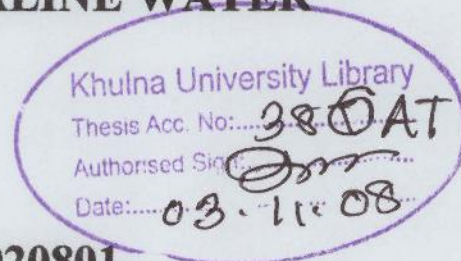


**INFLUENCE OF NITROGEN AND PHOSPHORUS
FERTILIZERS ON MUNGBEAN (*Vigna radiata* L.
Wilczek) IRRIGATED WITH SALINE WATER**



Examination Roll No. MS 020801

**A thesis submitted to Khulna University in partial fulfillment of the
requirements for the degree of**

Master of Science in Agronomy



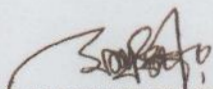
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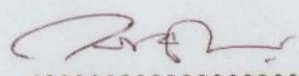
January, 2008

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ABSTRACT

Salt tolerance of mungbean has usually been studied under optimal fertility conditions. The objectives of the present studies were to compare the response of mungbean to salinity when nutrients were limiting, adequate, or in excess to determine whether additional fertilizer could repair salt injury.

Two sets of pot experiment were conducted at the Reserch Centre of Agrotechnology Discipline of Khulna University during April to June 2004. In all the experiments BARI mung 5 was grown with 0 and 75 dS m⁻¹ NaCl salinity. In the first experiment, the response of mungbean to three levels of fertilizer nitrogen 14, 40 and 80 kg N ha⁻¹ under saline condition was compared with that of recommend N level under nonsaline condition (control). In the second experiment, P levels were 20, 60 and 120 kg P ha⁻¹. Application of increased levels of N and P improved water relation of mungbean to some extent. The dry matter production in different plant parts decreased by salinity which was showed increasing tendency with higher levels of N and P. Salinity also decreased yield and yield attributes of mungbean seriously that was increased with increasing levels of N and P fertilization. Seed yield under saline condition was very low than that of control condition. N, P and K uptake decreased and Na uptake increased by salinity. Na uptake decreased and N, P and K uptake increased by increasing levels of N and P fertilization. It was concluded that the external application of major nutrient elements ameliorates the harmful effect of salinity on mungbean growth, to some extent, by improving the plant water relation and mineral ions accumulation.



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The Author



TABLE OF CONTENTS

	Page no.
LIST OF TABLES	V
LIST OF FIGURES	VI
I. GENERAL INTRODUCTION	1
II. REVIEW OF LITERATURE	3
III. EXPERIMENT 1	12
IV. MATERIALS AND METHOD	14
V. RESULTS AND DISSCUSSION	19
VI. EXPERIMENT 2	36
VII. MATERIALS AND METHOD	38
VIII. RESULTS AND DISSCUSSION	39
IX. SUMMARY AND CONCLUSIONS	54
X. REFERENCES	56
XI. APPENDIX	68

LIST OF TABLES

Tables	Page no.
1. Physical and chemical properties of the experimental soil.	15
2. Effect of salinity and nitrogen levels on relative water content, water saturation deficit, water retention capacity and water uptake capacity of mungbean	22
3. Effect of salinity and nitrogen levels on yield and yield attributes of mungbean	31
4. Effect of salinity and phosphorus levels on relative water content, water saturation deficit, water retention capacity and water uptake capacity of mungbean	42
5. Effect of salinity and phosphorus levels on yield and yield attributes of mungbean	50

LIST OF FIGURES

Figures	Page no.
1. Relationship between nitrogen levels and relative water conteny of mungbean under saline condition.	20
2. Relationship between nitrogen levels and water saturation defisit of mungbean under saline condition.	20
3. Relationship between nitrogen levels and water retention capacity of mungbean under saline condition.	21
4. Relationship between nitrogen levels and water uptake capacity of mungbean under saline condition.	21
5. Effect of salinity and nitrogen levels on leaf dry weight, sem dry weight, petiole dry weight, pod dry weight and total dry weight of mungbean.	25
6. Effect of salinity and nitrogen levels on total dry weight of mungbean.	27
7. Relationship between nitrogen levels and pods plant ⁻¹ of mungbean under saline condition.	29
8. Relationship between nitrogen levels and water seeds pods ⁻¹ of mungbean under saline condition.	29
9. Relationship between nitrogen levels and 1000 grain weight (g) of mungbean under saline condition.	30
10. Relationship between nitrogen levels and seed yield (g plant ⁻¹) of mungbean under saline condition.	30
11. Effect of nitrogen levels on uptake of different nutrients in mungbean under saline condition.	33
12. Relationship between phosphorus levels and relative water content of mungbean under saline condition.	40
13. Relationship between phosphorus levels and water saturation defisit of mungbean under saline condition.	40
14. Relationship between phosphorus levels and water retention capacity of mungbean under saline condition.	41

