tended to increase.

Results presented in Table 4.13 indicated that interaction effect between varieties and salinity levels was found non significant for soil EC.

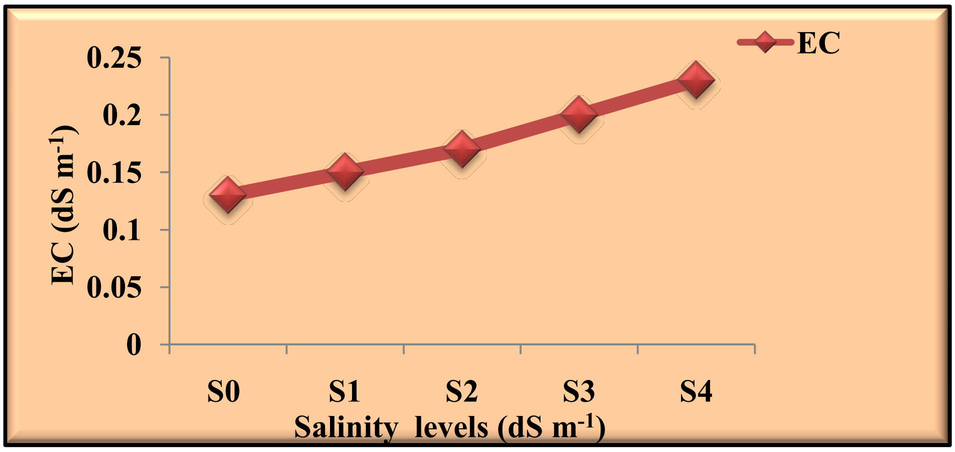

Fig.4.13: Effect of salt concentrations on EC (dS m^{-1}) of soil after harvest

4.5.1.3 Effect on soil organic carbon

Organic carbon content of soil was not significantly affected by both varieties but, it was significantly increased with salinity levels (Fig. 4.14). Maximum organic carbon content (4.8 g kg^{-1}) obtained with S_4 level (EC_{iw} 6.0 dS m^{-1}), which was significantly highest. The lower organic carbon content (3.40 g kg^{-1}) recorded with salinity levels was S_0 (EC 0.9 dS m^{-1}).

The increase in organic carbon was highest at S_4 level (EC_{iw} 6.0 dS m^{-1}) which was 1.25 times higher than control (tap water). This is might be due to increase in water salinity levels decomposition of organic matter was retarded. Similar results were reported by Gupta *et al*., (2001).

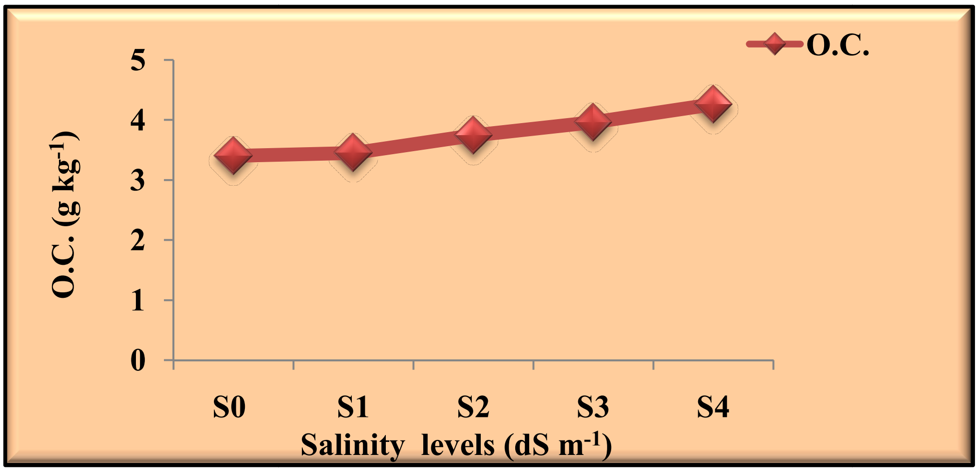

Fig.4.14: Effect of salt concentrations on organic carbon (g kg^{-1}) of soil after harvest

Results presented in Table 4.13 indicated that interaction effect between varieties and salinity levels was found non significant for soil organic carbon.

Table 4.13 Effect of salt concentrations on pH, EC and organic carbon of soil after harvest

Sr. No.	Treatments	pH (1:2.5)	EC (dS m^{-1}) (1:2.5)	O.C. (g kg^{-1})
A. Varieties (V)				
V_1	**Meha**	8.9	0.18	3.77
V_2	**GAM 5**	8.8	0.18	3.76
	S.Em. ±	0.076	0.003	0.04
	C.D. at 5%	NS	NS	NS
B. Salinity Levels (S)				
S_0	**Tap water (EC 0.9 dS m^{-1})**	9.2	0.13	3.40
S_1	**EC 1.0 dS m^{-1}**	8.9	0.15	3.45
S_2	**EC 2.0 dS m^{-1}**	8.8	0.17	3.74
S_3	**EC 4.0 dS m^{-1}**	8.8	0.20	3.96
S_4	**EC 6.0 dS m^{-1}**	8.6	0.23	4.26
	S.Em. ±	0.121	0.005	0.06
	C.D. at 5%	NS	0.014	0.18
C. S × V Interaction				
	S.Em.±	0.171	0.007	4.50
	C.D. at 5%	NS	NS	NS
	C.V. %	3.86	7.64	0.09

4.5.2 Effect on Available Nitrogen, Phosphorous, Potassium and Sulphur of Soil

The data on available nitrogen, phosphorous, potassium and sulphur of soil as influenced by varieties of green gram and salinity levels given in Table 4.14.

4.5.2.1 Effect on available nitrogen

The result showed that the varietal effect and interaction effect on available nitrogen content of soil was found non significant, while salinity levels produced significant influences on nitrogen content (Table 4.14).

Maximum nitrogen content was observed with S_0 level (EC_{iw} 0.9 dS m^{-1}) and it was significantly highest. There was significant reduction in nitrogen content noted with increasing salinity levels (Fig. 4.15).

At S_4 level (EC_{iw} 6.0 dS m^{-1}) available nitrogen of soil reduced 11.88 per cent over S_0 level (EC_{iw} 0.9 dS m^{-1}). Increased salt concentration had some depressing effect on the release of nitrogen, possibly due to adverse effect of higher salinity on microbial population, responsible for the process of mineralisation (Paliwal, 1972).

