MITIGATION OF SALT STRESS THROUGH KAZI COMPOST IN CHICKPEA

A THESIS

BY

MARIOM AKTAR

Student No. 1905013

Session: 2019-20

Thesis Semester: January-June, 2020

MASTER OF SCIENCE (M. S.)

IN

AGRONOMY

DEPARTMENT OF AGRONOMY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY

UNIVERSITY DINAJPUR

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A Thesis Submitted To

The Department of Agronomy

Hajee Mohammad Danesh Science and Technology University, Dinajpur

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (M.S.)

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JUNE 2020

Dedicated
To My
Beloved Parents

ACKNOWLEDGEMENTS

First of all, the author bow down her head to Him, the merciful "Almighty Allah" for His blessing hand and bestowing a creative and healthy environment throughout her academic and research period. The author wishes to acknowledge the immeasurable grace and profound kindness of Allah for giving mental peace, health and strength to submit the thesis for the degree of Master of Science (MS) in Agronomy.

The author would like to extend her heart-squeezed gratitude, deepest appreciation, best regards and indebtedness to her honorable teacher and research Supervisor ***Professor Dr. Md. Sohidul Islam****, Chairman, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur, for his untiring guidance, scholastic supervision, valuable advice, innovative suggestions, constant encouragement, helpful comment, affectionate feeling and inspiration in all phases of conducting the research work and preparation of the thesis.*

The author would like to express her sincere appreciation, heartfelt gratitude to her research Co-supervisor ***Professor Dr. Md. Shafiqul Islam Sikdar****, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur, for his valuable advice, constructive criticism and factual comments in upgrading the research work and this document.*

The author would like to express her deepest respect and boundless gratitude to Mohosena Akter, Assistant Professor, Shams Shaila Islam, Assistant Professor and other teachers of the Department of Agronomy, HSTU for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study and research work.

The author also expresses her heartfelt thanks to ***Dr. Md. Rafiqul Islam****, Senior Scientific Officer, Bangladesh Agricultural Research Institute BARI, Agronomy Division, Regional Agricultural Research Station (RARS), Ishurdi, Pabna.*

The author feel privileged to express her sincere thanks to the laboratory staff for providing necessary cooperation during research work and the author offer special thanks to Ministry of Science and Technology, Bangladesh for providing her the support and research grand (NST fellowship) for the completion of this valuable task.

Finally the author is ever grateful to her respective parents Zahurul Islam and Asmetara Begum for their everlasting love, patience, moral and constant blessings and specially maternal uncle Md. Ashadul Islam who always guides and helps the author in every difficult situation of her life. Cheerful acknowledgements are expressed to her brothers, sisters, niece, nephew, relatives and all classmates and friends (especially Zannat Alvi and Mashrufa Tasnim Tithi).

The Author

ABSTRACT

A pot experiment was conducted in semi-controlled condition during the period from 11th December 2019 to 22nd March 2020 at the Department of Agronomy, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur to assess the effect of Kazi compost (KC) to mitigate salinity stress in chickpea var. BARI Chola-11. Three levels of Kazi compost viz., i) KC_0 = No compost (Control), ii) KC_1 = 10% compost, and iii) KC_2 = 20% compost @ 9 kg soil pot^{-1}. Saline solution was prepared by adding semi-refined coarse salt (NaCl) in tap water to make three levels of salt stress viz., i) S_0 = No salt (Control), ii) S_1 = 50 mM NaCl, and iii) S_2 = 100 mM NaCl salinity. Plants were irrigated with the salt solution from seedling stage to maturity, and the control plants were irrigated with tap water. Data on different parameters like the plant height, leaf, stem, root dry matter and yield contributing parameters were recorded at harvest. Experimental results revealed that salinity decreased plant height, dry weight of leaf, stem and root as well as yield of chickpea $plant^{-1}$. Application of Kazi compost had positive effects to mitigate salinity stress on all those studied parameters. Nevertheless, Kazi compost at the rate of 10% showed better result to mitigate salinity stress at 50mM NaCl, and 20% showed best result to mitigate salinity stress at 100 mM NaCl. From the study, it was proposed that under salt stress, the application of Kazi compost can be a suitable practice for more production of chickpea in saline affected soil Bangladesh. Present study provided basic information related to the plant growth, yield attributes and yield which suggest chickpea as a salt sensitive leguminous crop, and can be grown saline affected regions with application of 20% compost.

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ABBREVIATIONS AND ACRONYMS

KC	:	Kazi Compost
AEZ	:	Agro-Ecological Zone
ANOVA	:	Analysis of Variance
NaCl	:	Sodium Chloride
BARI	:	Bangladesh Agricultural Research Institute
BBS	:	Bangladesh Bureau of Statistics
FAO	:	Food and Agriculture Organization
BNF	:	Biological Nitrogen Fixation
GDP	:	Gross Domestic Product
CV	:	Co-efficient of Variation
N	:	Nitrogen
IMF	:	International Monetary Fund
SOM	:	Soil Organic Matter
Na	:	Sodium
K	:	Potassium
Cl	:	Chloride
HYV	:	High Yielding Varieties
mM	:	Millimole
mm	:	Milimeter
g	:	Gram
FYM	:	Farm Yard Manure
VC	:	Vermicompost
SRDI	:	Soil Resource Development Institute
P	:	Phosphorus
MoP	:	Muriate of Potash
TSP	:	Triple Super Phosphate
EC	:	Electrical Conductivity
ppm	:	Parts per million

ABBREVIATIONS AND ACRONYMS (Continued)

LSD	:	Least Significant Difference
BY	:	Biological Yield
DAS	:	Days After Sowing
CRD	:	Completely Randomized Design
DMRT	:	Duncan’s Multiple Range Test
UNDP	:	United Nations Development Program
LFW	:	Leaf Fresh Weight
SFW	:	Stem Fresh Weight
RFW	:	Root Fresh Weight
PFW	:	Pod Fresh Weight
LDW	:	Leaf Dry Weight
SDW	:	Stem Dry Weight
RDW	:	Root Dry Weight
PDW	:	Pod Dry Weight

CHAPTER I

INTRODUCTION

The chickpea (*Cicer arietinum* L.) belongs to Fabaceae family. It also called Bengal gram or Garbanzo, is the largest produced food legume in South Asia, and the third largest produced food legume globally, after common bean (*Phaseolus vulgaris* L.) and field pea (*Piston sativum* L.). Chickpea is grown in more than 50 countries (90% area in Asia, 4.7% in Africa, 3.1% in Oceania, 1.6% in Americas and 0.5% in Europe), but developing countries account for over 95% of its production (FAO, 2011). Pulses are rich in protein and contain more than three times higher quality protein than cereals. Chickpea is the most important food legume after common bean with protein content ranges of 15-30%, and becomes the most significant part of a vegetarian diet to overcome protein deficiency. It contains higher level of protein, fiber, minerals (phosphorus, calcium, magnesium, iron and zinc) and β-carotene (Legesse *et al*., 2017). Its lipid fraction is high in unsaturated fatty acids. Nutrition qualities and health benefits of chickpea have been summarized in a recent review by Jukanti *et al*. (2012). Bangladesh has been facing seriously in protein malnutrition that threatening to gammy the whole nation. Pulses are considered as the "poor men's meat" as these are the cheaper source of protein (Mian, 1976). In Bangladesh, the consumption rate of pulses is only 12 gm capita^{-1} day^{-1} whereas the World Health Organization suggests an intake of 45gm of pulses capita^{-1} day^{-1} (BARl, 1998). Pulse crops preserve and improve soil fertility through biological nitrogen fixation (BNF) in soil and hence, contribute a significant role in sustainable agriculture. Chickpea plays a significant role in improving soil fertility by fixing the atmospheric nitrogen. Chickpea meets 80% of its nitrogen (N) requirement from symbiotic nitrogen fixation, and can fix up to 140 kg N ha^{-1} from air (Saraf *et al*., 1998). It leaves substantial amount of residual nitrogen for subsequent crops, and adds plenty of organic matter to maintain and improve soil health and fertility. Because of its deep tap root system, chickpea can avoid drought conditions by extracting water from deeper layers in fine soil profile. Increasing preference for vegetable protein and interest, the consumption of chickpea has increased the global demand. Chickpea is imported by over 130 countries (FAO, 2011). Awareness of benefits of chickpea in crop diversification and sustainable agriculture has increased interest of farmers in growing chickpea. During Covid-19, agriculture and the rural economy are playing a significant role in ensuring that the economy of Bangladesh remains secure, as the industrial and service sectors could not perform well. Geographical and agronomic conditions of Bangladesh are favorable for chickpea cultivation. Chickpea is one of the major pulses cultivated and consumed in Bangladesh. It is grown in winter season of Bangladesh, and competes with a variety of winter crops.

Globally the agriculture has currently been facing enormous challenges including soil salinity which significantly reduces the yield of crops. The over salinity of the soil is one of the main factors that limits the spread of plants in their natural habitats. It is an ever-increasing problem in arid and semi-arid regions (Shanon, 1986), and arid and semi-arid lands represent around 40% of the earth's area (Fisher and Turner, 1978). The productivity of agricultural lands in arid and semi-arid environments is affected by the accumulation of salts and the loss of soil organic matter (SOM). The latter one leads to the loss of soil fertility and deteriorates of its agro-physical, biological and other properties. The deficiency of K initially leads to chlorosis and then causes necrosis (Gopal and Dube, 2003). Excess soluble salts reduce yields by impairing germination, or creating osmotic gradients which interfere with the uptake of essential nutrients by plants (Stamatiadis *et al.*, 1999). Salinity affects plant growth by inducing water deficit, low uptake and accumulation of essential nutrients, and high accumulation of toxic ions such as Na^+ and Cl^- in plant cells (Islam, 2001; Islam *et al.*, 2011). Due to increasing demand of cereals, farmers are interested to allocate good soils for cereals instead of legumes resulting cultivation of legumes is pushing to the problems soils including saline soils (Islam, 2001). But its productivity is very low due to soil salinity. Reclamation of saline soil is difficult. Many legume crops including chickpea are severely affected by soil salinization at almost all stages of the plant growth such as germination, vegetative growth, and especially during reproductive processes. Successful production of chickpea depends on various factors where mitigation of salt stress is one of them that contribute to the yield and production of chickpea.

However, alternative ways may be adopted like mitigation of salinity using compost. Compost is an organic material which decomposes and improves physicochemical properties of soil. There are evidences that soil amendments with various organic substances such as farmyard manure, poultry manure and mulch can be used for the reduction of toxic effects of salinity in various plant species (Abou El-Magd *et al*., 2008; Leithy *et al*., 2010; Raafat and Thawrat, 2011; AlTaey, 2017; Niamat *et al*., 2019; Ibrahim *et al*., 2020). However, scarce information is available on the effect of the organic amendments on mitigation of salinity on chickpea. Kazi Farms Group recently developed a compost namely Kazi compost, and marketing in the Northern part of Bangladesh. Kazi compost is a dark grey, non-granular form and absence of foul odour that consists mostly of decayed organic matter. In this case, Kazi compost may reduce the harmful effect of salinity on crop productivity. But no study has yet been examined to the ameliorative effects of Kazi compost on chickpea under saline conditions in Bangladesh. In view of the above back ground, the present investigation was undertaken with the following objectives:

i) To find out the tolerable level of salt stress for growing BARI Chola-11, and
ii) To know the ameliorative effect of Kazi compost in chickpea crop under saline conditions and optimum level of compost.

CHAPTER II

REVIEW OF LITERATURE

Higher productivity of any crops is manipulated by the basic ingredients of agriculture. The basic ingredients include stress management, environment and agronomic practices. Salinity is one of the most serious factors limiting the productivity of agricultural crops. High yielding varieties (HYV) are generally more sensitive to salt stress and they produce lower yield. Application of compost is an important factor that influences the plant growth and development, nutrient uptake, water holding capacity, cation exchange capacity and other properties of soil etc. Salt stress mitigation through compost application is more effective for the growth and yield of chickpea. A large number of researchers throughout the world have carried out research works about the effects of salinity stress on various crops including chickpea. Some of the relevant works and their findings in connection with the present work have been reviewed and presented in this chapter.

2.1 Effect of salt stress on the growth, yield and yield attributes of chickpea

Salinity is an ever-present major constraint and a major threat to legume crops, particularly in areas with irrigated agriculture. Legumes demonstrate high sensitivity, especially during vegetative and reproductive phases. Salt stress is one of the limiting factors for successful chickpea production. To justify the present study attempts have been made to incorporate some of the important findings of different scientists and researchers in this country and elsewhere of the world.