LIST OF FIGURES

Figures	Page no.
15. Relationship between phosphorus levels and water uptake capacity of mungbean under saline condition.	41
16. Effect of salinity and phosphorus levels on leaf dry weight, stem dry weight, petiole dry weight, pod dry weight of mungbean.	44
17. Effect of salinity and phosphorus levels on total dry weight of Mungbean.	46
18. Relationship between phosphorus levels and pods plant ⁻¹ of mungbean under saline condition.	48
19. Relationship between phosphorus levels and seeds pods ⁻¹ of mungbean under saline condition.	48
20. Relationship between phosphorus levels and 1000 grain weight (g) of mungbean under saline condition.	49
21. Relationship between phosphorus levels and seed yield (g plant ⁻¹) of mungbean under saline condition.	49
22. Effect of P levels on uptake of different nutrients in mungbean under saline condition	52

GENERAL INTRODUCTION

Mungbean [*Vigna radiata* (L) Wilczek] is an important legume crop in the tropics and subtropics. It is an important source of protein as well as vitamin and mineral of the common people of these areas. This crop is especially suitable for developing country like Bangladesh, where people intake insufficient protein. Among the pulses in Bangladesh mungbean ranks fourth in terms of both in area and in production (Kabir, 2002). It can be consumed as soup but in many countries sprouted seeds are widely used. It contains about 24% protein, which is about two-third of soybean, twice that of wheat and threefold that of rice (Poehlman, 1991).

In the coastal region of Bangladesh, considerable amounts of salt accumulate on the soil surface by evaporation, particularly during the fallow dry period of February to May. If the fallow period is long, severe salinity may be developed.

Most plants suffer from salt injury at an electrical conductivity of the soil saturation extract (EC_e) higher than 4 dS m^{-1} . At such a level of salinity, plants suffer from water stress even though enough water is present in the root zone because of higher osmotic potential created by the salts present in the system (ADCE, 1990; Karim *et al.*, 1990). Soil salinity is well known to affect many physiological and metabolic processes of plants. Even mild level of salinity may reduce crop growth and development by decreasing availability of soil water to plant, creating nutritional imbalance and causing specific ion toxicity to vital plant organs (Blum, 1988; Islam, 2001). Salinity appears to affect mainly two plant processes- water and ionic relations. During the initial exposure to salinity the plant experiences water stress (Munns and Termaat, 1986; Faruqui, 2002). Whereas, long term exposure causes ionic stress along-with water stress (Cramer *et al.*, 1994). Numerous studies have confirmed that fertilizer management is an important aspect of economic agriculture in the saline soils (Irshad *et al.*, 2002; Khan *et al.*, 1997; Zaiter and Saade, 1993; Abd-Ella and Shalaby, 1993; Grattan and Grieve, 1992). Studies further suggest that moderate soil salinity may interact with plant nutrition and may enhance plant metabolism for high dry matter production (Mohanty *et al.*, 1999; Zaiter and Saade, 1993; Abrol, 1968; Dregne and Mojallali, 1968). In a study of Raptan *et al.* (2001) found that mungbean plant showed low amount of N, P and K when grown under mild level of salinity. However, the literatures on the effects of fertilization of saline soils to plant growth remain still scarce. Hence, in the

absence of an adequate understanding of the performance of mungbean at different fertilizer levels under saline condition, this study was undertaken with the following objectives:

- 1) to find out the effect of N and P on yield and yield attributes of mungbean;
- 2) to observe the influence of irrigation with saline water on uptake of N and P; and
- 3) to observe the influence of irrigation with saline water on the water relation of mungbean plant.