4.5.2.2 Effect on available phosphorous

The data presented in Table 4.14 indicated that effect of varieties on available phosphorous was found non-significant, but salinity levels had significant effect on available phosphorous. Interaction effect between varieties and salinity levels was found non significant.

Available phosphorous in soil was found significantly highest under S_0 level (EC_{iw} 0.9 dS m^{-1}), while lowest was recorded at S_4 level (EC_{iw} 6.0 dS m^{-1}).

Generally, decreasing trend was observed in available phosphorous in soil as increased salinity levels (Fig. 4.15). Gupta *et al*., (2001) reported decrease in available phosphorus with the increase in salinity level might be due to fixation of available phosphorus at higher salinity.

4.5.2.3 Effect on available potassium

Available potassium content in soil after harvest of crop did not differed significantly due to varieties of green gram, but salinity levels had significant effect on available potassium. Interaction effect between varieties and salinity levels was found non-significant for available potassium in soil which was presented in Table 4.14.

Available potassium in soil was significantly higher (290 kg ha^{-1}) at S_0 level (EC_{iw} 0.9 dS m^{-1}) which was at par with salinity level S_1 and S_2 (EC_{iw} 1.0 & 2.0 dS m^{-1}, respectively). Generally, decreasing trend was observed in available potassium in soil as increased salinity levels (Fig. 4.16). High accumulation of salts decreases availability of potassium which in turn affects the osmotic adjustment and plants may suffer.

4.5.2.4 Effect on available sulphur

Available sulphur content in soil was not significantly changed due to variety and salinity levels. The interaction between varieties and salinity levels was also found non significant for available sulphur content in soil.

Table 4.14 Effect of salt concentrations on available nitrogen, phosphorous, potassium (kg ha^{-1}) and sulphur (mg kg^{-1}) of soil after harvest

Sr. No.	Treatments	N	P_2O_5	K_2O	S
A. Varieties (V)					
V_1	**Meha**	169.7	57.1	279.1	10.1
V_2	**GAM 5**	165.6	56.0	277.9	9.9
	S.Em. ±	1.93	0.58	2.56	0.12
	C.D. at 5%	NS	NS	NS	NS
B. Salinity Levels (S)					
S_0	**Tap water (EC 0.9 dS m^{-1})**	179.8	71.1	290.0	10.3
S_1	**EC 1.0 dS m^{-1}**	170.6	65.4	283.3	10.2
S_2	**EC 2.0 dS m^{-1}**	168.8	52.0	280.0	9.9
S_3	**EC 4.0 dS m^{-1}**	160.6	49.9	271.7	9.8
S_4	**EC 6.0 dS m^{-1}**	158.5	43.6	267.5	9.8
	S.Em. ±	3.05	0.92	4.05	0.18
	C.D. at 5%	8.89	2.69	11.81	NS
C. S × V Interaction					
	S.Em.±	4.31	1.30	5.72	0.26
	C.D. at 5%	NS	NS	NS	NS
	C.V. %	5.14	4.61	4.11	5.14

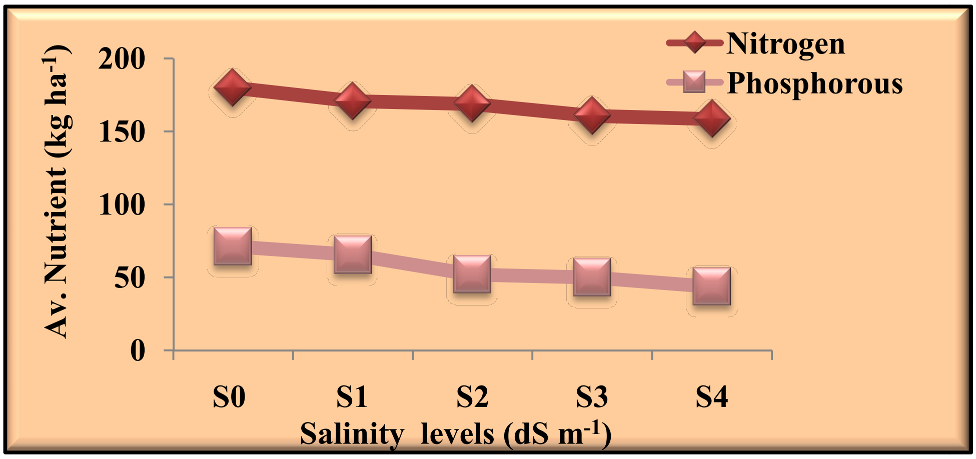

Fig.4.15: Effect of salt concentrations on available nitrogen and phosphorous (kg ha^{-1}) of soil after harvest

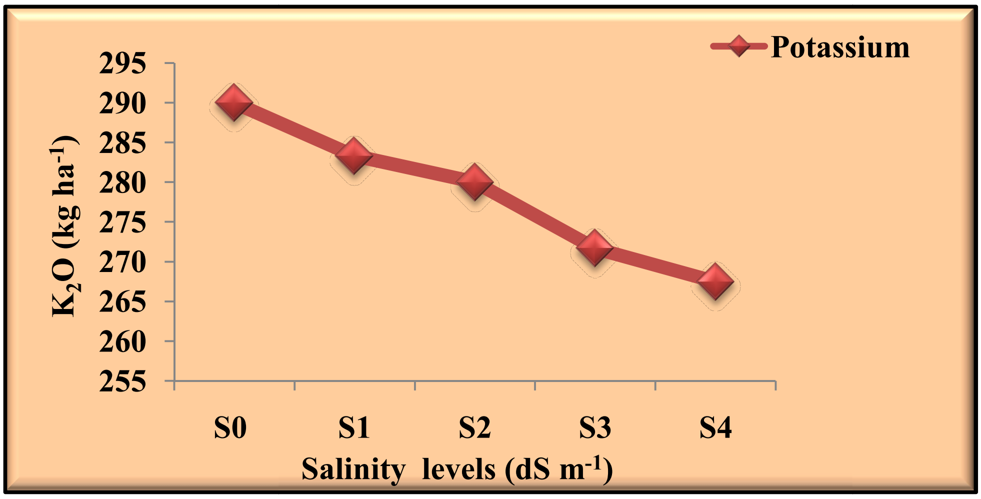

Fig.4.16: Effect of salt concentrations on available potassium (kg ha^{-1}) of soil after harvest

4.5.3 Effect on Exchangeable Sodium, Calcium and Magnesium

The data on exchangeable sodium, calcium and magnesium of soil as influenced by salt concentrations and both the varieties of green gram are presented in Table 4.15.