2.1.1 Effect on germination and early seedling growth

Ali *et al*. (2014) carried out an experiment on chickpea at Forestry Sciences Nursery, University of Zalingei, Sudan and observed that the germination percentage (GP), plumule length, radical length, and fresh and dry seedling weights were higher in the control treatment. High salinity level (1.5%) significantly ($p \leq 0.05$) reduced the GP. The maximum

GP (98%) was observed in the control treatment and the minimum (58%) was found with 1.5% NaCl concentration. Seedling length decreased with increasing NaCl concentration. The differences were highly significant ($p \leq 0.01$). The seedling length reduction by 44, 13.5 and 2.7% relative to control with 1.5, 1.0 and 0.5% NaCl concentration, respectively. Seedling fresh and dry weights followed the same trend of seedling length, and high salinity (1.5%) resulted in highly significant reduction ($p \leq 0.01$) in both parameters measured.

Lavrenko *et al*. (2019) conducted an experiment in greenhouse conditions of Kherson State Agrarian University, and reported that the germination and seedling growth properties of chickpea (variety Rosanna, kabuli type) reduced with increasing salinity stress. A considerable decrease of the germination and initial seedling growth started with NaCl concentration of $1.79 gL^{-1}$. Salinity decreased the germination percentage by 33.9%, plant height by 7.8%, and root length by 5.5% in comparison to the control condition.

Haileselasie and Teferii (2012) conducted an experiment at the Botany laboratory, Department of Biology, Mekelle University, Northern Ethiopia and observed that the concentrations of salt have a negative impact on the germination and seedling growth of chickpea. The germination percentage, water uptake and length of root and shoot decreased with increasing the concentration of salt stress. NaCl highly affects germination and seedling growth of chickpea than Na_2SO_4. Meanwhile, the effect of salinity for both landrace (Hagereselam and Samre) have significance difference in parameters of water up take, percentage of germination, length of root and shoot ($p<0.05$).

Sohrabi *et al.* (2008) carried out an experiment in Research Greenhouse of Mokrian Agricultural Extension Center near Mahabad, Iran in 2006 and reported that when seeds of four chickpea cultivars {(Kabuli-Hashem and Jam) and (Desi-Kaka and Pirooz)} were grown under 0, 3, 6 and 9dS m^{-1} levels of salinity until maturity, the plant growth, flower, pod and seed number and seed weight reduced. As increase in salinity, the undesirable effect of Na^+ was more pronounced and reached the highest value at $9dSm^{-1}$ in all cultivars. Chickpea cultivars have different responses to salinity and the Kabuli cultivars seemed to have a greater capacity for salt tolerance compared to Desi cultivars. Hahshem cultivar has the highest salinity tolerance among all cultivars.

Ceritoğlu *et al.* (2020) observed that the seven cultivars (Diyar-95, Arda, Sarı-98, Yaşa-05, Hisar, Çakır and Aydın-92) were affected by NaCl concentration (0, 50 mM and 100 mM). The maximum and the minimum reduction rates in germination percentage, plant height, number of branches, stem diameter and fresh weight compared with the control were calculated as 8.4-39.6, 10.5-36.7, 15.1-43.3, 8.4-31.0 and 12.5-42.5%, respectively. Çakır and Arda cultivars were tolerant of salinity while Diyar-95 and Sarı-98 were susceptible.

Özaktan *et al.* (2018) conducted an experiment at the Department of Field Crops, Faculty of Agriculture, Erciyes University, Kayseri, Turkeya and reported that chickpea cultivars (Akçin 91, Aziziye, Gökçe, Inci, Işık-05 and Yaşa-05) germination and seedling growth attributes such as germination percentage, mean germination time, lengths, fresh and dry weights of radicle and plumule, chloride (Cl^-) content of seedling, and seedling length, fresh and dry weight reduced with the EC of 4, 8 and $16dSm^{-1}$. The dose of 16 dSm^{-1} of salt stress was found to be lethal. Cl^- content of seedling was increased from 0.05 ppm in control to 4.10 ppm in 16 dSm^{-1}, resulting decreased the germination, emergence and seedling growth. The best performed cultivar was Aziziye under NaCl, Işık-05 under $CaCl_2$ and Gökçe under $MgCl_2$ stresses indicating that there was a genotypic variation towards different salt sources.

Kaya *et al.* (2008) reported that small seeds {seed sizes (7, 8 and 9 mm)} germinated and grew more rapidly compared to medium and large seeds of the same cultivars (three popular chickpea cultivars: AKN-97, Gokce and Uzunlu-99) against all levels of salt stress (EC of

4.5, 8.6, 12.7 and 16.3 dSm^{-1}), and observed the best results in the cultivar Uzunlu-99. Regression analysis results showed a significantly positive relationship ($P<0.01$) between seed size and mean germination time, whereas a significantly negative relationship was recorded between seed size and germination index, root length, shoot length.

Shanko *et al.* (2017) carried out an experiment at Bule Hora University in the Biology laboratory in May 2016, and observed that significant difference present in germination percentage, germination rate, radicle and plumule length parameters under salinity conditions (0, 5, 10 and 15 dSm^{-1}) in five chickpea landraces (Dadi, Dido, Dida, Dimi and Soya). The genotype Dimi, Dido and Dadi showed highest values of germination percentage, radicle length and plumule length, respectively. Chickpea landraces Dimi, Dido and Dadi were salt tolerant during germination stage. However, chickpea landraces Soya was salt sensitive during this stage. The rest chickpea landraces were intermediate in its salt tolerance.

2.1.2 Effect on yield attributes

Ram *et al.* (1989) reported that varying levels of chloride and sulphate salinity in sand culture delayed the nodule initiation, decreased nodule weight and leghaemoglobin content of fresh nodules in chickpea. Reduction in pod number and weight, seed yield, 100-seed weight and biological yield was observed. Harvest index increased at lower but decreased at higher salinity levels. Salinity also restricted the movement of fixed nitrogen out of the nodules and resulted in greater accumulation of nitrogen into leaves and pod shells. Seed nitrogen drastically reduced under both types of salinity.

2.2 Effect of salt stress on the growth, yield and yield attributes of other legumes

Tayyab *et al*. (2016) conducted an experiment at Biosaline Research Field, Department of Botany, University of Karachi, Pakistan to investigate the effect of salinity on pigeon pea, and observed the salt sensitive growth responses of chickpea, however, it survived up to 3.5

(ECe dSm^{-1}) sea salt salinity. Plant height, biomass, SSL and RGR linearly decreased under saline conditions. Leaf pigments increased (chlorophylls) or maintained (carotenoids) at 1.6 dSm^{-1} and subsequently decreased in higher salinity. Low moisture content and succulence along with more accumulation of soluble sugars and proteins may be attributed to leaf osmotic adjustments at low salinity. Salinity adversely affects the reproductive growth of *Cajanus cajan* where production of flowers, pods, number of seeds and seed weight were significantly reduced.

Taibai *et al*. (2016) reported that the difference between the genotypes of *Phaseolus vulgaris* L. in response to salinity is a quantitative trait rather than qualitative since they develop the same strategies with a significant variation in the rate of synthesis and accumulation, with the exemption of the antioxidant defense based on the synthesis of phenolic compounds. For both genotypes, salinity induced a marked reduction in dry matter gain in roots and shoots along with oxidative stress as indicated by the significant increase in malondialdehyde content. In addition, the photosynthetic pigments decreased with the increase of salinity. The only qualitative difference was the decrease of total production of phenolic compounds in leaves that was only detectable in the low-yielding genotype under high salinity. The high-yielding genotype may have a better protection against the oxidative damages by increasing the activity of antioxidant enzymes and the amounts of total flavonoids and ascorbic acid under high salinity, which allows maintaining higher yield even upon stress conditions. These results indicate that salt induced oxidative stress in bean is mainly counteracted by enzymatic defense systems, and that the metabolism of phenolic compounds is induced under very extreme conditions. The selection of genotypes for this trait will increase yield under stress conditions.

Amira and Qados (2011) carried out an experiment in a greenhouse, at princess Nura Bint Abdul-Rahman University, Riyadh, and investigated the effect of sodium chloride (NaCl) concentrations (0.0, 60, 120, 240 mM) on the growth, osmotic potential, chlorophyll content, protein content of (*Vicia faba* L.) seedlings. NaCl caused an increase in plant height with low and medium concentrations, and a decrease with the highest concentration in both measurement periods. Salinity increased the fresh and dry weights of the shoot in the two measurement periods. Osmotic potential showed a significant decrease with the increase in concentrations, and in the duration of the stress periods. Salinity significantly reduced chlorophyll ‘a’ content in measurement periods and reduced chlorophyll ‘b’, total chl, and carotenoids contents after 10 days of treatment. An increase was observed in the protein content in the two measurement periods due to the impact of salinity stress.

2.3 Effect of compost on the yield and yield attributes of chickpea

Singh *et al.* (2012) reported that the application of 5 t FYM ha^{-1} improved chickpea grain yield by 14.89%, 30 and 60 kg P_2O_5 ha^{-1} by L4.81 and 21.85% and 25 kg $ZnSO_4$ ha^{-1} by 5.18% on the basis of three-year mean, as compared to no application of nutrients. Chickpea grain yield increased with successive increase in dose of vermicompost from 0 to 3 t ha^{-1}, and 2 t ha^{-1} seemed to be the optimum dose. Applications of 10 kg N + 20 kg P_2O_5 ha^{-1} and 20 kg N + 40 kg P_2O_5 ha^{-1} increased the grain yield by 18.97 and 24.20%, respectively over no application of nitrogen and phosphorus.

Basir *et al.* (2008) carried out an experiment at Agricultural Research Farm, NWFP Agricultural University, Peshawar, Pakistan and observed that 60 kg P_2O_5 ha^{-1} significantly improved agronomic traits among the other P treatments (0, 30, 60, 90 kg P_2O_5 ha^{-1}). The maximum values of the plant height (94.7 cm), number of pods $plant^{-1}$ (81.9), thousand grain weight (241.5 g), number of nodules $plant^{-1}$ (87), above ground biomass yield (7793 kg ha^{-1}), straw yield (3475 kg ha^{-1}) and grain yield (1993 kg ha^{-1}) were recorded for 60 kg P_2O_5 ha^{-1}. The maximum values of the number of pods $plant^{-1}$ (76.3), biomass yield (7522 kg ha^{-1}), and straw yield (3180 kg ha^{-1}) were recorded for 15 t FYM ha^{-1}. The interaction of FYM and phosphorus was non-significant for all the parameters.

Singh *et al.* (2014) conducted an experiment during rabi season 2011-12 at C.S. Azad University of Agriculture and Technology, Kanpur (UP), India and reported that the treatment RDF + VC 5 t ha^{-1} + RC + PSB recorded the highest values of 26.49 q ha^{-1} grain yield, 31.98 q ha^{-1} stover yield, Rs. 77388/ha gross income and Rs. 38949 t ha^{-1} net return with 2.01 B:C ratio. The treatment RDF + VC 3t ha^{-1} + RC + PSB also remained at par with 25.41 q ha^{-1} grain yield, 31.15 q ha^{-1} stover yield, Rs. 38593/ha net return and 2.08 B:C ratio. Control treatment recorded the lowest values of yield, economic parameters and quality characters of chickpea. Protein content and protein yield were also recorded the highest level in the treatment of RDF + VC 5 t ha^{-1} + RC + PSB closely followed by the treatment RDF + VC 3 t ha^{-1} + RC + PSB being both significantly at par.

Patil *et al*. (2013) carried out an experiment at Agricultural Research Station, Annigeri, UAS, Dharwad, Karnataka during Rabi seasons of 2009-10 and 2010-11 in which 18 treatment combinations consisting of four different organic manures in combination viz., farm yard manure (FYM), vermicompost (VC), glyricidia leaf manure (GLM), enriched compost (EC) and neem cake (NC), and four different liquid manures viz., panchagavya, biodigester, cow urine and vermiwash with two control treatments RDF and absolute control (water spray) and observed that various growth attributes like leaf area, leaf area index, AGR, RGR and CGR recorded the maximum values with the treatment EC 1/3rd + VC 1/3rd + GLM 1/3rd equivalent to 100% RDN + panchagavya @ 3% at flower initiation and 15 DAF during both the years.

Chetankumar *et al.* (2020) conducted an experiment during Rabi season of 2016-17 at farm, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Latur in Marathwadha region Maharastra, and reported that the maximum availability of macro- and micro- nutrients in soil, growth attributes viz. plant height and number of branches in all growth stages of chickpea were found at application of 7.5 tons of MSW vermicompost ha^{-1} along with 100% RDF (25:50:00 NPK) followed by application of 7.5 tones MSW compost ha^{-1} along with 100% RDF and which was significantly increased with increased levels of MSW vermicompost and compost.