REVIEW OF LITERATURE

Mungbean (*Vigna radiata* (L) Wilczek) is an important legume crop in Bangladesh. Limited studies have been undertaken on the topic of salinity tolerance of mungbean. However, literature on the interaction effect of salinity and nutrient on salt tolerance mechanism of this crop is scanty. Available literatures, pertinent to the present study, are presented here under:

Effect of Salinity and Nutrient on Dry Matter of Stem, Leaf and Total Dry Matter

Salinity decreased dry matter of stem, leaf and total dry matter of mungbean. The dry matter distribution in different organs in salt affected plants showed an increasing tendency with the increasing level of nitrogen, phosphorus and potassium (Kabir, 2002).

Usually growth reduction is related to the duration of plant exposure to salinity, the longer the exposure, the greater is the reduction (Maas and Hoffman, 1977). They demonstrated that total dry matter as well as grain yields were affected by salinity. Balasubramanian and Sinha (1976) observed that the relative growth rates of stressed cowpea and mungbean plants declined initially. Since salinity tolerance is a complex physiological process, the reasons for the dissimilar response of different plant parts of the same plant to salinity or changes in salt tolerance with the change in exposure period are still not fully understood (Ashraf and Karim, 1990).

Ashraf and Karim (1990) assessed salt tolerance of 27 local and exotic accessions of blackgram, and noticed that in all accessions the leaf dry weight decreased with increasing salinity levels. Similar results were found by Chowdhury (1992) and Ashraf and Rasul (1987) in mungbean, Raptan *et al.* (2001) and Islam (2001b) in blackgram and mungbean. Reduction of leaf dry matter also observed under saline condition by Ram *et al.* (1989) in chickpea.

Gill (1988) and Patil *et al.* (1996) stated that reduction in stem dry matter production of mungbean substantially decreased under saline condition. Raptan *et al.* (2001) noticed reduced stem dry weight in blackgram under saline condition. Reduced stem dry weight production in blackgram due to salinity was also reported

by Ashraf and Karim (1990). Silverla *et al.* (1999) stated that stem dry weight of cowpea decreased drastically under saline condition. Similar results were found in cowpea and mungbean by Balasubramanian and Sinha (1976).

Effect of Salinity and Nutrient on Pods per Plant, Seeds per Pod, 1000-grain Weight, Yield and HI

In general, all the plant organs are affected by salinity, though the growth reduction of different plant-parts of the same plant is not similar. For example, leaf biomass was less affected by salinity than the shoot in alfalfa (Hoffman *et al.*, 1975), grain yield decreased more than straw yield in *Triticale* (Karim *et al.*, 1992), while the roots were damaged more than shoot in root crops (Hoffman and Rawlins, 1971), although the reasons for such disparity in salt tolerance between the organs are not clear.

Mungbean is reported to be more susceptible to salinity than many grain legumes (Pandey *et al.*, 1984). Salinity affects canopy development (Kriedemann, 1986) and overall growth process but there are varietal differences in stress tolerance. Sadasivam *et al.* (1988) reported that stress during vegetative phase reduces grain yield through reducing plant size, limiting root growth and number of pods and harvest index in mungbean. Decreased grain yield due to salinity stress was also reported for chickpea (Probhakar and Saraf, 1991), soybean (Rajput *et al.*, 1991), green gram and black gram (Tripurari and Yadav, 1990), faba bean (Khade *et al.*, 1990).

Raptan *et al.* (2001) reported a reduction of pods plant⁻¹ and seeds pod⁻¹ under saline condition in mungbean. Similar results were found in mungbean by Hafeez *et al.* (1988) and in greengram by Patil *et al.* (1996). Fauzia *et al.* (1988) found in mungbean that pods per plant and seeds pod⁻¹ were not significantly affected up to a salinity level of 7.5 dS m⁻¹ NaCl salinity.

Hasan and Mashhady (1983) reported that interactions between soil salinity and available soil water induced significant effects on dry matter content, grain yield, grain number and 1000-grain weight. The stress conditions caused by high soil salinity and limited soil moisture progressively decreased the dry matter content of the wheat plant

Islam (2001b) showed in bushbean (*Phaseolus vulgaris*) that plants grown under a high soil moisture regime had a higher water retention capacity than that of the plants grown under mild stress and severe stress condition. Salt stress reduced the WRC significantly compared to that of control at all levels of nitrogen.

Gill and Dutta (1987) worked with barley and wheat in saline condition. They showed that leaf water potential decreased with the increasing soil salinity. Under saline conditions plant suffers from osmotic shock due to lower osmotic potential in the soil solution (Greenway and Munns, 1980; Orcutt and Nilsen, 2000). Plant synthesizes different metabolites across the tonoplast to maintain turgor. However, the plants must spend substantial energy to maintain turgor under water deficit conditions (Munns and Termat, 1986).