4.5.3.1 Effect on exchangeable sodium

From the data presented in Table 4.15 it was revealed that the varietal effect and interaction effect on exchangeable sodium of soil were found non significant but it was significantly changed due to effect of salt concentration. It was significantly highest (1.99 meq/100g) at S_4 level (EC_{iw} 6.0 dS m^{-1}).

From the data it was revealed that there was increase in exchangeable sodium of soil with increasing salt concentration (Fig. 4.17). This is might be due to at high level of salt concentration, the more salts of sodium chloride and sodium bicarbonate accumulated in the soil with application of saline water.

4.5.3.2 Effect on exchangeable calcium

From the data presented in Table 4.15 it was revealed that the varietal effect and interaction effect on exchangeable calcium of soil were found non significant but it was significantly changed due to effect of salt concentration. It was significantly highest (6.09 meq/100g) at S_4 level (EC_{iw} 6.0 dS m^{-1}).

From the data it was revealed that there was increase in exchangeable sodium of soil with increasing salt concentration (Fig. 4.17). This is might be due to at high level of salt concentration, the more salts of calcium chloride and calcium carbonate accumulated in the soil with application of saline water.

4.5.3.3 Effect on exchangeable magnesium

From the data presented in Table 4.15 it was revealed that the varietal effect and interaction effect on exchangeable calcium of soil were found non significant but it was significantly changed due to effect of salt concentration. It was significantly highest (2.20 meq/100g) at S_4 level (EC_{iw} 6.0 dS m^{-1}).

From the data it was revealed that there was increase in exchangeable sodium of soil with increasing salt concentration (Fig. 4.17). This is might be due to at high level of salt concentration, the more salts of magnesium chloride accumulated in the soil with application of saline water.

Table 4.15 Effect of salt concentrations on exchangeable cations (meq/100g) of soil after harvest

Sr. No.	Treatments	Na^+	Ca^{2+}	Mg^{2+}
A. Varieties (V)				
V_1	**Meha**	1.81	4.24	1.50
V_2	**GAM 5**	1.79	4.17	1.50
	S.Em. ±	0.02	0.06	0.02
	C.D. at 5%	NS	NS	NS
B. Salinity Levels (S)				
S_0	**Tap water (EC 0.9 dS m^{-1})**	1.60	2.62	0.98
S_1	**EC 1.0 dS m^{-1}**	1.71	3.03	1.22
S_2	**EC 2.0 dS m^{-1}**	1.82	4.26	1.30
S_3	**EC 4.0 dS m^{-1}**	1.88	5.01	1.81
S_4	**EC 6.0 dS m^{-1}**	1.99	6.09	2.20
	S.Em. ±	0.03	0.09	0.03
	C.D. at 5%	0.09	0.26	0.09
C. S × V Interaction				
	S.Em.±	0.05	0.13	0.05
	C.D. at 5%	NS	NS	NS
	C.V. %	4.98	6.09	6.31

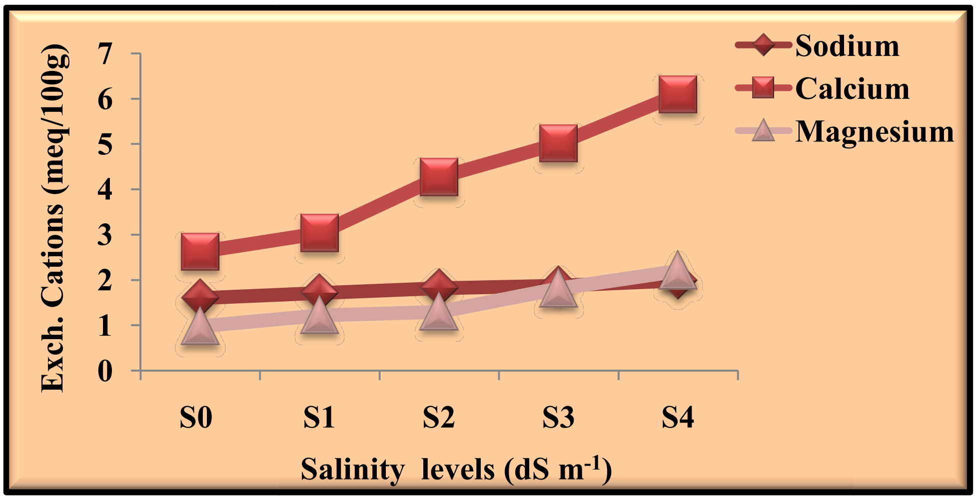

Fig.4.17: Effect of salt concentrations on exchangeable cations (meq/100g) of soil after harvest

4.5.6 Effect on Available Micronutrient

The data on available micronutrients of soil as influenced by salt concentration and both the varieties of green gram are presented in Table 4.16. The varietal effect and interaction effect on available micronutrients of soil was found non significant.

The data on available micronutrient of soil as influenced by salt concentration after harvest are also presented in Table 4.16. From the data it was revealed that effect of salt concentration on available Mn, Zn and Cu was found non significant while It was found significant in case of Fe. The results indicate that it was significantly highest (6.27 mg kg^{-1}) at S_0 level (EC_{iw} 0.9 dS m^{-1}).

From the data it was revealed that there was decrease in available Fe with increasing salt concentration (Fig. 4.18). The high level of salt concentration results in high EC and exchangeable cations which affects the availability of micronutrients.