Ditta *et al.* (2018) observed that rock phosphate enriched compost (RP-EC) with a combination ratio of 50:50 applied before 7 days of sowing in pot experiments resulted in the maximum nodulation, growth and productivity of chickpea. Under field conditions, the maximum increase of 35.3% in number of nodules $plant^{-1}$, 26.7% in dry wt. of nodules $plant^{-1}$ and 20.8% in grain yield (t ha^{-1}) compared to control was obtained by RP-EC @ 1000 kg ha^{-1}. The same treatment indicated an increase of 12.9 and 4.3% in P contents in straw and grains, respectively, compared to control. However, most of the results were non-significant when RP-EC applied at the rate of 1000 kg ha^{-1}.

Yadav *et al.* (2017) conducted an experiment during rabi season of 2016-2017 at Instructional Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan) and reported that application of vermicompost 2 t ha^{-1} recorded significantly the highest values of plant height (54.70 cm), total number of root nodules (40.73 $plant^{-1}$), effective root nodules (36.05 $plant^{-1}$), DMA (18.61 g $plant^{-1}$), pods (50.12 $plant^{-1}$), seed yield (1916 kg ha^{-1}) and haulm yield (2998 kg ha^{-1}) compared to other organic manure treatments. Among liquid organic manures, application of panchagvya 3% remained on par with vermiwash 10% also recorded significantly the maximum values of the plant height (54.48 cm), total number of root nodules (39.78 $plant^{-1}$), effective root nodules (35.10 $plant^{-1}$), DMA (17.90 g $plant^{-1}$), pods (49.54 $plant^{-1}$), seed yield (1888 kg ha^{-1}) and haulm yield (2804 kg ha^{-1}) as compared to cow urine and control.

Patel *et al.* (2012) carried out an experiment during Rabi season of the year 2009-10 at the College Agronomy Farm, B. A. College of Agriculture, Anand, India and reported that application of 1.25 t vermicompost ha^{-1} recorded significantly higher seed yield over control. DAP @ 100 kg/ha significantly gave the highest number of nodules, pods $plant^{-1}$, seed weight $plant^{-1}$ over 0 and 50 kg DAP ha^{-1}. The number of pods $plant^{-1}$ was significantly higher in 25 kg $ZnSO_4$ ha^{-1} but, it did not affect the yield of chickpea. The treatment combination of 1.25 t vermicompost ha^{-1} + 100 kg DAP ha^{-1} + 25 kg $ZnSO_4$ ha^{-1} recorded significantly the highest seed yield than other treatment combinations.

2.4 Salt stress mitigation by compost application on other legumes

Ferdous *et al*. (2018) carried out an experiment at the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur and reported that salinity decreased the plant height, dry weight of leaf, stem and root as well as yield of soybean $plant^{-1}$. Application of water hyacinth compost and rice husk biochar had positive effects on mitigating the negative effects of salinity stress on all those parameters studied. However, rice husk biochar at the rate of 5 t ha^{-1} showed the best result to mitigate salinity stress at low salinity (5 dSm^{-1}) condition.

Rady *et al*. (2016) reported that addition of OMF compost improved the soil chemical and physical properties. Application of OMF compost at a rate of 20 ton h^{-1}, as an alternative to 50% of the recommended dose of mineral-NPK fertilizers, significantly decreased the concentrations of Cd^{2+} and NO_3^- in *Phaseolus vulgaris* L. plant leaves, pods and seeds, showing the same growth characteristics, and pod and seed yields compared to the control (100% of mineral-NPK fertilizers). This treatment also improved all determined physio-biochemical attributes and tested soil characteristics compared to the control.

Badar *et al.* (2015) carried out an experiment, in that case three different salinity levels (0.25, 0.45, and 0.65%) were used alone, with compost and with microbial inoculants as treatments. Coconut coir composted with *Trichoderma* sp. used as composted material. Results showed that treatments with different salinity levels alone had more severe effects on the physical and biochemical parameters of experimental plants as compare with compost and microbial inoculants. Organic amendments improved the growth of plants with salinity levels.

Netwal (2003) conducted an experiment at RAU, Bikaner, India to know the effect of farm yard manure (FYM) (0, 2.5 and 5.0 t ha^{-1}) and vermi-compost (VC) (0, 2.5 and 5.0 t ha^{-1}) on nutrient uptake and quality of cowpea (*Vigna unguiculata* L. Walp.) grown under saline condition. They revealed that salinity significantly reduced the growth and nutrients uptake of cowpea but application of FYM and VC positively enhanced the growth traits, nutrients uptake and quality. They also concluded that VC was more effective than FYM, and VC @ 5.0 t ha^{-1} showed the best results among all the treatments.

Lawson *et al*. (2004) studied the effect of two composts (Bark and Tenporon) on the growth and nodulation of kidney beans, soybeans and alfalfa under different concentrations of salinity (0, 50, 100, 150 and 200 mM NaCl). The results showed that the growth and nodulation of kidney beans, soybeans and alfalfa was improved by the application of compost, and the inhibitory effect of high concentrations of salinity was also alleviated by the application of compost. The importance of compost is well known due to its multiple functions in soil. Compost can be beneficial not only to enhance organic matter, physical and chemical properties of soil, water holding capacity, and aeration in soil but also to provide plant nutrients (John *et al*., 1998).

Saeed *et al*. (2016) carried out an experiment at the Department of Botany at Federal Urdu University of Arts, Science and Technology, Karachi, Pakistan to evaluate the effect of tea compost on plant growth under salinity, and reported that evapotranspiration (ET) rate was increased with increasing salinity, whereas, it decreased with application of tea compost under all salinity. Vegetative (shoot height, number of leaves, fresh and dry biomass) and reproductive (number of seeds per plant) growth significantly declined with increasing salinity levels (50-100mM NaCl). Tea compost treatment helped in improving all these parameters. Total photosynthetic pigments (chlorophyll a, b, carotenoids and total chlorophyll content) showed reduction under raising salinity levels, while betterment was recorded with application of tea compost. Organic solutes (soluble sugars, proteins, free amino acids and phenolic content) increased with increasing salinity. Increased soluble sugars were found with tea compost treatment under non-saline control and decreased in salinity. Soluble proteins, amino acids and phenolic content increased with application of tea compost under both control and salinity.

Islam (2019) conducted a pot experiment at the Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh to find the response of vermicompost (VC) in mungbean plants under saline condition, and reported that salinity significantly reduced the growth, physiology, yield traits and yield of mungbean, while application of VC remarkably increased the aforesaid properties and grain yield of mungbean.

2.5 Other strategies of salt stress management in chickpea

Hemida Abd-Alla *et al*. (2019) reported that salinity levels ranging from 25 to 150 mM significantly inhibited the growth of chickpea plants, while the 200 mM level hindered their germination. Inoculation with mycorrhizal fungi, Fe_3O_4 NP-induced *Rhizobium*, and endophytic *Stenotrophomonas maltophilia* significantly improved the nodulation, leghaemoglobin content, nitrogenase activity, and growth of chickpea grown at salinity level of 75 and 150 mM compared with the controls. The mitigation of the destructive effect of salinity stress was due to improvement in the nutritional status of plants as determined by their K, P, carbohydrate and protein contents. Such triple microbial inoculation could be a successful bio-fertilizer that can contribute to protect chickpea plants from salinity by attenuating salt-induced oxidative damage.

Riaz *et al*. (2019) carried out an experiment at the Soil Bacteriology Section, Ayub Agricultural Research Institute, Faisalabad, Pakistan and reported the positive response of plant growth promoting rhizobacteria (PGPR) on productivity of chickpea but more enunciated response about grain yield was observed with the combined application of salicylic acid (SA) and PGPR compared to control. Growth parameters i.e. the root length, root mass, number of nodules and shoot mass were highly affected where SA was applied along with PGPR. It has been proposed that the combination of SA + PGPR can be a suitable practice for more production of chickpea under salt stress in Pakistan.

CHAPTER III

MATERIALS AND METHODS

Details of different materials used and methodology followed in the experiment are presented in this chapter.

3.1 Description of the experimental site

3.1.1 Location

The research work was conducted in Shade House, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur. The experimental site was located at 25°38' N latitude and 88°41' E longitudes with an elevation of 37 meter above the mean sea level. The soil of the experiment was collected from the land under the Agro-ecological zone-1 (AEZ-1) which is named as Old Himalayan Piedmont Plain (UNDP and FAO, 1988).

3.1.2 Soil

The soil for the experimental unit was collected from 0-15 cm depth from HSTU research field. The prepared soil samples used in the pots were dried, and mixed thoroughly. The soil samples were analyzed in the Soil Resource Development Institute (SRDI), Dinajpur. The result of soil analysis has been presented in Appendix II.

3.1.3 Weather and climate

The research work was conducted during the winter season (December to March). The experimental area occupied sub-tropical climatic condition. At the beginning of the winter season the air temperature was relatively low (January-February) and was gradually increased with the advancement of the season. Endurable rainfall and gusty wind were detected during the experimental period.

3.2 Plant material

BARI Chola-11 a very early variety of chickpea was used as the test crop in this experiment. This variety was released by the Bangladesh Agricultural Research Institute, Pulse Research Center, Regional Agricultural Research Station, Ishurdi, Pabna in 2018. Life cycle of this variety ranges from 100 to 106 days in Rabi season. Insect and pest attack comparatively less, due to being an early variety it is resistant to the harmful disease of chickpea Botrytis Grey Mold. This early variety can overcome the loss of production due to adverse climatic condition in the last period of Rabi season. So, it is possible to increase the production of chickpea in national level by cultivating this early variety.

3.3 Experimental treatments

The study consisted of the following factors and treatments: Factor A: three levels of salt, and Factor B: three levels of kazi compost.

Factor A: Salt (NaCl)

S_0 = No salt (Control)

S_1 = 50 mM salt ≅ 5 dSm^{-1}

S_2 = 100 mM salt ≅ 10 dSm^{-1}

Factor B: Kazi Compost

KC_0 = No compost (Control)

KC_1 = 10 % compost

KC_2 = 20 % compost

Treatment combinations-

T_1= S_0KC_0 (No salt -Control and no compost-Control-9 kg soil)

T_2= S_0KC_1 (No salt-Control and 10% compost- 900g compost + 8.100 kg soil)

T_3= S_0KC_2 (No salt-Control and 20% compost- 1800 g compost +7.200 kg soil)

T_4= S_1KC_0 (50 mM salt and no compost-Control- 9 kg soil)

T_5= S_1KC_1 (50 mM salt and 10% compost- 900g compost + 8.100 kg soil)

T_6= S_1KC_2 (50 mM salt and 20% compost- 1800 g compost +7.200 kg soil)

T_7= S_2KC_0 (100 mM salt and no compost-Control -9 kg soil)

T_8 = S_2KC_1 (100 mM salt and 10% compost- 900g compost + 8.100 kg soil)

T_9 = S_2KC_2 (100 mM salt and 20% compost- 1800 g compost + 7.200 kg soil)

3.4 Experimental design

The experiment was laid out in completely randomized design (CRD) with three replications. Each replication was divided into 9 unit pots where the treatments were allotted randomly.

3.5 Layout of the experiment

The layout of the experiment was as follows:

Treatments	Replications		
	R_1	R_2	R_3
1. S_0KC_0	Pot-1	Pot-10	Pot-19
2. S_0KC_1	Pot-2	Pot-11	Pot-20
3. S_0KC_2	Pot-3	Pot-12	Pot-21
4. S_1KC_0	Pot-4	Pot-13	Pot-22
5. S_1KC_1	Pot-5	Pot-14	Pot-23
6. S_1KC_2	Pot-6	Pot-15	Pot-24
7. S_2KC_0	Pot-7	Pot-16	Pot-25
8. S_2KC_1	Pot-8	Pot-17	Pot-26
9. S_2KC_2	Pot-9	Pot-18	Pot-27

Figure 1: Layout of the experiment

3.6 Procedures of the experiment

3.6.1 Seed collection

The seeds of chickpea early variety BARI Chola-11 were obtained from Pulse Research Center, Regional Agricultural Research Station (Bangladesh Agricultural Research Institute, BARI), Ishurdi, Pabna.

3.6.2 Preparation of experimental pot

A common procedure was followed in raising of seedlings in the experimental pots. The experimental pots (27) were first filled with soil on 3 December, 2019. Potted soil was brought into desirable fine tilth by hand mixing. The stubble and weeds were removed from the soil. The pots were prepared in three levels, these were i) no-compost (control) ii) 10% compost (90% soil), and iii) 20% compost (80% soil). The area of each pot was 0.0567 m^2.