Effect of Salinity and Nutrient on N, P, Na, K, Ca and Mg Ions

Karim *et al.* (1993) reported that Na concentration was increased by salinity in *Triticale*. *Triticale* showed the highest concentration of Na in the plants treated with combined 100 mM NaCl and water stress. Potassium accumulation in *Triticale* was increased by water stress as well as by combined stress treatments. The highest concentration of K was observed when water stress was imposed on 100 mM NaCl treated *Triticale* plants.

Singh (1998) reported that increasing N levels (0-90 mg N kg⁻¹) increased the pod production of *Hibiscus esculentus*, alleviating in part the adverse effect of salinity. Higher levels of N application increased the contents and uptake of almost all nutrients. Split additions of NO₃-N (irrigation with a solution of 50 mg N litre⁻¹) under saline conditions (irrigation with a 10 mM NaCl solution, which did not negatively affect plant growth) and non-saline conditions (water), enhanced the Na uptake by Italian ryegrass (*Lolium multiflorum* cv. Barwoltra) grown in two soils potentially rich in K. Mg uptake was also enhanced. This was not observed for split additions of P (Murillo *et al.*, 1998).

Increasing N rate increased dry matter accumulation, K content in straw and P and K uptake of wheat in saline condition (Ashok *et al.* 1997). Barley produced a significantly

higher dry matter yield (8 dS m^{-1}) when grown with mixed N nutrition than with NH_4^+ or NO_3^- alone. Total dry matter production and root and shoot N contents decreased with increasing salinity in the root medium. The interaction between salinity and N nutrition was found to be significant for all the variables. A significant positive correlation ($r=0.97$) was found between nitrogen level in the plant shoot and its dry matter yield (Ali *et al.*, 2001).

Vorob and Zhurba (1995) stated that increases in Na uptake kg^{-1} dry matter under saline conditions were greater in Kulon rice than in Spal'chik (relatively salt tolerant rice) but decreased as NPK rate increased in both cultivars. K and N uptake increased with increasing NPK rate. Salinity reduced K uptake and increased N uptake per kg dry matter.

Leaf P concentrations of *Capsicum annuum* tended to increase with increasing P rates, and to a greater extent under saline conditions. Salinity and increased rates of applied P increased the tissue Na concentrations. Salinity also increased the chlorine concentrations of the plants (Gunes *et al.*, 1999).

Anand (1995) stated that application of P and K significantly increased their concentration and uptake by pearl millet and wheat in saline condition ($\text{ECe } 4.9 \text{ to } 8.5 \text{ dS m}^{-1}$). Marginal improvements in available soil phosphorus and potassium were observed when P and K were applied at a rate of 22 kg P and 42 kg K ha^{-1} , respectively.

Aslam *et al.* (1996) found that increasing the supply of phosphorus (from $1 \text{ to } 100 \text{ }\mu\text{M Pi}$) to the saline medium tended to decrease the concentrations of Na and Cl in all cultivars of *Oryza sativa* except IR 1561. Shoot P and Zn concentrations showed an increasing trend in the presence of external Pi and salt in the rooting medium but most strikingly P:Zn ratio was lower in salt tolerant and moderately salt tolerant cultivars. Significantly higher concentrations of Na, P and Cl, and lower concentrations of Zn, were determined in the shoots of salt sensitive cultivars when exposed to salt stress in the presence of Pi.

Gill and Dutta (1987) reported that Na and K concentration increased in barley with the increasing salinity. Na^+ concentration increased with increasing salinity in chickpea as reported by Sharma *et al.* (1993). Dhingra and Sharma (1993) stated that Na^+ content increased in mungbean seedling with the increasing salinity level.

Concentrations of Na^+ , Ca^{2+} and Cl^- in roots and shoots increased due to salinity in fieldpea (Lal and Bhardwaj, 1984) and in horsegram and greengram (Sudhakar *et al.*, 1990). Nakamura *et al.* (1990) reported that under saline to the external medium alleviated the inhibition of root elongation by salt stress and the plant under such condition maintained a high intercellular concentration of K^+ in the elongation region of the roots. The findings indicated that Ca^{+2} prevented the leakage of intercellular K and thereby support the elongation of roots under salt stress. It is reported that accumulated in the source (leaf) of the plant might be helpful to maintain osmoregulation to protect plant cells from osmotic shock caused by salinity (Greenway and Munns, 1980).