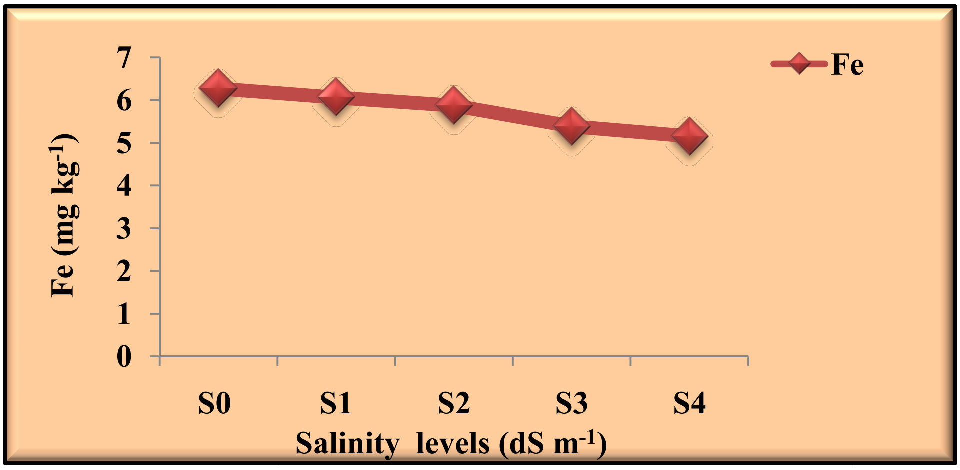

Fig.4.18: Effect of salt concentrations on available Fe (mg kg^{-1}) of soil after harvest

Table 4.16 Effect of salt concentrations on available micronutrients (mg kg^{-1}) of soil after harvest

Sr. No.	Treatments	Fe	Mn	Zn	Cu
A. Varieties (V)					
V_1	**Meha**	5.80	6.89	0.87	1.16
V_2	**GAM 5**	5.69	7.12	0.87	1.15
	S.Em. ±	0.06	0.07	0.01	0.01
	C.D. at 5%	NS	NS	NS	NS
B. Salinity Levels (S)					
S_0	**Tap water (EC 0.9 dS m^{-1})**	6.27	7.16	0.89	1.19
S_1	**EC 1.0 dS m^{-1}**	6.06	7.13	0.89	1.14
S_2	**EC 2.0 dS m^{-1}**	5.87	7.09	0.85	1.17
S_3	**EC 4.0 dS m^{-1}**	5.38	6.98	0.88	1.15
S_4	**EC 6.0 dS m^{-1}**	5.15	6.66	0.86	1.14
	S.Em. ±	0.09	0.10	0.01	0.02
	C.D. at 5%	0.27	NS	NS	NS
C. S × V Interaction					
	S.Em.±	0.13	0.15	0.02	0.03
	C.D. at 5%	NS	NS	NS	NS
	C.V. %	4.57	4.18	4.06	5.48

5. SUMMARY AND CONCLUSION

A pot culture experiment entitled "**Effect of saline water on growth, yield and quality of green gram (*Vigna radiata* L.) varieties"** was carried out during summer season of 2017 in the net house of Micronutrient Research Project (ICAR), Anand Agricultural University, Anand (Gujarat) with a view to studying the effect of varying salt concentrations on the performance of green gram varieties. The experiment was laid out in Factorial Completely Randomized Design with four repetitions. The artificially salinized water was used with five different levels *viz.* 0.9 (tap water), 1.0, 2.0, 4.0 and 6.0 dS m^{-1} by using the salts of NaCl, $CaCl_2$, $MgCl_2$, $NaHCO_3$, Na_2SO_4 and $CaCO_3$ by mixing it with R.O. water (0.01 dS m^{-1}). The effect of salt concentrations on germination percentage (7 DAS), plant height at 30 and 45 DAS and at harvest, proline content at 15 DAS and protein content of grain, nutrient composition *viz.* N, P, K, S, Na, Fe, Mn, Zn, and Cu in grain and stover and EC, pH, N, P, K, S, Ca, Mg, Na, OC, Fe, Mn, Zn, and Cu in soil after harvesting for two green gram varieties *viz.* Meha and GAM 5 was studied. The important findings of this investigation are summarized as under.

5.1 EFFECT OF SALT CONCENTRATIONS ON GERMINATION PERCENTAGE OF GREEN GRAM VARIETIES

The germination percentage was significantly affected by salt concentrations. The germination percentage at S_3 (EC_{iw} 4.0 dS m^{-1}) and S_4 (EC_{iw} 6.0 dS m^{-1}) levels was reduced by 38.10 and 50.81 per cent, respectively. The highest germination percentage was observed at S_0 level (EC_{iw} 0.9 dS m^{-1}) which was at par with S_1 level (EC_{iw} 1.0 dS m^{-1}). Germination percentage was not significantly affected due to varieties; however variety Meha recorded numerically higher germination percentage (77.5) as compared to GAM 5.

5.2 EFFECT OF SALT CONCENTRATIONS ON THE PROLINE CONTENT OF GREEN GRAM VARIETIES

The proline content of green gram varieties was significantly affected by salt concentrations and varietal effect at 15 DAS. The significantly highest proline content was found at S_4 level (EC_{iw} 6.0 dS m^{-1}) which was 241.28 µg g^{-1}. It was ranged from 50.17 to 241.28 µg g^{-1} of fresh weight of leaves. The variety Meha (V_1) recorded significantly highest (148.30 µg g^{-1}) proline content among both the varieties.

5.3 EFFECT OF SALT CONCENTRATIONS ON THE PLANT GROWTH, PROTEIN CONTENT AND YIELD OF GREEN GRAM VARIETIES

The plant height was significantly affected by varietal effect as well as salt concentrations at different growth stages i.e. at 30 & 45 DAS and at harvest. At S_1 level (EC_{iw} 1.0 dS m^{-1}) it was recorded significantly highest plant height of 16.28 and 41.19 cm at 30, 45 DAS, respectively while it was significantly higher (68.10 cm) at harvest which was at par with level S_0 (EC_{iw} 0.9 dS m^{-1}). The significantly highest plant height (15.01, 37.04 and 60.23 cm at 30, 45 DAS and at harvest, respectively) was recorded under V_1 (Meha).

Varieties did not change protein content in grain significantly but salt concentrations were found significant for protein content in grain. The significantly highest protein content (21.31%) and lowest (18.39%) were found under S_0 level (EC_{iw} 0.9 dS m^{-1}) and S_2 level (EC_{iw} 2.0 dS m^{-1}), respectively.

The effect of salt concentrations and variety on grain and stover was also found significant. The significantly highest grain yield (7.30 g pot^{-1}) and stover yield (28.66 g pot^{-1}) was found under S_1 level (EC_{iw} 1.0 dS m^{-1}). Among genotypes tested for salt tolerance, variety V_1 (Meha) gave significantly highest grain and stover yield (6.53 and 23.92 g pot^{-1}).