According to the area of the pot 9 kg of well crushed soil was poured in level one pots (no-compost), 8.100 kg soil + 900g compost in the second treatment pots (10% compost), and 7.200kg soil + 1800g compost in the third treatment pots (20% compost).

3.6.3 Seed selection and treatment

Healthy seeds were selected following standard method. Seeds were treated with Bavistin @ 3g/1000 g of seeds.

3.6.4 Seed sowing and raising of seedlings

Twenty seeds were sown in the pot on 11 December, 2019 in 2-3 cm soil depth. Light irrigation was given by the water cane to ensure uniform germination of seeds after sowing.

3.6.5 Fertilizer doses

The experimental pots were fertilized with N, P, K and KC @ urea 0.2538g pot^{-1}, TSP @ 0.4794g pot^{-1}, MoP @ 0.20304g pot^{-1} and Kazi compost as per treatment. The nutrient elements used in this experiment are given in the following table:

Table 1. Nutrient elements along with their doses of the supplied fertilizers and KC

Nutrient element	% and ppm Nutrient element	Dose (g pot^{-1})
Nitrogen	46% N	0.2538
Phosphorus	44-46% P_2O_5	0.4794
Potassium	60% K_2O	0.20304
Organic-Carbon	20-25%	As per treatment (0, 10 and 20%)
Nitrogen	0.5-4.0% N	
Phosphorus	0.5-3.0% P	
Potassium	0.5-3.0% K	
Sulphur	0.1-0.5% S	
Zinc	0.1% Zn	
Coper	0.05% Cu	
Chromium	50 ppm Cr	
Cadmium	5 ppm Cd	
Lead	30 ppm Pb	
Nickel	30 ppm Ni	

3.6.6 Fertilizer application

Kazi compost was mixed with well crushed soil as per treatment during pot preparation for seedling raising and fertilizer such as urea, TSP and MoP were used as source for N, P and K respectively in each pot before seed sowing.

3.6.7 Application of NaCl

After germination and establishment of seedlings, 10 mM NaCl solution was applied in salt treated pots up to three days, and 20 mM for the next three days for hardening of seedlings before applying actual treatments. The salt solutions of 50 and 100 mM NaCl were applied till maturity. Electrical conductivity (EC) of the respective treatments was monitored throughout the experimental period. Average EC (dSm^{-1}) of saturation extract from salinized soil during plant growth and development period was as follows:

Table 2: Equivalent EC values of the supplied saline treatments at different growth stages

NaCl concentration (mM)	Desired EC (dSm^{-1})	Measured EC (dSm^{-1})		
		25 DAE	50 DAE	At harvesting
0	0	0	0.1	0.1
50	5	4.9±0.5	5.3±0.2	5.7±0.1
100	10	9.7±0.4	10.1±0.1	10.4±0.2

3.6.8 Intercultural operations

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of chickpea seedlings.

3.6.8.1 Thinning

Seeds started germination from four days after sowing (DAS). Thinning was done in each pot at three times by keeping 15, 10 and finally 5 healthy seedlings, respectively as to maintain optimum plant population in each pot.

3.6.8.2 Irrigation

Irrigation was done as per requirements with saline water and normal water (tap water) based on treatment requirements.

3.6.8.3 Gap filling

Gap filling was done for the required pots with the same ages of seedlings from the same source.

3.6.8.4 Weeding

The hand weeding was done as necessary to keep the pots free from weeds.

3.6.8.5 Stalking and plant protection

The plants of this variety were comparatively long so stalking was done with hand sized bamboo stick and thread to protect the plants from damaging through winds and weight of branches. The experimental site looked nice with normal green plants. The experimental crop was not infected with any insects and diseases.

3.7 General observation of the experimental site

The site was supervised time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases to minimize considerable losses by pests. The site views were quite good with normal green color plants. The variation in the plant height, number of branches, number of pods and flowering was observed.

3.8 Harvest and postharvest operations

The crop was harvested on 17 March, 2020 when about 80% of the pods attained maturity and become brown to off-white in color. The matured pods were collected by hand picking from each pot. The harvested plant of each pot was bundled separately, properly tagged and brought to the threshing floor. Enough care was taken for harvesting, threshing and also cleaning of chickpea seed.

3.9 Collection of plant sample

Plants were randomly selected from each pot from vegetative to reproductive stage to record the growth and yield contributing characters.

3.10 Data recording

The following data were recorded

A. **Growth parameters**
   1. Plant height (cm)
   2. Number of branches plant^{-1}
   3. Root length (cm)

B. **Crop phenology**
   1. Days to first flowering
   2. Days to pod initiation
   3. Days to maturity

C. **Yield contributing parameters**
   1. Number of pods plant^{-1}
   2. Pod length (cm)
   3. Number of grains pod^{-1}
   4. Leaf fresh weight (g)
   5. Stem fresh weight (g)
   6. Root fresh weight (g)
   7. Pod fresh weight (g)
   8. Leaf dry weight (g)
   9. Stem dry weight (g)
   10. Root dry weight (g)
   11. Pod dry weight (g)
   12. Hundred grains weight (g)

D. Yield

1. Grain weight plant^{-1} (g)
2. Stover weight plant^{-1} (g)
3. Biological yield plant^{-1} (g)

3.11 Procedures of data collection

Three plants were randomly selected from each pot to record the growth parameters like plant height (cm) and number of branch etc. and also to record yield contributing characters like plant height (cm), number of pods plant^{-1}, leaf fresh weight (g), pod fresh weight (g), leaf dry weight (g) and pod dry weight (g) etc.

3.11.1 Growth parameters

3.11.1.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at the time of 60, 70, 80 and 90 DAS and at harvest. The height was measured from the ground level to the tip of the leaves. Plants were selected randomly to record data and averaged this data.

3.11.1.2 Number of branches plant^{-1}

Number of branches per plant was counted from selected plants. The average number of branches per plant was determined.

3.11.1.3 Root length (cm)

Root of the harvested plant was cleaned by light beating on hand as a result the soil was removed from the root. The length of the root was measured from the bottom of the plant to the root tip. Average was made by adding individual value and dividing them with the total number of plants.

3.11.2 Crop phenology

Number of days from sowing to 1st flowering, 1st pod setting and physiological maturity of lentil were determined visually.

3.11.3 Yield contributing parameters

3.11.3.1 Number of pods plant^{-1}

The numbers of total pods of three plants from each pot were counted and the mean numbers were expressed as plant^{-1} basis.

3.11.3.2 Pod length (cm)

Pod length was taken from randomly and the mean length was expressed as per pod basis.

3.11.3.3 Number of grains pod^{-1}

The number of grains pods^{-1} was recorded from randomly selected pods at the time of harvest. Data were recorded as the at random from each pot.

3.11.3.4 Hundred grains weight (g)

Fifty cleaned, dried grains were counted randomly from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram. Thereafter it converted in to 100-grains weight.

3.11.3.5 Leaf fresh weight (g)

After harvesting fresh leaves were removed from plant and the weight was measured with electric balance.

3.11.3.6 Stem fresh weight (g)

After removal of leaves from shoot the weight of the shoot was measured with electric balance. Average was made by adding individual value and dividing them with the total number of plants.

3.11.3.7 Root fresh weight (g)

Cleaned root was cut from the bottom plant and its fresh weight was measured with electric balance. Average was made by adding individual value and dividing them with the total number of plants.

3.11.3.8 Pod fresh weight (g)

Pods were collected from the plant and its fresh weight was measured with electric balance. Average was made by adding individual value and dividing them with the total number of plants.

3.11.3.9 Leaf dry weight (g)

After measuring the fresh weight, the leaves were carefully packed and tagged then kept in oven for 72 hours at 80^0 C. Before measuring the leaf dry weight, the oven dried leaf sample was kept in normal room temperature for 10 minutes. Then its dry weight was measured with electric balance. Average was made by adding individual value and dividing them with the total number of plants.

3.11.3.10 Stem dry weight (g)

For measuring the shoot dry weight, it was carefully packed and tagged then kept in oven for 72 hours at 80^0 C. Before measuring dry weight the oven dried shoot sample was kept in normal room temperature for 10 minutes. Then its dry weight was measured with electric balance. Average was made by adding individual value and dividing them with the total number of plants.

3.11.3.11 Root dry weight (g)

The root was carefully packed and tagged then kept in oven for 72 hours at 80^0 C. Before measuring dry weight the oven dried root sample was kept in normal room temperature for 10 minutes. Then its dry weight was measured with electric balance. Average was made by adding individual value and dividing them with the total number of plants.

3.11.3.12 Pod dry weight (g)

Carefully packed and tagged pods were kept in oven for 72 hours at 80°C. Before measuring dry weight the oven dried sample was kept in normal room temperature for 10 minutes. Then its dry weight was measured with electric balance. Average was made by adding individual value and dividing them with the total number of plants.

3.11.4 Yield

3.11.4.1 Grain weight plant^{-1} (g)

The seeds collected from plant of each pot were sun dried properly. The weight of seeds was taken and converted the grain yield in g plant^{-1}.

3.11.4.2 Stover weight plant^{-1} (g)

The stover collected from plant of each pot was sun dried properly. The weight of stover was taken and converted the stover yield in g plant^{-1}.

3.11.4.3 Biological yield plant^{-1} (g)

Grain yield and stover yield together were regarded as biological yield of lentil. The biological yield was calculated with the following formula:

Biological yield (g plant^{-1}) = Grain yield + Stover yield

3.12 Analysis of data

The data were analyzed statistically using the analysis of variance (ANOVA) technique with the help of statistical computer package program R-Analytics.

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from this study in relation to the effects of salt stress and ameliorating effect of compost have been presented in this chapter. The results of the present investigation have been presented, discussed and compared with the help of table and graphs as far as available with the results of the researchers.

4.1 Effect of KC on the crop phenology of chickpea (BARI Chola-11) under saline stress

The life span (crop duration) of chickpea was influenced by the salt stress and Kazi compost in this study.

4.1.1 Days to 1st flowering

Saline stress gradually reduced the days to 1st flowering in this study (Table 3). There is a general view that duration of crop is shortened by environmental stresses because of limited source size due to leaf senescence earlier. Salinity enhanced early flowering time by reducing days to 1st flowering in pigeonpea (Promila and Kumar, 1982), pea (Siddique and Kumar, 1985) and mungbean (Uddin, 2017). Amira and Abdul (2010) reported that growth parameters were significantly reduced with high salinity levels. Notwithstanding, application of different levels of KC played significant role by increasing the days to flowering (Table 4). Days to 1st flowering varied for different Kazi compost level and saline condition and environmental influences as well as management practices.

4.1.2 Days to 1st pod formation and maturation

Pod setting period and days to maturity was significantly decreased with increased salinity levels of 50 and 100 mM NaCl stress (Table 3). The days to maturation 95.11 and 93.33 days was recorded at 50 and 100 mM NaCl stress, respectively which reduced over control (98.00 days). Salinity stress shortened the days to pod formation and maturation was reported earlier by Islam (2001) in mungbean and blackgram, Uddin (2017) in mungbean. However, application KC delayed the 1st pod formation and maturation duration in this study. KC @ 0, 10 and 20% needed 58.22, 60.78 and 63.00 days to pod formation, and 93.33, 95.33 and 97.78 days for maturation, respectively. Moreover, 10 and 20% KC recovered the adverse effects of salt stress and increased the days to maturity periods over KC non-treated plants. These results are in line with the findings of Uddin (2017), who depicted that organic manure like tea compost conquered the stress induced early maturity periods in mungbean.