Crops differ widely in their ability to absorb mineral nutrients from saline substrate. Salinity decreased the uptake of N, P, K, Ca and Mg, while increase the uptake of Na (Bernstein, 1975; Islam, 2001b). Leguminous crops are generally sensitive to salinity though there is a considerable difference in salt tolerance between legume species (Maas and Hoffman, 1977; Raptan *et al.* 2001). Tolerant species can exclude Na^+ and Cl^- from the leaves better than salt susceptible species (Sharma and Kumar, 1990). However, the mechanism of salt exclusion and its significance to adaptation to saline environment are not fully understood (Lauchli, 1984). Salt resistance in soybean varieties was correlated with Cl^- exclusion ability from the shoot (Able and Mackenzie, 1964). *Trifolium alexandrum*, an effective Na^+ and Cl^- excluder, was found to be relatively salt tolerant compared to *T. pratense* (Winter and Lauchli, 1982). In contrast Alfocsea *et al.* (1993) reported that salinity tolerance in tomato was associated with higher Cl^- and Na^+ and lower K^+ in root, a typical character of a halophyte, as well as with their restricted translocation to shoot and maintenance of selectivity. Experiment of Gill (1990) with greengram revealed that the adverse effects of salinity at germination and three-leaf stage were due to disturbance in both osmotic (water stress) and ionic imbalance (specific ion effect) whereas due to the disturbance in only ionic balance during branching and pod formation stages.

Increasing salinity increased accumulation of salt (EC) in the root zone which created osmotic effect and a restriction of nutrient availability. Except Na^+ osmotic adjustment may occur in response of initial plant dehydration caused by salinity, although it is unclear whether the osmotic adjustment occurs in direct response to the ions

involved. However, various minerals ions (K^+ , Ca^{2+} , Mg^{2+} , Na^+) and compatible metabolites (proline, glycinebetaine, and various organic acids) were identified to be involved in osmotic adjustment under saline condition (Wynjones and Gorham, 1989). When the concentrations of Na^+ and Cl^- are in excess the plant has to encounter the toxic effect of these ions on the metabolic process (Blum, 1988). Thus the plants under saline substrates need extra energy to combat the harmful effect of salinity on plant growth process.

Effect of Nutrient on Salinity Management

Studies suggest that moderate soil salinity may interact with plant nutrition and may enhance plant metabolism for high dry matter production (Mohanty *et al.*, 1999; Zaiter and Saade, 1993; Abrol, 1968; Dregne and Mojallali, 1968). In a study of Raptan *et al.* (2001) mungbean plant showed low amount N, P and K when grown under mild level of salinity.

Ali *et al.* (1998) showed that substantial increase in biomass production of leaves and shoots were observed with increasing rates of N in the saline media. Carvalho and Stamford (1999) also showed that nitrogen fertilization resulted in larger shoot dry matter production under saline condition.

According to Grattan and Grieve (1992) addition of nutrients might result in enhancing or decreasing or even no change in plant salt tolerance depending on the level of salt stress. In many cases, salinity-to-fertility relationship, can be summarized as follows: 1) under low salt stress; nutrient deficiency limits plant growth more than salinity, and a positive interaction or increased salt-tolerance response occurs with additional nutrient supplies, 2) under moderate salinity, nutrient deficiency and salinity may equally limit plant growth and no interaction may occur, and 3) under high saline conditions, salinity limits growth to a greater extent than that of nutrient deficiency.

Mohanty *et al.* (1999) showed in rice that addition of nitrogen and phosphate fertilizers in various combinations worked as a remedial measure of the adverse effect of salinity. Amar *et al.* (1964) found that fertilization with N, P and K increase yield in cotton under saline condition. Luken (1962) stated that there is an increase in yield in some crops with fertilizer application at a certain salinity level. Lunin and

Gallatin (1965) also found that fertilization increase bean yield under saline condition.

Supplemental fertilization has been shown to overcome, to some extent, the nutritional deficiency in plants (Irshad *et al.*, 2002; JongGoo *et al.*, 2002; Erner *et al.* 2002; Abd-Ella and Shalaby, 1993). Addition of potassium to the nutrient solution diminished the negative effect of NaCl on growth of barley by increasing N uptake as well as N metabolism (Helal *et al.* 1975). Potassium favored protein synthesis which was affected by NaCl salinity (Ben-Zioni *et al.*, 1907; Lubin, 1963). Dregne and Mojallali (1968) reported that barley growth was improved in soil moderately salinized with Na-K salts, though Subbarao *et al.* (2000) showed that low potassium enhanced Na^+ uptake in red-beet under moderate saline condition.