5.4 EFFECT OF SALT CONCENTRATIONS ON NUTRIENT CONTENT OF GREEN GRAM VARIETIES

The increasing salt concentrations significantly decreased N and P content in grain as well as in stover. The significantly highest N and P content in grain was found at S_0 level (EC_{iw} 0.9 dS m^{-1}) which was 3.41 and 0.35%, respectively while in stover it was also found significant at S_0 level (EC_{iw} 0.9 dS m^{-1}) which was 0.69 and 0.153%, respectively. Varietal effect found significant for N and P content in stover and it was significantly highest 0.59 and 0.143%, respectively for Meha (V_1).

The K content also significantly decreased with increasing the salt concentrations. It was significantly highest (0.59 & 0.44% in grain and stover, respectively) at S_0 level (EC_{iw} 0.9 dS m^{-1}). The reduction in potassium content in grain and stover was 13.56 and 54.55 per cent, respectively at EC_{iw} 2.0 dS m^{-1} as compared to control.

The sodium content significantly increased with increasing salt concentrations and it was significantly highest (0.11 & 0.38% in grain and stover, respectively) at S_2

level (EC_{iw} 2.0 dS m^{-1}). Increase in sodium content in grain and stover was 40.50 and 36.65 per cent, respectively at EC_{iw} 2.0 dS m^{-1} as compared to control.

The effect of salt concentrations on sulphur content in grain was found significant and it was significantly highest (0.63%) in grain at S_0 level (EC_{iw} 0.9 dS m^{-1}). There was a progressive decrease in accumulation of sulphur with increase in the salt concentrations. The reduction in sulphur content in grain was 34.92 per cent at EC_{iw} 2.0 dS m^{-1} as compared to control.

The effect of salt concentrations on Fe and Mn content in grain and stover was found significant and it was significantly highest (45.50 & 261.70 mg kg^{-1} in grain and stover) for Fe at S_0 level (EC_{iw} 0.9 dS m^{-1}) and (23.0 & 66.99 mg kg^{-1} in grain and stover) for Mn at S_2 level (EC_{iw} 2.0 dS m^{-1}).

The effect of salt concentrations on Zn and Cu content in grain and stover was found significant and it was significantly highest (31.82 & 17.01 mg kg^{-1} in grain and stover for Zn and 11.33 & 20.86 mg kg^{-1} in grain and stover for Cu, respectively) at S_0 level (EC_{iw} 0.9 dS m^{-1}).

5.5 EFFECT OF SALT CONCENTRATIONS ON CHEMICAL PROPERTIES OF SOIL AFTER HARVESTING

pH is decreased with increasing salt concentrations but it did not reach to the level of significance but the effect of salt concentrations on EC was found significant and it was significantly highest (0.23 dS m^{-1}) at S_4 level (EC_{iw} 6.0 dS m^{-1}). The EC of soil increased from 0.13 (S_0) to 0.23 dS m^{-1} (S_4) and it was increased of 1.77 times than control.

Organic carbon of soil also influenced by salt concentrations and it was found significant. There was increase in organic carbon with increasing salt concentrations and it was significantly highest (4.26 g kg^{-1}) at S_4 level (EC_{iw} 6.0 dS m^{-1} which was 1.25 times higher than control (3.40 g kg^{-1}).

There was decrease in available N and P_2O_5 with increasing salt concentrations. Available N and P_2O_5 of soil affected by salt concentrations and they were significantly highest (179.8 & 71.1 kg ha^{-1} for N and P_2O_5, respectively) at S_0 level (EC_{iw} 0.9 dS m^{-1}). Maximum reduction found at S_4 level (EC_{iw} 6.0 dS m^{-1}) which was 11.84 and 38.68 per cent for N and P_2O_5, respectively as compared to control. Available K_2O of soil also influenced by salt concentrations and it was significantly higher (290 kg ha^{-1}) at S_0 level (EC_{iw} 0.9 dS m^{-1}) which was at par with salinity level

S_1 and S_2 (EC_{iw} 1.0 & 2.0 dS m^{-1}, respectively). At S_4 level (EC_{iw} 6.0 dS m^{-1}) available K_2O reduced by 7.76 per cent as compared to control.

There was increase in exchangeable cations *viz*. Na^+, Ca^{2+} and Mg^{2+} of soil with increasing salt concentrations and the effect of salt concentrations on exchangeable cations was found significant. It was significantly highest (1.99, 6.09 and 2.20 meq/100g for Na, Ca and Mg, respectively) at S_4 level (EC_{iw} 6.0 dS m^{-1}).

The effect of salt concentrations was not found significant for available micronutrients except for Fe. It was significantly highest (6.27 mg kg^{-1}) at S_0 level (EC_{iw} 0.9 dS m^{-1}) and was decreased with increasing salt concentrations. It was reduced by 17.86 per cent as compared to control.

CONCLUSION

The results obtained in the present investigation are discussed earlier and summarized above; the salient findings from the same are concluded as under.

From the growth and yield point of view, there was a drastic damage to the crop at high salt concentrations above 2.0 dS m^{-1} EC of irrigation water so it is not beneficial for green gram.

Among the varieties, variety Meha gave higher grain and stover yield as compared to GAM 5 under salt stress.

The application of irrigation water with 0.9 dS m^{-1} EC showed the significant accumulation of macro and micronutrients by green gram and at high concentrations it was reduced.

Higher concentrations of salt also affected the nutrient status of soil. With increasing salt concentrations at high level caused reduction in available nutrients *viz*. N, P_2O_5, K_2O and Fe in soil.

Higher yield, height and proline content was observed in Meha as compared to GAM 5 so among the both cultivars, Meha had higher relative salt tolerance nature under the saline condition.

From the above findings it can be concluded that in a sandy loam soil, application of irrigation water below 2.0 dS m^{-1} for green gram could be advised. However, results need to be confirmed under field condition.

REFERENCES

Ahmed, M. E., Mohammed, K. E., Ibrahim, E. A., & Suleiman, N. N. (2012). Impact of salinity on seed germination and early seedling growth of three sorghum (*Sorghum bicolor* L. Moench) cultivars! *Science and Technology*, 2 (2), 16-20.

Ahmed, S. (2009). Effect of soil salinity on the yield and yield components of mungbean! *Pakistan Journal of Botany*, 41 (1), 263-268.

Al - Seedi, S. N. N. (2004). The effect of salinity on germination, growth and emergence of mung (*Vigna radiata* L. Wilczek) in different soil textures! *Journal of Thi - Qar University*, 1, 12-18.