Table 3: Effect of salt stress (SS) on phenological changes of chickpea

Treatments	Days to first flowering	Days to pod initiation	Days to maturity
S_0	54.33	63.44	98.00
S_1	52.33	60.78	95.11
S_2	51.11	57.78	93.33
LSD(0.05)	3.44	4.55	2.15
CV(%)	5.00	5.74	1.72
LS	NS	*	**

Where, NS= non-significant at P=0.05; *Significant at P=0.05; LS= Level of significance; S_0= Salinity level 0 mM; S_1= Salinity level 50 mM; S_2= Salinity level 100Mm

Table 4: Effect of Kazi compost (KC) on phenological changes of chickpea

Treatments	Days to first flowering	Days to pod initiation	Days to maturity
KC_0	49.56	58.22	93.33
KC_1	51.89	60.78	95.33
KC_2	56.33	63.00	97.78
LSD(0.05)	3.44	3.96	1.97
CV(%)	6.38	6.36	2.01
LS	**	**	**

Where, NS= non-significant at P=0.05; *significant at P=0.05; **significant at P=0.01; ***significant at P=0.001; LS= Level of significance; K_0= Kazi compost 0%; K_1= Kazi compost 10 %; K_2= Kazi compost 20%

4.2 Effect of KC on the morphological traits, growth and yield contributing attributes of BARI Chola-11 under saline stress

4.2.1 Plant height (cm)

Plant height is one of the most important morphological characters that act as a potent indicator of availability of growth resources in its vicinity. The plant height, measured at different growth stages gradually decreased with the increasing of salt stress from 0 to 100 mM NaCl (Table 5). Salt stress caused a significant reduction in plant height of chickpea (Kaya *et al*., 2008; Tsegazeabe *et al*., 2012; Ali *et al*., 2014; Lavrenko *et al*., 2019; Ceritoğlu *et al*., 2020). Crops grown under salt stress exhibit disrupted metabolism culminating in stunted growth, and reduced plant height and higher salt stress caused a drastic reductions of the plant height. Salt stress caused a significant reduction in plant height in not only chickpea but also different crops like soybean (Ferdous *et al*., 2018), lentil (Islam *et al*., 2008), cluster beans (Saeed *et al*., 2016), mungbean (Islam, 2019), rice (Alam *et al*., 2016), maize (Das *et al*., 2013), *Medicago rigidula* (Akhzari *et al*., 2012). Nevertheless, application of KC significantly increased the plant height at all observed stages under saline and non-saline conditions. Application of 20% KC gave the tallest plant under both saline and non-saline conditions at 60, 70, 80, 90 DAS and final harvest. Under severe stress condition (100 mM NaCl), the tallest plant (35.89, 38.01, 42.11, 45.02 and 47.10 cm) was found at KC_2 (20% KC) treatment combination 60, 70, 80, 90 DAS and final harvest, respectively. Organic amendments with KC significantly increased the plant height, at 50 mM NaCl stress. KC with higher doses performed better over lower doses in producing the plant height at 50 mM NaCl stress. Results indicated that plant height decreased with increasing salinity level and varied with different organic amendments. Similar results were observed by several authors (Idrees *et al*., 2004; Abou El Magd *et al*., 2008; Leithy *et al*., 2010; Raafat and Thawrat, 2011), suggesting that soil amendments with organic manures alleviate the toxic effects of salinity in plants, and increased the plant height. Under different saline stresses, the plant height significantly increased with different organic manures like vermi-compost in mungbean (Islam, 2019) and in cowpea (Netwal, 2003), tea compost in cluster beans (Saeed *et al*., 2016) and in mungbean (Uddin, 2017), and FYM in cowpea (Netwal, 2003), water hyacinth and rice husk biochar in soybean (Ferdous *et al.*, 2018). Application of compost significantly increased the plant height under non-saline condition in chickpea has been reported by Basir *et al.* (2008), Yadav *et al.* (2017), Chetankumar *et al.* (2020).

4.2.2 Root length (cm)

The root length of chickpea significantly decreased due to increase of salinity. Under 100 mM NaCl saline condition (S_2), the shortest roots (4.55, 4.94, 5.70 and 6.66 cm) was recorded as compared to control condition (S_0) (6.10, 6.86, 7.95 and 8.64 cm) at 60, 70, 80 and 90 DAS, respectively (Table 5). This result agreed with the result of the study conducted by Kaya *et al.* (2008), Tsegazeabe *et al*. (2012), Lavrenko *et al*. (2019). Salt stress causes a substantial reduction in root length through negatively impacting nutrient uptake and less water absorption by roots, while organic amendments with KC increased the root length remarkably under stress and non-stress conditions. In this study, organic amendments with KC of 10 and 20% of soil (w/w) ameliorated the negative effects of saline toxicity and at 60, 70, 80 and 90 DAS sampling dates, the tallest root (7.06, 7.76, 8.49 and 8.99 cm, respectively) was recorded at 20% KC at severe stress condition. This finding was very closer to the finding of Khurmizi *et al*. (2015) who reported that vermicompost significantly increased the root length of salt induced bean plants. Samiran *et al*. (2010) reported that organic fertilization led to increase the root lengths of *Zea mays*, *Phaseolus vulgaris* and *Abelmoschus esculentus* under saline conditions.

Table 5: Effect of SS on the plant height and root length of chickpea at different DAS

Treatments	Plant height (cm)					Root length (cm)			
	60 DAS	70 DAS	80 DAS	90 DAS	Harvest	60 DAS	70 DAS	80 DAS	90 DAS
S_0	35.72	38.72	41.64	43.37	45.27	6.10	6.86	7.95	8.64
S_1	33.52	35.84	39.07	42.10	43.46	5.19	5.98	6.57	7.67
S_2	31.72	33.08	36.96	39.73	41.23	4.55	4.94	5.70	6.66
LSD (0.05)	6.56	5.55	3.20	5.58	5.25	1.97	2.75	2.52	1.48
CV (%)	14.88	11.82	6.23	10.21	9.27	8.52	5.46	8.57	14.73
LS	NS	NS	*	NS	*	NS	NS	*	*

Where, NS= non-significant at P=0.05; *Significant at P=0.05; LS= Level of significance; S_0= Salinity level 0 mM; S_1= Salinity level 50 mM; S_2= Salinity level 100Mm

Table 6: Effect of KC on plant height and root length of chickpea at different DAS

Treatments	Plant height (cm)					Root length (cm)			
	60 DAS	70 DAS	80 DAS	90 DAS	Harvest	60 DAS	70 DAS	80 DAS	90 DAS
KC_0	30.67	33.17	35.73	37.03	38.64	3.30	3.92	4.69	5.77
KC_1	34.41	36.47	39.84	43.14	44.21	5.46	6.09	7.05	8.21
KC_2	35.89	38.01	42.11	45.02	47.10	7.06	7.76	8.49	8.99
LSD (0.05)	4.31	7.44	4.11	5.52	4.54	1.17	1.21	1.17	1.53
CV (%)	12.45	20.17	10.20	12.89	10.19	21.52	19.90	16.85	19.45
LS	NS	NS	*	*	**	***	***	***	**

Where, NS= non-significant at P=0.05; *significant at P=0.05; **significant at P=0.01; ***significant at P=0.001; LS= Level of significance; K_0= Kazi compost 0%; K_1= Kazi compost 10 %; K_2= Kazi compost 20%

4.2.3 Number of branches plant^{-1}

The number of branches plant^{-1} of chickpea showed significant variation due to different levels of salinity, and it gradually decreased with increasing salinity stress measured at 60, 70, 80, 90 DAS and harvest (Table 7). The minimum number of branches plant^{-1} (2.11, 2.56, 3.00, 3.56 and 4.00) was found from S_2 treatment (100 mM of NaCl) at 60, 70, 80, 90 DAS and at harvest, respectively. The decrease in number of branches of chickpea owing to salinity stress has also been reported by Ceritoğlu *et al.* (2020). Similar results were observed by several authors in other legumes like mungbean (Amira and Abdul, 2010), and bean (Khurmizi *et al.*, 2015) thus validating this findings. However, application of KC significantly increased the number of branches plant^{-1} both in saline and non-saline conditions. At 60, 70, 80, 90DAS and at harvest, the maximum number of branches plant^{-1} (3.89, 4.33, 4.78, 5.22 and 5.56, respectively) was obtained from KC_2 (20% KC), while the minimum (2.00, 2.44, 2.89, 3.33 and 3.78, respectively) was recorded from KC_0 (control) under severe saline condition. This result is in close agreement with findings of Netwal *et al.* (2003), who reported that farmyard manure (FYM) and vermicompost (VC) increased the number of branches per plant of cowpea under saline conditions, where VC @ 5.0 t ha^{-1} demonstrated the best results as compare to VC of 2.5, FYM of 2.5 and 5.0 t ha^{-1}. In non-saline condition, application of compost significantly increased the number of branches plant^{-1} in chickpea and it has been reported by Chetankumar *et al.* (2020).

4.2.4 Number of pods plant^{-1}

Salt stress induced by 50 and 100 mM NaCl significantly decreased the number of pods plant^{-1} in this study. The increase in soil salinity trigger several negative effects on plant growth due to the osmotic stress, ionic stress, nutritional imbalances or a combined effect of all these factors (Ashraf, 1994; Islam *et al*., 2011), low soil fertility and poor structure with heavy metals in rhizosphere (Acosta *et al*., 2011), consequently poor plant growth and reduced number of pods plant^{-1}. This result is in agreement with the findings of Ram *et al*. (1989) and Sohrabi *et al*. (2008) who found that the number of filled pod plant^{-1} decreased with increasing salinity in chickpea. Renu (2019) and Islam (2019) who found same results in mungbean. Nevertheless, incorporation of KC as basal dose in saline and non-saline soil significantly increased the number of pods plant^{-1}. The highest number of pods plant^{-1} (4.00, 4.78, 5.22, 5.89 and 6.33) was attained at 60, 70, 80, 90 DAS and harvest, respectively in

KC_2 (20% KC) (Table 8). The highest pods plant^{-1} may be the resultant effect of maximum number of branches were produced from the same treatment (Table 8). The soil applications of organic manures have been shown to improve soil fertility, reduce salt stress and heavy metals to plant roots (Weggler *et al*., 2004), increase soil organic matter content, improve the chemical and biological properties (Ok *et al*., 2011), reduce the metal toxicity, and consequently increase soil microbial activities (Usman *et al*., 2013) which might have improved plant growth and increased the number of pods plant^{-1}. Unlike KC, the addition of FYM (Aslam *et al*., 2010), tea compost (Uddin, 2017), and VC (Islam, 2019) in mungbean increased the number of pods plant^{-1}. In non-saline condition application of compost significantly increased the number of pods plant^{-1} in chickpea has documented in earlier studies (Basir *et al*., 2008; Patel *et al*., 2012; Yadav *et al*., 2017).

Table 7: Effect of SS on the number of branches and pods plant^{-1} of chickpea at different DAS

Treatments	Number of branch plant^{-1}					Number of pods plant^{-1}				
	60 DAS	70 DAS	80 DAS	90 DAS	Harvest	60 DAS	70 DAS	80 DAS	90 DAS	Harvest
S_0	4.00	4.33	4.67	5.00	5.44	3.67	4.44	4.78	5.44	6.22
S_1	2.89	3.33	3.78	4.33	4.78	2.89	3.33	3.78	4.33	4.78
S_2	2.11	2.56	3.00	3.56	4.00	2.11	2.78	3.33	3.78	4.11
LSD(0.05)	1.63	1.00	1.26	1.79	1.14	1.02	0.85	1.82	2.74	1.37
CV(%)	4.58	6.60	5.23	3.83	8.37	7.06	18.55	5.01	6.26	20.76
LS	NS	*	NS	NS	NS	*	*	**	*	*

Where, NS= non-significant at P=0.05; *Significant at P=0.05; LS= Level of significance; S_0= Salinity level 0 mM; S_1= Salinity level 50 mM; S_2= Salinity level 100Mm

Table 8: Effect of KC on the number of branches and pods plant^{-1} of chickpea at different DAS

Treatments	Number of branch plant^{-1}					Number of pods plant^{-1}				
	60 DAS	70 DAS	80 DAS	90 DAS	Harvest	60 DAS	70 DAS	80 DAS	90 DAS	Harvest
KC_o	2.00	2.44	2.89	3.33	3.78	1.67	2.22	2.67	3.11	3.67
KC_1	3.11	3.44	3.78	4.33	4.89	3.00	3.56	4.00	4.56	5.11
KC_2	3.89	4.33	4.78	5.22	5.56	4.00	4.78	5.22	5.89	6.33
LSD(0.05)	0.91	1.04	1.20	0.92	0.98	1.12	1.29	1.38	1.24	1.23
CV(%)	9.74	9.89	3.68	21.01	20.08	7.68	5.66	3.82	6.77	3.86
LS	**	**	*	**	**	**	**	**	**	**

Where, NS= non-significant at P=0.05; *significant at P=0.05; **significant at P=0.01; ***significant at P=0.001; LS= Level of significance; K_0= Kazi compost 0%; K_1= Kazi compost 10 %; K_2= Kazi compost 20%

4.2.5 Leaf fresh weight (g)

The leaf fresh weight of chickpea significantly decreased due to increase in salinity. The lowest leaf fresh weight (2.15, 2.41, 2.93 and 3.49 g) was recorded under 100 mM NaCl saline condition (S_2), and the highest values (3.28, 4.01, 4.45 and 4.78 g) were recorded under control condition (S_0) at 60, 70, 80 and 90 DAS, respectively (Table 9). Nevertheless, incorporation of KC as basal dose in saline and non-saline soil significantly increased the leaf fresh weight. The highest leaf fresh weight (3.93, 4.54, 5.10 and 5.39 g) was attained in KC_2 (20%KC) and the lowest leaf fresh weight (1.30, 1.63, 1.99 and 2.55 g) was attained in KC_0 (0% KC) (Table 10).

4.2.6 Stem fresh weight (g)

Plant growth and development is considered as an index of yield. As a beginning of physiological process, adequate water absorption is required for plant fresh weight. The SFW was decreased with the increasing of salt levels (0, 50 and 100 mM NaCl), observed at all observations periods (Table 9). However, the highest SFW (3.28, 3.55, 3.89 and 4.25 g) was obtained in control condition at 60, 70, 80 and 90 DAS, respectively. The values were decreased significantly with increasing salinity stress. Salt stress caused a significant reduction in SFW of chickpea (Ali *et al.*, 2014; Ceritoğlu *et al.*, 2020). Moreover, the SFW increased significantly with the increasing levels of KC, and it had considerable effect on plant growth which ultimately increased on the SFW. However, the highest SFW of 4.03, 4.36, 4.71 and 5.00 g plant^{-1} was recorded with 20% KC at 60, 70, 80 and 90 DAS, respectively (Table 10). Generally, the plant fresh weight declined with increasing salinity in the rooting media (Uddin, 2017; Renu, 2019; Islam, 2019) and organic amendments like tea compost (Uddin, 2017), vermi-compost (Bidabadi *et al.*, 2017; Islam, 2019) lightened saline stress and increased the plant fresh weight.

Table 9: Effect of SS on the leaf and stem fresh weight plant^{-1} of chickpea at different DAS

Treatments	Leaf fresh weight plant^{-1} (g)				Stem fresh weight plant^{-1} (g)			
	60 DAS	70 DAS	80 DAS	90 DAS	60 DAS	70 DAS	80 DAS	90 DAS
S_0	3.28	4.01	4.45	4.78	3.28	3.55	3.89	4.25
S_1	2.49	2.84	3.21	3.73	2.84	3.07	3.49	3.76
S_2	2.15	2.41	2.93	3.49	2.12	2.54	2.81	3.07
LSD(0.05)	1.06	2.07	0.74	0.70	1.40	1.87	0.82	1.29
CV(%)	3.55	5.18	5.99	13.44	8.93	6.85	8.39	6.69
LS	NS	*	**	*	NS	**	*	***

Where, NS= non-significant at P=0.05; *Significant at P=0.05; LS= Level of significance; S_0= Salinity level 0 mM; S_1= Salinity level 50 mM; S_2= Salinity level 100Mm

Table 10: Effect of KC on the leaf and stem fresh weight plant^{-1} of chickpea at different DAS

Treatments	Leaf fresh weight plant^{-1} (g)				Stem fresh weight plant^{-1} (g)			
	60 DAS	70 DAS	80 DAS	90 DAS	60 DAS	70 DAS	80 DAS	90 DAS
KC_0	1.30	1.63	1.99	2.55	1.52	1.80	2.17	2.44
KC_1	2.69	3.09	3.50	4.07	2.69	3.00	3.30	3.64
KC_2	3.93	4.54	5.10	5.39	4.03	4.36	4.71	5.00
LSD(0.05)	1.20	1.46	0.74	0.88	0.71	0.84	1.04	0.80
CV(%)	4.21	6.06	20.48	21.53	5.29	6.68	9.73	21.04
LS	**	**	***	***	***	***	***	***

Where, NS= non-significant at P=0.05; *significant at P=0.05; **significant at P=0.01; ***significant at P=0.001; LS= Level of significance; K_0= Kazi compost 0%; K_1= Kazi compost 10 %; K_2= Kazi compost 20%

4.2.7 Root fresh weight (g)

The RFW decreased gradually with increasing salinity levels at different growth stages. The lowest RFW was (0.13, 0.23, 0.31 and 0.44 g) at 100 mM NaCl stress and the highest (0.34, 0.48, 0.58 and 0.67 g) was obtained at 0 mM NaCl condition at 60, 70, 80 and 90 DAS, respectively (Table 11). Salinity stress inhibits the growth of roots and finally reduces the size and fresh weight. Same results were observed under saline stress in other legumes such as mungbean (Mohammed, 2007; Kanwal *et al.*, 2013; Hasan, 2015, Uddin, 2017, Renu, 2019, Islam, 2019), blackgram (Shaddam, 2016), and cluster beans (Saeed *et al.*, 2016). On the other hand, KC application alleviated the toxic effects of salt stress and stimulatory effect on the fresh weight of root. The highest RFW (0.34, 0.46, 0.57 and 0.67 g $plant^{-1}$) was at 20% KC and the lowest value (0.10, 0.18, 0.32 and 0.42 g $plant^{-1}$) at 60, 70, 80 and 90 DAS, respectively (Table 12). The root weight decreased with salinity stress and increased with VC application in *Medicago rigidula* plant (Akhzari *et al.*, 2016), and in mungbean (Islam, 2019).

4.2.8 Pod fresh weight (g)

The pod fresh weight of chickpea significantly decreased due to increase in salinity. Under 100 mM NaCl saline condition (S_2), the lowest pod fresh weight (0.47, 0.61, 0.88 and 1.07g) was recorded as compared to control condition (1.06, 1.21, 1.33 and 1.45g) from 0 mM (S_0) at 60, 70, 80 and 90 DAS, respectively (Table 11). In case of chickpea, the reduction of pod fresh weight due to increasing salinity was reported by Ram *et al.* (1989). Moreover, the PFW increased significantly with the increasing levels of KC, and it had considerable effect on plant growth which ultimately increased on the PFW. However, 20% KC produced the highest PFW (1.17, 1.31, 1.48 and 1.62g) at 60, 70, 80 and 90 DAS, respectively (Table 12).

Table 11: Effect of SS on the root and pod fresh weight plant^{-1} of chickpea at different DAS

Treatments	Root fresh weight plant^{-1} (g)				Pod fresh weight plant^{-1} (g)			
	60 DAS	70 DAS	80 DAS	90 DAS	60 DAS	70 DAS	80 DAS	90 DAS
S_0	0.34	0.48	0.58	0.67	1.06	1.21	1.33	1.45
S_1	0.22	0.30	0.45	0.55	0.74	0.88	1.10	1.30
S_2	0.13	0.23	0.31	0.44	0.47	0.61	0.88	1.07
LSD(0.05)	0.08	0.17	0.16	0.13	0.44	0.75	0.87	0.32
CV(%)	6.57	8.00	7.24	8.42	4.45	6.07	6.24	19.27
LS	**	*	*	*	*	*	*	**

Where, NS= non-significant at P=0.05; *Significant at P=0.05; LS= Level of significance; S_0= Salinity level 0 mM; S_1= Salinity level 50 mM; S_2= Salinity level 100Mm

Table 12: Effect of KC on the root and pod fresh weight plant^{-1} of chickpea at different DAS

Treatments	Root fresh weight plant^{-1} (g)				Pod fresh weight plant^{-1} (g)			
	60 DAS	70 DAS	80 DAS	90 DAS	60 DAS	70 DAS	80 DAS	90 DAS
KC_0	0.10	0.18	0.32	0.42	0.38	0.52	0.70	0.89
KC_1	0.23	0.37	0.45	0.57	0.71	0.88	1.12	1.31
KC_2	0.34	0.46	0.57	0.67	1.17	1.31	1.48	1.62
LSD (0.05)	0.15	0.15	0.12	0.16	0.42	0.34	0.30	0.32
CV (%)	6.44	4.11	6.64	8.99	5.17	7.10	6.51	4.12
LS	*	**	**	*	**	**	***	**

Where, NS= non-significant at P=0.05; *significant at P=0.05; **significant at P=0.01; ***significant at P=0.001; LS= Level of significance; K_0= Kazi compost 0%; K_1= Kazi compost 10 %; K_2= Kazi compost 20%

4.2.9 Leaf dry weight (g)

Salinity significantly decreased the leaf dry weight per plant (Table 13). Leaf dry weight per plant was statistically highly significant due to salt stress. It has been reported earlier that salinity decreased the LDW in soybean (Ferdous *et al*., 2018) and in lentil (Islam *et al*., 2008). It was found that the leaves dry matter gradually reduced with increasing salinity levels (Islam, 2004; Yassin *et al*., 2019). The decrease in leaf dry weight at later part of growth may be due to leaf senescence and remobilization of stored materials to the reproductive organs (Khan and Ungar, 2001; Islam *et al*., 2011). Salinity stress significantly reduced the shoot weight due to clear stunting of plant growth as accompanied by Parida and Das (2005), Hajier *et al*. (2006), Rahman *et al*. (2017), Hassan *et al*. (2018), and Out *et al.* (2018). Ferdous *et al.* (2018) reported that organic amendments mitigate the negative effect of salt stress and show positive result in LDW in soybean. The highest leaf dry weight (1.29, 1.40, 1.48 and 1.58 g) was obtained under 20% KC, and the lowest leaf dry weight (0.29, 0.38, 0.57 and 0.69 g) was observed in 0% KC at 60, 70, 80 and 90 DAS, respectively.

4.2.10 Stem dry weight (g)

Chickpea drastically reduced the stem dry weight per plant at different stages by salinity. The SDW progressively decreased with increasing salinity from 50 to 100 mM NaCl stress (Table 13). Nonetheless, the lowest SDW (0.29, 0.39, 0.46 and 0.58 g) was observed under 100 mM NaCl at 60, 70, 80, 90 DAS, respectively. Same result has also been reported by Ali *et al.* (2014) in chickpea. The result is in agreement with the previous findings who found salinity decreased the LDW in lentil (Islam *et al*., 2008) and in soybean (Ferdous *et al*., 2018). Murillo-Amador and Tryo-Diequez (2000) who also reported that the stem dry weight decreased gradually with increasing salinity level. Salt stress enhanced the stunting of plant growth resulting a measurable decrease in fresh and dry weights of stems (Parida and Das, 2005; Hajier *et al*., 2006). On the other hand, application of KC at salt stressed plants increased the SDW by ameliorating the adverse effects of salt stress. The highest SDW (0.58, 0.68, 0.76 and 0.92 g) was recorded with the application of 20%, KC at 60, 70, 80 and 90 DAS, respectively (Table 14). Ferdous *et al*. (2018) who found that organic amendments (water hyacinth and rice husk biochar) had positive effects in mitigating the negative effects of salinity stress on SDW in soybean. The plant dry weight was increased significantly by other organic matter like vermi-compost (Akhzari *et al*., 2016; Islam, 2019), and tea compost (Uddin, 2017).

Table 13: Effect of SS on the leaf and stem dry weight plant^{-1} at different DAS

Treatments	Leaf dry weight plant^{-1} (g)				Stem dry weight plant^{-1} (g)			
	60 DAS	70 DAS	80 DAS	90 DAS	60 DAS	70 DAS	80 DAS	90 DAS
S_0	1.02	1.11	1.23	1.32	0.57	0.64	0.70	0.77
S_1	0.83	0.93	1.07	1.20	0.39	0.47	0.55	0.68
S_2	0.61	0.75	0.90	1.00	0.29	0.39	0.46	0.58
LSD(0.05)	0.28	0.25	0.44	0.28	0.35	0.36	0.37	0.31
CV(%)	25.44	20.52	3.18	17.99	6.38	5.43	5.24	5.45
LS	*	*	**	**	*	*	**	***

Where, NS= non-significant at P=0.05; *Significant at P=0.05; LS= Level of significance; S_0= Salinity level 0 mM; S_1= Salinity level 50 mM; S_2= Salinity level 100Mm

Table 14: Effect of KC on the leaf and stem dry weight plant^{-1} of chickpea at different DAS

Treatments	Leaf dry weight plant^{-1} (g)				Stem dry weight plant^{-1} (g)			
	60 DAS	70 DAS	80 DAS	90 DAS	60 DAS	70 DAS	80 DAS	90 DAS
KC_0	0.29	0.38	0.57	0.69	0.25	0.32	0.39	0.46
KC_1	0.87	1.01	1.15	1.25	0.41	0.51	0.55	0.64
KC_2	1.29	1.40	1.48	1.58	0.58	0.68	0.76	0.92
LSD(0.05)	0.48	0.39	0.20	0.39	0.25	0.35	0.31	0.32
CV(%)	6.87	4.42	8.58	3.05	7.86	7.23	5.31	45.84
LS	**	***	***	**	*	**	*	*

Where, NS= non-significant at P=0.05; *significant at P=0.05; **significant at P=0.01; ***significant at P=0.001; LS= Level of significance; K_0= Kazi compost 0%; K_1= Kazi compost 10 %; K_2= Kazi compost 20%

4.2.11 Root dry weight (g)

Salt stress significantly influenced the RDW at different growing stages of BARI Chola-11. The RDW gradually decreased with increasing salinity stress, and the RDW with 50 mM NaCl stress (0.07, 0.09, 0.11 and 0.13 g) and with 100 mM NaCl stress (0.05, 0.07, 0.09 and 0.11 g) were recorded at 60, 70, 80 and 90 DAS, respectively (Table 15). Unlike to the studies of Islam *et al*. (2008), Islam (2012), Ismaan (2017), Ferdous *et al*. (2018), Renu (2019), and Islam (2019), who reported that soil salinity reduced the root dry weight. Incorporation of KC in the soil positively influenced the RDW, and it increased significantly with the increasing KC levels. At 60, 70, 80 and 90 DAS, the values of RDW were (0.07, 0.10, 0.12 and 0.13 g, respectively) and (0.10, 0.13, 0.15 and 0.17 g, respectively) due to application of KC of 10 and 20%, respectively. The observed increase in RDW under this condition was very consistent with the several studies where it was revealed that organic manures under saline conditions significantly increased the root dry weight of mungbean (Islam, 2019), soybean (Ferdous *et al*., 2018), foxtail millet and prosomillet (Islam *et al*., 2011), and pepper (AlTaey *et al*., 2017).