Al - Zubaydi, S. R., Al-Mousawi, A. H., & Zair, H. (1992). Effect of salinity on germination, growth and ionic content of rice *Oryza sativa* L. at early seedling stage! *Basrah Journal of Science*, 5 (2), 251 - 261.

Amirjani, M. R. (2010). Effect of salinity stress on growth, mineral composition, proline content, antioxidant enzymes of soybean! *American Journal of Plant Physiology*, 5, 350-360.

Anonymous (2004). Indian harvest centre for monitoring Indian economy Pvt. Ltd., Mumbai.

Anonymous (2014). http://agropedia. litk.ac.in/content/area-production-and-productivity major pulses.

Arshad Ullah, M., Baber, R., Hyder, S. I., Mahmood, I. A., & Muhammad, T. (2016). Effect of salinity on growth of different mungbean varieties! *International Journal of Research Studies in Biosciences*, 4 (9), 7-9.

Ashraf, M. (2009). Biotechnological approach of improving plant salt tolerance using antioxidants as markers! *Biotech Advance*, 27, 84-93.

Bandyopadhyay, B. K., Dutt, S. K., & Bandyopadhyay, A. K. (1985). Ionic balance and growth of rice under saline soil condition! *Journal of Indian Society of Soil Science*, 33, 346-351.

Bates, L. A., Waldren R. P. and Taira, T. D. (1973). Rapid determination of free proline for water stress studies! *Plant and soil*, 39, 295-297.

Bernstein, L. (1975). Effect of salinity and sodicity on plant growth! *Annual Review of Phytopathology*, 13, 295-312.

Bhatt, M. J., Patel, A. D., Bhatt, P. M., & Pandey, A. (2008). Effect of soil salinity on growth, water status and nutrient accumulation in seedlings of *Ziziphus mauritiana* (Rhamnaceae)! *Journal of Fruit and Ornamental Plant Research*, 16, 383-401.

Bhumbla, D. R., & Singh, N. T. (1965). Effect of salt on seed germination! *Science and Culture*, 31, 96-97.

Cha-um, S., Pokasombat, Y., & Kirdmanee, C. (2011). Remediation of salt-affected soil by gypsum and farmyard manure − Importance for the production of Jasmine rice! *Australian Journal of Crop Science*, 5, 458-465.

Chang, K. L. and Bray R. H. (1951). Determination of calcium and magnesium in soil! *Soil Science*, 72, 449-458.

Deepika & Hans, R. D. (2014). Effect of salinity stress on morpho-physiological, biochemical and yield characters of cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.)! *Indian Journal of Plant Physiol*ogy, 19 (4), 393-398.

Dhawan, R. S., Sharma, D. R., & Chowdhary, J. B. (1987). Effect of salinity on germination and yield components in three species of Brassica! *Indian Journal of Agricultural Science*, 57,107-111.

Dutt, S. K. (1976). The leaf water potential of wheat and barley and its relation to soil salinity and alkalinity! *Biologia Plantarium*, 13, 299-300.

Dutta, P. & Bera, A. K. (2013). Effect of NaCl salinity on seed germination and seedling growth of mungbean cultivars! *Legume Research*, 37 (2), 161-164.

Epstein, E. (1972). Mineral nutrition of plants: Principles and perspectives! *Journal of Willey and Sons*, pp.412.

Fageria, N. K. (1985). Salt tolerance of rice cultivars! *Plant and Soil* (Netherland), 88, 237-243.

Francois, L. E., & West, D. W. (2004). Reduction in yield and market quality of celery caused by soil salinity! *American Society for Horticultural Science*, 107, 952-954.

Ghosh, S., Mitra, S., & Paul, A. (2014). Physiochemical studies of sodium chloride on mungbean (*Vigna radiata* L. Wilczek) and its possible recovery with spermine and gibberellic acid! *The Scientific World Journal*. 1 (1), 37-45.

Gloria, I. A., & Lilia, A. M. (2010). Salinity effects on protein content, lipid peroxidation, pigments, and proline in *Paulownia imperiali*s (Siebold & Zuccarini) and *Paulownia fortunei* (Seemann & Hemsley) grown *in vitro*! *Journal of Biotechnology*, 0717-3458.

Grattan, S. R., & Mass, E. V. (1985). Root and leaf phosphorus and chloride accumulation in soybean under salinity stress! *Agronomy Journal,* 77, 890-895.

Gupta, B. P., Muralidhar, M., Joseph, K. O., & Krishnani K. K. (2001). Effect of salinity level and manure dose on the release of nutrients from the brackishwater soil! *Aquaculture*, 2 (2), 191-200.

Hakkwan, K., Hanseok, J., Jihye, J., & Seungjong, B. (2016). Effects of irrigation with saline water on crop growth and yield in greenhouse cultivation! *Water*, 8, 127-136.

Hassen, K. A. K. (1999). Effect of salinity on germination , growth and ionic content of three varieties of barley *Hordeum vulgaris* L.! *Basrah Journal of Science*, 2, 87-98.

Hasan, M. M., Baque, M. A., Habib, M. A., Yeasmin, M., & Hakim, M. A. (2017). Screening of salt tolerance capability of wheat genotypes under salt stress condition! *Universal Journal of Agricultural Research*, 5 (4), 235-249.

Hasanuzzaman, Nahar, K., & Fujita, M. (2013). Plant response to salt stress and role of exogenous protectants to mitigate salt-induced damages! *Springer*, pp 25-87.

Hirpara, K. D., Ramoliya, P. J., Patel, A. D., & Pandey, A. (2005). Effect of salinisation of soil on growth and macro and micronutrient accumulation in seedlings of *Butea monosperma* (Fabaceae)! *Anales de Biologia*, 27, 3-14.

Huang, Z., Zhao, L., Chen, D., Liang, M., & Liu, Z. (2013). Salt stress encourages proline accumulation by regulating proline biosynthesis and degradation in jerusalem artichoke plantlets! *Plos One*, 8 (4), 37-42.

Jackson, M.L. (1973) Soil chemical analysis! Prentice Hall of India Pvt. Ltd., New Delhi.

Jacoby, B. (1999). *Handbook of Plant and Crop Stress*, pp. 97-123.

Jamil, A., Riaz, S., Ashraf, M., & Foolad, M. R. (2011). Gene expression profiling of plants under salt stress! *Crit Rev Plant Science,* 30, 435-458.