4.2.12 Pod dry weight (g)

Chickpea drastically reduced the pod dry weight per plant at different growth stages by the salinity stress. The PDW progressively decreased with increasing salinity from 50 to 100 mM NaCl stress (Table 15). However, the lowest PDW (0.12, 0.20, 0.29 and 0.37 g) was observed under 100 mM NaCl at 60, 70, 80, 90 DAS, respectively. Ram *et al*. (1989) reported that the PDW was reduced due to salinity stress in case of chickpea. In contrary, application of KC increased the PDW. The increased values of PDW over control at different sampling dates were 0.17, 0.25, 0.33 and 0.40 g, and 0.31, 0.41, 0.51, 0.59 g due to application of KC of 10 and 20%, respectively.

Table 15: Effect of SS on the root and pod dry weight plant^{-1} at different DAS

Treatments	Root dry weight plant^{-1} (g)				Pod dry weight plant^{-1} (g)			
	60 DAS	70 DAS	80 DAS	90 DAS	60 DAS	70 DAS	80 DAS	90 DAS
S_0	0.09	0.12	0.15	0.16	0.26	0.33	0.44	0.52
S_1	0.07	0.09	0.11	0.13	0.19	0.26	0.39	0.46
S_2	0.05	0.07	0.09	0.11	0.12	0.20	0.29	0.37
LSD(0.05)	0.03	0.06	0.07	0.10	0.21	0.18	0.21	0.30
CV(%)	6.73	7.28	4.79	5.35	8.50	5.23	4.01	5.90
LS	NS	*	*	**	*	**	*	***

Where, NS= non-significant at P=0.05; *Significant at P=0.05; LS= Level of significance; S_0= Salinity level 0 mM; S_1= Salinity level 50 mM; S_2= Salinity level 100Mm

Table 16: Effect of KC on the root and pod dry weight plant^{-1} of chickpea at different DAS

Treatments	Root dry weight plant^{-1} (g)				Pod dry weight plant^{-1} (g)			
	60 DAS	70 DAS	80 DAS	90 DAS	60 DAS	70 DAS	80 DAS	90 DAS
KC_0	0.04	0.06	0.08	0.10	0.08	0.13	0.28	0.36
KC_1	0.07	0.10	0.12	0.13	0.17	0.25	0.33	0.40
KC_2	0.10	0.13	0.15	0.17	0.31	0.41	0.51	0.59
LSD(0.05)	0.04	0.05	0.05	0.06	0.12	0.10	0.15	0.18
CV(%)	8.61	5.09	4.61	4.84	6.02	6.51	9.23	9.67
LS	*	*	*	*	**	***	*	*

Where, NS= non-significant at P=0.05; *significant at P=0.05; **significant at P=0.01; ***significant at P=0.001; LS= Level of significance; K_0= Kazi compost 0%; K_1= Kazi compost 10 %; K_2= Kazi compost 20%

4.2.13 Pod length (cm)

Chickpea drastically reduced the pod length by salinity at different growth stages. Due to salinity the pod length was decreased gradually from 50 to 100 mM NaCl stress (Table 17). The shortest pod (1.27, 1.38, 1.43 and 1.48 cm) was observed under 100 mM NaCl at 60, 70, 80, 90 DAS and at harvest respectively. Application of KC at salt stressed plants, on the other hand, increased the pod length by ameliorating the adverse effects of salt stress. The longest pod length (1.61, 1.73, 1.87, 1.97 and 2.11 cm) was recorded with the application of 20% KC at 60, 70, 80, 90 and at harvest, respectively (Table 18).

4.2.14 Number of grains pod^{-1}

The number of grains pod^{-1} of chickpea varied significantly due to different levels of salinity. Saline stress of 50 and 100 mM NaCl produced the minimum number of grains pod^{-1} of 1.33 and 1.11 over control (1.67), respectively (Table 17). At the flowering stage, plants damaged severely due to heavily imposed salt stress (100 mM) and plant did not bear pods. Sohrabi *et al.* (2008) who observed that salinity significantly reduced the number of grains pod^{-1} in chickpea. The results of the present experiment agreed well with the findings of Islam (2001), Hasan (2015), Shaddam (2016), who observed that salinity significantly reduced the number of grains pod^{-1} in mungbean and blackgram. Nevertheless, KC application alleviated from the negative effect of saline stress and significantly increased the number of grains pod^{-1} (Table 18). In both level KC of 10 and 20% increased the number of grains pod^{-1} of 1.33 and 1.67, respectively. The increase in the number of grains pod^{-1} in mungean observed with organic manures like tea compost, vermicompost under saline conditions is consistent by way of the studies by several previous researchers (Saeed *et al.*, 2016; Uddin, 2017; Islam, 2019).

Table 17: Effect of SS on the pod length and number of grains pod^{-1} of chickpea at DAS

Treatments	Pod length (cm)					Number of grains pod^{-1}				
	60 DAS	70 DAS	80 DAS	90 DAS	Harvest	60 DAS	70 DAS	80 DAS	90 DAS	Harvest
S_0	1.57	1.61	1.73	1.80	1.91	1.67	1.67	1.67	1.67	1.67
S_1	1.37	1.45	1.51	1.59	1.69	1.33	1.33	1.33	1.33	1.33
S_2	1.27	1.38	1.43	1.48	1.56	1.11	1.11	1.11	1.11	1.11
LSD(0.05)	0.15	0.11	0.16	0.17	0.10	0.67	0.25	0.25	0.50	0.50
CV(%)	8.0	5.77	7.92	8.16	4.56	37.16	14.04	14.04	8.08	8.08
LS	*	*	*	*	**	NS	**	**	NS	NS

Where, NS= non-significant at P=0.05; *Significant at P=0.05; LS= Level of significance; S_0= Salinity level 0 mM; S_1= Salinity level 50 mM; S_2= Salinity level 100Mm

Table 18: Effect of KC on the pod length and number of grains pod^{-1} of chickpea at different DAS

Treatments	Pod length (cm)					Number of grains pod^{-1}				
	60 DAS	70 DAS	80 DAS	90 DAS	Harvest	60 DAS	70 DAS	80 DAS	90 DAS	Harvest
KC_0	1.24	1.31	1.36	1.41	1.45	1.11	1.11	1.11	1.11	1.11
KC_1	1.36	1.39	1.44	1.50	1.60	1.33	1.33	1.33	1.33	1.33
KC_2	1.61	1.73	1.87	1.97	2.11	1.67	1.67	1.67	1.67	1.67
LSD(0.05)	0.17	0.13	0.13	0.13	0.17	0.40	0.40	0.40	0.46	0.40
CV(%)	11.60	8.44	8.17	7.56	9.80	8.08	8.08	8.08	3.93	8.08
LS	**	***	***	***	***	*	*	*	NS	*

Where, NS= non-significant at P=0.05; *significant at P=0.05; **significant at P=0.01; ***significant at P=0.001; LS= Level of significance; K_0= Kazi compost 0%; K_1= Kazi compost 10 %; K_2= Kazi compost 20%

4.2.15 Hundred grains weight

Moderate salinity stress (50 mM NaCl) in this study significantly decreased the 100-grains weight and a greater reduction was observed in 100 mM NaCl salt stress due to damaging the plant during pod formation stage (Table 19). The reduction percentage was 4.32 and 5.49% due 50 and 100 mM NaCl, respectively. Ram *et al.* (1989) also found the same result in chickpea under salt stress. Several studies showed that 100-grains weight decreased with increasing salinity stress in many crops such as mungbean and blackgram (Islam, 2001; Hasan, 2015; Shaddam, 2016), lentil (Tasnim, 2020), rice (Eunis, 2016), maize (Ismaan, 2017), sorghum (Ahmed, 2018; Waiz, 2019). Application of KC counteracted the harmful effects of salinity stress and increased the 100-grains weight. The 100-grains weight increased to 1.23 and 3.47% over control with the application 10 and 20% KC, respectively. The results of the present investigation were in close conformity with the findings of several researchers in other legumes such as bean (Saeed *et al*., 2016), and mungbean (Aslam *et al*., 2010). As like KC, other organic manures also increased 100-grains weight like tea compost (Uddin, 2017), vermi-compost (Islam, 2019), FYM (Aslam *et al*., 2010) in mungbean and poultry manure (Tasnim, 2020) in lentil. Grain weight and 1000 grains weight were also increased in chickpea due to compost incorporation under non-saline condition has been reported by Patel *et al*. (2012) and Basir *et al*. (2008).

4.3 Effect of KC on the yield of chickpea (BARI Chola-11) under saline stress

4.3.1 Grain weight plant^{-1}

Grain yield is the function of number of productive pods plant^{-1}, grains pod^{-1} and 100-grains weight. Generally, the grain weight plant^{-1} decreased with increasing salinity levels in the root zone (Läuchli and Grattan, 2007; Saeed and Ahmad, 2013). In this study, salinity stress significantly reduced the grain weight plant^{-1} of chickpea, and the reduction over control was 20.75 and 32.08% at 50 and 100 mM NaCl, respectively. Salt stress caused a significant reduction in grain weight plant^{-1} of chickpea (Sohrabi *et al*., 2008; Ram *et al*., 1989). Ferdous *et al*. (2018) observed that salinity stress decreased the yield plant^{-1} in soybean, and Islam *et al*. (2008) and Tasnim (2020) also found the same in lentil. On the other hand, incorporation of KC considerably increased the grain weight plant^{-1} under NaCl stress induced chickpea plant. The grain weight plant^{-1} increased to 17.14 and 34.15% over control with the application 10 and 20% KC, respectively. Organic amendments in saline soil increased crop yield as reported by Naeem *et al.* (2006), Aslam *et al.* (2010), Pant *et al.* (2011), Hirich *et al.* (2014). Organic mulch increased the yield of okra under saline as well as non-saline conditions (Saeed and Ahmad, 2013). Water hyacinth and rise husk biochar increased the yield of soybean under saline stress (Ferdous *et al*., 2018). Organic amendments in non-saline soil increased seed yield of chickpea as reported by many researchers earlier (Basir *et al.*, 2008; Patel *et al*., 2012; Singh *et al.*, 2012; Yadav *et al.*, 2017; Singh *et al*., 2014; Ditta *et al*., 2018).

4.3.2 Stover weight plant^{-1}

The stover yield of chickpea was significantly affected by salt stress and stover yield decreased with increasing salinity levels. The stover yield reduced to 19.64 and 13.33% over control at 50 and 100 mM NaCl stress, respectively. Ferdous *et al*. (2018) reported that salinity stress reduced the yield of soybean. However, plants grown in KC containing soil increased the stover yield both under saline and non-saline conditions. Application of KC in soil mitigates the harmful and toxic effects of salinity stress and increased the stover yield in both stress conditions. However, the lowest stover yield 20.55% was recorded at 10% KC and KC applied plant (@ 20%) increased the stover yield 35.23% over the control condition. The improvement of vegetative growth in terms of the plant height, number of leaves plant^{-1}, and number of pods plant^{-1}, and number of grains pods^{-1} due to the application of KC as to the requirements of crop resulted in the improvement of stover yield. According to Hirich *et* *al*. (2014) and Pant *et al*. (2011), organic amendments showed the increased crop yield even under saline soil. Organic amendments increased the stover yield of chickpea under non-saline soil (Basir *et al*., 2008; Singh *et al*., 2014 and Yadav *et al*., 2017).