Jampeetong, A., & Brix, H. (2009). Effects of NaCl salinity on growth, morphology, photosynthesis and proline accumulation of *Salvinia natans*! *Aquatic Botany,* 91, 181-186.

Joaguin, P., Dantur, N. C., Casanova, M. R., & Bastos, V. N. (2007). Performance of soybean *cv.* Bragg under condition of soil salinity in the field! *Universal Journal of Agricultural Research*, 31, 147-149.

Kabir, M. E., Karim, M. A., & Azad, M. A. K. (2004). Effect of potassium on salinity tolerance of mungbean (*Vigana radiata* L. Wilczek)! *Journal of Biological Sciences,* 4, 103-110.

Kaur, H., & Gupta, N. (2018). Ameliorative effect of proline and ascorbic acid on seed germination and vigour parameters of tomato (*Solanum lycopersicum* L.) under salt stress! *International Journal of Current Microbiology and Applied Sciences*, **7** (1), 3523-3532.

Kaymakanova, M. (2009). Effect of salinity on germination and seed physiology in bean (*Phaseolus Vulgaris* L.)! *Biotechnology & Biotechnological Equipment*, 23, 326-329.

Khan, M. N., Ungar, I. A., & Showalter, A. M. (1999). The effect of salinity on the growth, ion content and osmotic relation in *Halopyrum mucronatum* L.! *Journal of Plant Nutrition*, 22 (1), 19 -204.

Khatkar, D., & Kuhad, M. S. (2000). Short-term salinity induced changes in two wheat cultivars at different growth stages! *Biologia Plantarum*, 43 (4), 629-632.

Krasensky, J., & Jonak, C. (2012). Drought, salt and temperature stress-induced metabolic rearrangements and regulatory networks! *Journal of Express Botany*, 63, 1593-1608.

Kumar, D., & Daulay, H. S. (1995). Screening of castor germplasm for salt tolerance towards seedling emergence! *Current Agriculture*, 12, 71-75.

Kumar, D., & Malik, R. S. (1983). Salt tolerance in six Indian mustard cultivar! *Indian Journal of Agronomy*, 28, 325-331.

Kumar, R., Singh, M. P., & Kumar, S. (2012). Effect of salinity on germination, growth, yield and yield attributes of wheat. *International Journal of Scientific and Technology Research*, 1 (6), 19-23.

Kumar, V. & Kumar, D. (1985). Effect of sodicity and seedrate on seedling and oil content of Indian mustard! *Current Agriculture*, 9, 21-26.

Kumari R. P., & Vishnuvardhan Z. (2015). Effect of salinity on growth, protein and antioxidant enzymes in three kodo millet (*Paspalum scrobiculatum*) germplasm! *International Journal of Current Microbiology and Applied Sciences*, 4 (6), 475-483.

Lal, P., & Singh, K. S. (1974). Effect of water qualities and fertilizer levels on nutrient uptake by wheat! *Soil and Fertilizer*, 38 (11), 5096.

Lal, R. K., & Bhardwaj, S. N. (2004). Effect of salinity on mineral composition and ionic balance in field pea (*Pisum sativum* L. Var. Arvensis)! *Indian Journal of Plant Physiology*, 27, 351-354.

Lambridge, C. J., & Godwin, I. D. (2007). Genome mapping and molecular breeding in plants! *Springer*, 3, 69-90.

Liener, I. E. (1975). Antitryptic and other anti-nutritional factors in legumes! *Nutritional improvement of food legumes by breeding* (ed. Milner M) John Wiley and Sons, New York.

Lindsay, W. L. and Norvell, W. A. (1978). Development of a DTPA soil test for zinc, iron, manganese and copper! *Soil Science Society of American Journal*, 42 (3), 421.

Lutts, S., Majerus, V., & Kinet, J. M. (2007). NaCl effects on proline metabolism in rice (*Oryza sativa* L.) seedlings! *Physiologia Plantarum*, 105, 450-458.

Magda, H. M., & Kramany, M. F. (2005). Salinity tolerance of some mungbean varieties! *Journal of Applied Sciences Research*, 1 (1), 78-84.

Mahmood, A., Latif, T., & Khan, M. A. (2009). Effect of salinity on growth, yield and yield components in basmati rice germplasm! *Pakistan Journal of Botany*, 41 (6), 3035-3045.

Maliwal, G. L., & Paliwal, K. V. (1982). Salt tolerance of gram (*Cicer arietinum* L.) and linseed (*Linum usitatissium* L.) varieties at germination and seedling stage. *Current Agriculture*, 6, 79-83.

Manchanda, H. R. (1976). Quality of ground waters of Harayana! *Harayana Agricultural University*, 160.

Mass, E. V., & Hoffman, G. J. (1977). Salt tolerance current assessment! *Journal of Irrigation and Drainage* Div. ASCE, 103, 11534.

Mass, E. V., Ogata, G., & Garber, M. J. (2012). Influence of salinity on Fe, Mn, and Zn uptake by plants! *Agronomy Journal*, 64 (6), 793-795.

Meloni, D. A., Gulotta, M. R., Martinez, C. A., & Oliva, M. A. (2004). The effects of salt stress on growth and nitrate reduction in *Prosopis Alba*! *Brazilian Journal of Plant Physiology*, 16 (1), 39-46.

Misra, N., & Dwivedi, U.N. (2004). Genotypic difference in salinity tolerance of green gram cultivars! *Plant Science*, 166, 1135–1142.

Misra, N., & Gupta, A. K. (2005). Effect of salt stress on proline metabolism in two high yielding genotypes of green gram! *Plant Science*, 169, 331-339.

Mudgal, V., Madaan, N., Mudgal, A., Mishra, S., Singh, A., & Singh, P. K. (2009). Changes in growth and metabolic profile of chickpea under salt stress! *Journal of Applied Biosciences*, 23, 1436-1446.

Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance! *Annual Revolution of Plant Biology*, 59, 651-681.

Nasir, S. N. (2002). Effect of salinity on germination, growth and mineral contents of three varieties of wheat *Triticum durum* L.! *Journal of Babylon University*, 7 (2),1334-1340.

Nazarbeygi, E., Yazdi, H. L., Naseri, R., & Soleimani, R. (2011). The effects of different levels of salinity on proline and A-, B- Chlorophylls in canola! *Journal of Agricultural and Environmental Science*, 10 (1), 70-74.

Nivedita, P., Shishira, T., Singh, K. G., & D'souza, M. R. (2016). Biochemical response of *Solanum melongena* to salinity stress in relation to stress factors! *Journal of Chemical, Biological and Physical Sciences*, 6 (3), 756-766.

Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. (1954). Estimation of available phosphorus in soil by extraction with sodium hydrogen carbonate, U.S.D.A. Circ. 939: 9.

Paliwal, K. V., & Maliwal, G. L. (1980). Growth and nutrient uptake relationship of some crop in saline substarte! *Annals of Arid Zone*, 19, 251-257.

Paliwal, K. V. (1972). Irrigation with saline water IARI, Monograph No.3 (New Series) WTC/IARI, New Delhi. 198 p.

Panda, S. K., & Khan, M. H. (2009). Growth, oxidative damage and antioxidant responses in green gram (*Vigna radiata* L.) under short-term salinity stress and its recovery! *Journal of Agronomy and Soil Science*, 195 (6), 442-454.

Panuccio, M. R., Jacobsen, S. E., Akhtar, S. S., & Muscolo, A. (2014). Effect of saline water on seed germination and early seedling growth of the halophyte quinoa! *AoB Plants,* 6, 47-64.

Patel, P. R., Sushil, S. K., Patel, V. R., Patel, V. J., & Khristi, S. M. (2010). Impact of salt stress on nutrient uptake and growth of cowpea! *Brazilian Society of Plant Physiology*, 22 (1), 43-48.

Piper, C. S. (1966). Soil and plant analysis! Hans publishers, Bombay.

Prakash, M. (2017). Effect of salinity on germination and seedling growth of green gram varieties! *International Journal of Plant Sciences*, 12 (1), 79-84.

Prapagar, K., Dasina, S., & Shanika, W. (2015). Effect of different salinity levels of a soil on nutrient availability of manure amended soil! *Tropical Agricultural Research*, 23 (2), 168-176.

Prasad, A., Chattopdhyay & Chand, S. (2010). Effect of zinc sulphate and farm yard manured on lemongrass (*Cymbopogan flexuous*) under sodic water irrigation! *Journal of the Indian Society of Soil Science,* 58, 315-322.

Rajakumar, R. (2013). A study on effect of salt stress in the seed germination and biochemical parameters of rice (*Oryza sativa* L.) under *in vitro* condition! *Asian Journal of Plant Science and Research*, 3 (6), 20-25.

Reddy, G. V., Pandamanabham, M., Reddy, D. R., & Sankararao, V. (1982). Effect of saline water irrigation on properties of sandy loam soil and crop growth of groundnut! *Current Agriculture*, 6, 40-46.

Reddy, S. R. (2013). *Agronomy of field crops*. Kalyani Publication, New Delhi, pp. 325-329.

Richards, L. A. (1954). The diagnosis and improvement of saline and alkali soils! USDA, Handbook No. 60.

Saady, N. A., Khan, A. J., Rajesh, L., & Esechie, H. (2012). Effect of Salt Stress on germination, proline metabolism and chlorophyll content of fenugreek (*Trigonella foenum gracium* L.)! *Journal of Plant Sciences*, 7 (5), 176-185.

Sabah, N. N., & Hana, J. G. (2010). Effect of salinity on seed germination, growth and organic compounds of mungbean plant! *Journal of Thi-Qar University*, 5, 65-69.

Sehrawat, N., Jaiwal , P. K., Yadav, M., Bhat, K. V., & Sairam, R. K. (2013). Salinity stress restraining mungbean (*Vigna radiata* (L.) Wilczek) production: Gateway for genetic improvement! *International Journal of Agriculture and Crop Sciences*, 6 (9), 505-509.

Sharma, A., & Dhanda, S. (2015). Application of calcium chloride to mitigate salt stress in *Vigna Radiata* L. cultivars! *International Journal of Current Microbiology and Applied Sciences*, 4 (2), 764-769.

Singh, S. S., Malik, Y. S., Pandita, M. L., & Jaiswal, R. C. (1999). Salt tolerance in chilli (*Capsicum annuum* L.) variety NP-46A! *Haryana Agricultural University Journal of Research*, 12, 308-312.

Sinha, A., Gupta, R. S. & Rana, R. S. (2007). Effect of salinity and soil water availability and chemical composition of *Sorghum helepense* L.! *Plant and Soil*, 95, 411-418.

Sohrabi, Y., Haidari, G. & Esmailpoor, B. (2008). Effects of salinity on growth and yield of Desi and Kabuli chickpea cultivars! *Pakistan Journal of Biological Science*, 11 (4), 664-667.

Soussi, M., Santamaroa, M., Ocana, A., & Lluch, C. (2001). Effects of salinity on protein and lipopolysaccharide pattern in a salt-tolerant strain of Mesorhizobium ciceri! *Journal of Applied Microbiology*, 90, 476-481.

Sreejith, P. S., Divya, S., Praseeja, R. J., & Asha, V. V. (2014). Effect of salt stress on seed germination and seedling growth of green gram! *The Journal of Plant Pathology*, 114, 156-164.

Steel, R. G. and Torrie, J. H. (1982). Principles and procedure of statistics! Mc. Graw Hill Book Company, New Delhi-110 001.

Strongonov, B. P. (1964). Physiological basis of salt tolerance of plants! *Israel Program for Scientific Translations*, 279.

Subbiah, B. V. and Asija, G. L. (1956). A rapid procedure for determination of available nitrogen in soils! *Current Science*, 25, 259-260.

Sudhakar, C., Reddy, P. S., & Veeranjaneyulu, K. (1993). Effect of salt stress on the enzymes of proline synthesis and oxidation in greengram (*Phaseolus aureus* roxb.) seedlings! *Journal of Plant Physiology*, 141 (5), 621-623.

Tejera, N. A., Campos, R., Sanjuan, J., & Lluch, C. (2005). Effect of sodium chloride on growth, nutrient accumulation, and nitrogen fixation of common bean plants in symbiosis with isogenic strains! *Journal of Plant Nutrition*, 28, 1907-1921.

Tester, M., & Davenport, R. (2003). Na tolerance and Na transport in higher plants! *Annals of Botany*, 91, 503 - 527.

Williams, C. H. and Steinberg, A. (1959). Soil sulphur fractions as chemical indices of available sulphur in some Australian soils! *Australian Journal of Agricultural Research*, 10, 340 - 352.

CERTIFICATE

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