4.3.3 Biological yield plant^{-1}

The biological yield was decreased significantly with the increasing salinity levels and a greater reduction 13.73% was observed in 100 mM NaCl salt stress over control. Ram *et al*. (1989) who also found the similar result in chickpea. Biological yield was influenced significantly by different levels of KC in different salinity levels. Application of KC under different levels of salinity attenuated the harmful and destructive effects of salinity stress, and increased by 19.05 and 59.52% due to 10 and 20% manuring, respectively.

Table 19: Effect of SS on hundred grains weight (HGW), grain weight plant^{-1} (GWPP), stover weight plant^{-1} (SWPP) and biological yield plant^{-1} (BYPP) of chickpea at final harvest

Treatments	HGW	Reduction %	GWPP	Reduction %	SWPP	Reduction %	BYPP	Reduction %
S_0	19.69	-	0.53	-	0.112	-	0.64	-
S_1	18.84	4.32	0.42	20.75	0.090	19.64	0.51	20.31
S_2	18.61	5.49	0.36	32.08	0.078	13.33	0.44	13.73
LSD(0.05)	0.68	-	0.12	-	0.03	-	0.20	-
CV(%)	2.71	-	9.67	-	7.20	-	24.41	-
LS	*	-	**	-	*	-	*	-

Where, NS= non-significant at P=0.05; *Significant at P=0.05; LS= Level of significance; S_0= Salinity level 0 mM; S_1= Salinity level 50 mM; S_2= Salinity level 100Mm

Table 20: Effect of KC on HGW, GWPP, SWPP and BYPP of chickpea at final harvest

Treatments	HGW	Increase %	GWPP	Increase %	SWPP	Increase %	BYPP	Increase %
KC_0	18.75	-	0.35	-	0.073	-	0.42	-
KC_1	18.98	1.23	0.41	17.14	0.088	20.55	0.50	19.05
KC_2	19.40	3.47	0.55	34.15	0.119	35.23	0.67	59.52
LSD(0.05)	0.32	-	0.07	-	0.03	-	0.17	-
CV(%)	1.64	-	12.57	-	3.34	-	3.91	-
LS	**	-	**	-	*	-	*	-

Where, NS= non-significant at P=0.05; *significant at P=0.05; **significant at P=0.01; ***significant at P=0.001; LS= Level of significance; K_0= Kazi compost 0%; K_1= Kazi compost 10 %; K_2= Kazi compost 20%

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy Shade house, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period from December 2019 to March 2020. The experiment consisted two factors naming Factor A: three salinity levels viz., S_0 (0 mM NaCl), S_1 (50 mM NaCl), S_2 (100 mM NaCl), and Factor B: three levels of Kazi compost viz., KC_0: 0% (w/w), KC_1: 10% (w/w) and KC_2: 20% (w/w). The experiment was laid out in completely randomized design (CRD) with three replications. The experiment was conducted in pot. The area of each pot was 0.0567 m^2. Each pot contained 9 kg of soil including 0, 10 and 20% Kazi compost.

The highest days to flowering (54.33 days) was observed in S_0 treatment (control condition) and (56.33 days) was recorded at 20% Kazi compost level, while the lowest days to flowering (51.11days) was recorded in S_2 (100 mM). Yield and yield contributing characters were significantly influenced by different levels of Kazi compost.

The results revealed that the shortest plant (31.72, 33.08, 36.96, 39.73 and 41.23 cm) was recorded under the saline condition of S_2 (100 mM NaCl) and the tallest plant (35.72, 38.72, 41.64, 43.37and 45.27cm) was recorded under the control condition of S_0 (0 mM NaCl) at 60, 70, 80, 90 DAS and final harvest, respectively. Among those 10% Kazi compost at 50 mM NaCl showed optimum performance due to the alleviating effect of Kazi compost on saline condition. However, Kazi compost improved the salt stress effect in all parameters.

The highest pod dry weight plant^{-1} (0.26, 0.33, 0.44 and 0.52 g) was obtained from S_0 (0 mM NaCl), while the lowest (0.12, 0.20, 0.29 and 0.37 g) was recorded from S_2 (100 mM NaCl) at 60, 70, 80 and 90 DAS, respectively. Among the various level of Kazi compost, 20% KC produced the highest pod dry weight under saline condition due to the alleviating effect of

Kazi compost. The highest number of pods plant^{-1} (3.67, 4.44, 4.78, 5.44 and 22) was found in S_0 and the lowest number (2.11, 2.78, 3.33, 3.78 and 4.11) was in S_2, while the highest number of pods plant^{-1} was (4.00, 4.78, 5.22, 5.89 and 6.33) observed 20% Kazi compost level, and lowest in 0% Kazi compost level (1.67, 2.22, 2.67, 3.11 and 3.67) at 60, 70, 80, 90 and final harvest, respectively. The optimum result was found in 10% Kazi compost and 50 mM NaCl. The highest number of grains pod^{-1} (1.67) was recorded from S_0, and the lowest number (1.11) was in S_2, respectively. The highest and lowest value was obtained at 20% and 0% Kazi compost, respectively. The highest pod length (1.91 cm) was in S_0 and the lowest pod length (1.56 cm) was recorded in S_2. While the intermediate pod length (1.37, 1.45, 1.51, 1.59 and 1.69 cm) was recorded in S_1 at 60, 70, 80, 90 and final harvest, respectively. In case of Kazi compost the highest pod length was (1.61, 1.73, 1.87, 1.97 and 2.11 cm) with KC_2 and the lowest (1.24, 1.31, 1.36, 1.41 and 1.45 cm) was with KC_0 at 60, 70, 80, 90 and final harvest, respectively. The reduction percentage of HGW was 4.32 and 5.49% due 50 and 100 mM NaCl, respectively. While the 100-grains weight increased to 1.23 and 3.47% over control with the application 10 and 20% KC, respectively. Salinity stress significantly reduced the grains weight plant^{-1} of chickpea, and the reduction over control was 20.75 and 32.08% at 50 and 100 mM NaCl, respectively. The grains weight plant^{-1} increased to 17.14 and 34.15% over control with the application 10 and 20% KC, respectively. The stover weight plant^{-1} reduced to 19.64 and 13.33% over control at 50 and 100 mM NaCl stress, respectively. Application of KC enhanced the stover weight plant^{-1} of chickpea. However, the lowest stover weight plant^{-1} 20.55% was recorded at 10% KC and KC applied plant (@ 20%) increased the stover weight plant^{-1} 35.23% over the control condition. The biological yield plant^{-1} was decreased significantly with the increasing salinity levels and a greater reduction 13.73% was observed in 100 mM NaCl salt stress over control. Biological yield plant^{-1} was influenced significantly by different levels of KC in different salinity levels. Application of

KC under different levels of salinity attenuated the harmful and destructive effects of salinity stress, and increased by 19.05 and 59.52% due to 10 and 20% manuring, respectively. The result showed that the growth parameters like plant height, number of branches plant^{-1}, root length etc. were significantly enhanced by different level of Kazi compost.

From the above results it is revealed that yield and yield attributes significantly reduced due to imposition of salt stress, while application of KC remarkably counteracted the salt stress of chickpea. It is concluded that Kazi compost treatment is found to cope with salinity stress and improve plant growth and yield parameters by diluting the hazardous effects of salinity.

The results revealed that there is scope to increase the yield of chickpea by applying proper dose (20%) of Kazi compost under the saline soil (up to 100 mM).

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APPENDICES

Appendix I: Monthly recorded of air temperature, relative humidity and rainfall at the experimental site (December 2019-March 2020)

Months	Temperature (◦c)		Relative humidity (%)	Rainfall (mm) Total)
	Maximum	Minimum		
December 2019	23	11	87.00	0.00
January 2020	26	8	73.00	2.00
February 2020	29	12	78.75	0.00
March 2020	33	16	85.00	5.00

Source: Bangladesh Meteorological Department (Weather Research Station) Rajbari, Dinajpur

Appendix II. Physical and chemical properties of soil used in experiment

Characteristics	**Non-saline soil**	**Saline soil**	**Analytical Method**
Sand (%)	50.8		Sedimentation and Decantation method
Silt (%)	32.4		
Clay (%)	16.8		
Textural class	Loam		
Bulk Density (g/cm3)	1.23	1.25	Undisturbed core method
pH	6.13		Using pH meter
EC (dS/m)	0.97	11.0	Using EC meter
Organic carbon (%)	0.479		Wet oxidation method
Organic matter (%)	0.825		
Total N (%)	0.04		Micro Kjeldhal method
Available P (ppm)	12.43		Borax method
Exchangeable K (me 100^{-1} g soil)	0.3		Using an Atomic Absorption Spectrophotometer
Available S (ppm)	4.46		

Source: Soil Resources Development Institute (SRDI) Nashipur, Dinajpur

Appendix III: Map of Agro-Ecological Zone

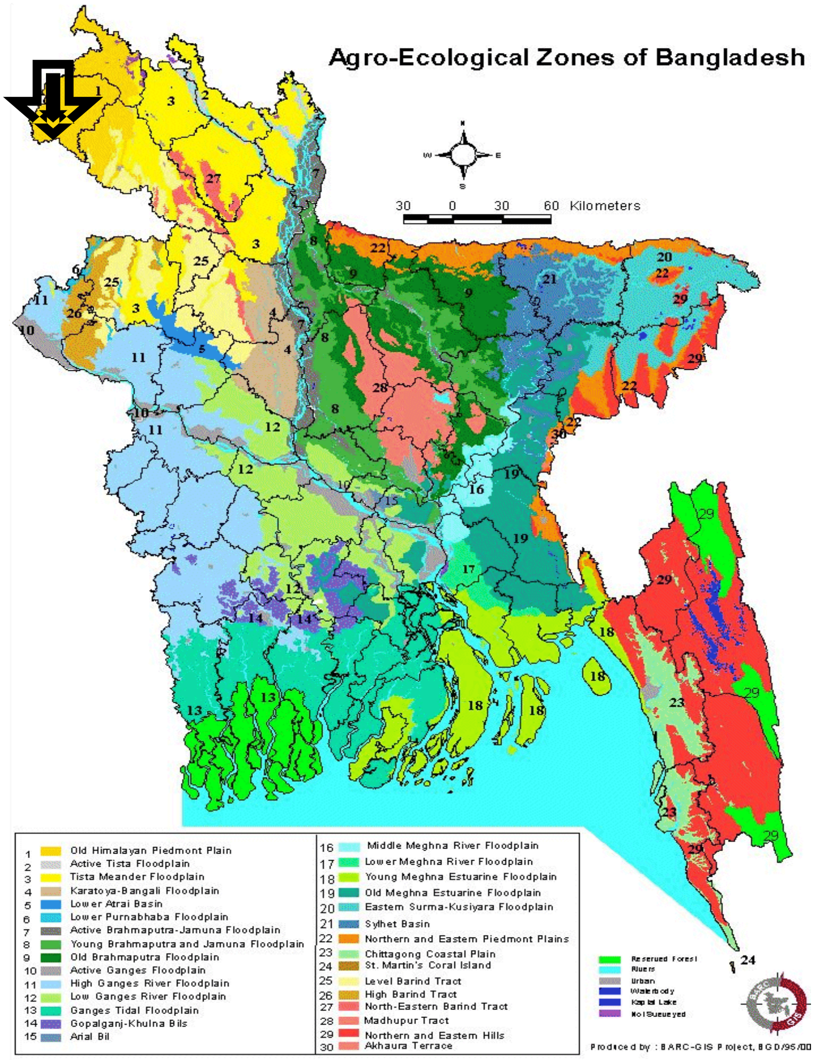

Fig: Agro-Ecological Zone of Bangladesh (Pointing the research area)

SOME PICTURES OF RESEARCH ACTIVITIES

Prepared pot for seed sowing

Kazi compost

Morphological view of seedlings in different treatments

S_0KC_0

S_1KC_0

S_0KC_1

S_1KC_1

S_0KC_2

S_1KC_2

S_2KC_0

S_2KC_1

S_2KC_2

Vegetative stage

Reproductive stage

Maturity stage

Salt solution application

Monitoring for quality data

Comparison at maturity stage

$S_0KC_1 > S_0KC_0$

$S_2KC_0<S_1KC_0<S_0KC_0$

Various data recording after harvesting