Kabir (2002) sated that application of increasing levels of NPK increased the yield and yield attributes of mungbean. The nutrient uptake showed an increasing tendency with the application of increased levels of NPK except Na, which showed a decreasing tendency. He concluded that the external application of the major nutrient elements ameliorates the harmful effect of salinity on mungbean growth, to some extent, by improving the plant water relations and mineral ions accumulation.

Increased fertilization has sometimes been advocated to alleviate growth inhibition by salinity, with some emphasis on K but with major attention to P and N. Some recent publications do indicate a grater response to these latter elements under saline conditions than under nonsaline; e.g. increased levels of N, P or both appeared to increase the salt tolerance of millet and clover (Leon *et al.*, 1974). Increasing N levels ($0-90 \text{ mg N kg}^{-1}$) increased the pod production of *Hibiscus esculentus*, alleviating in part the adverse effect of salinity. Higher levels of N application increased the contents and uptake of almost all nutrients (Singh, 1998).

Barley produced a significantly higher dry matter yield (8 dS m^{-1}) when grown with mixed N nutrition than with NH_4^+ or NO_3^- alone. Total dry matter production and root and shoot N contents decreased with increasing salinity in the root medium. The interaction between salinity and N nutrition was found to be significant for all the variables. A significant positive correlation ($r = 0.97$) was found between nitrogen level in the plant shoot and its dry matter yield (Ali *et al.* 2001).

In two rice cultivars Spalchik (relatively salt tolerant) and Kulon (less tolerant), salinity (0.35% NaCl) reduced Leaf area index and dry matter yield m^{-2} at flowering and net photosynthetic productivity ($\text{gm}^{-2}\text{d}^{-1}$) between stem elongation and flowering. The percentage reductions decreased with increasing NPK rate and were less in Spalchik than in Kulon. LAI and DM yield increased with increasing NPK rate under saline and non-saline conditions in both cultivars (Vorob *et al.*, 1995). The combined application of P and Zn with saline irrigation improved DM accumulation and P utilization in wheat compared with their single application (Dravid 1996).

Increasing phosphorus (0, 11 and 22 kg P ha^{-1}) enhanced significantly the grain yield of pearl millet and wheat in saline condition (ECe 4.9 to 8.5 dS m^{-1}). Application of potassium (0, 21 and 42 kg K ha^{-1}) also increased yield of pearl millet and wheat. Application of P and K significantly increased their concentration and uptake by the crops. Marginal improvements in available soil phosphorus and potassium were observed when P and K were applied at a rate of 22 kg P and 42 kg K ha^{-1} , respectively (Anand, 1995).

Khalil *et al.* (1974) noted that fertilizing with N increased the sensitivity of corn and cotton (*Gossypium hirsutum* L.) to salinity and Ogo and Morikawi (1965) observed similar effects with rice (*Oryza sativa* L.) and wheat. Leon *et al.* (1974) also observed similar result with cabbage and broccoli. They suggested that although salt tolerance is not increased by fertilization, crop on saline soils may respond to higher levels of P fertilization because the restriction of root growth by salinity may decrease the recovery of P by the roots. They also suggest that increased K fertilization may be required in saline soils to counteract the competitive effects of high concentrations of cations.

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Experiment 1

INFLUENCE OF SALINITY AND NITROGEN ON WATER RELATION, YIELD AND YIELD ATTRIBUTES OF MUNGBEAN [*Vigna radiata* (L.) Wilczek]

INTRODUCTION

Nitrogen is an essential element and important determinant of growth and development of crop plants (Tanaka *et al.*, 1984). Nitrogen deficiency constrains leaf area expansion, enhances leaf senescence, alters canopy structure and subsequently reduces crop yields (Wolfe *et al.*, 1998).

The response of a crop to salinity and water quality is the basis for its selection and management under given saline condition. Salinity has been recognized as a major agricultural problem for economic crop production in arid and semi-arid regions. Retardation of crop yield by salinization has been known for a long time. Studies revealed that salinity induced growth retardation is related with osmotic and specific ion effects (Csizinsky, 1986; Coons and Pratt, 1988; George *et al.*, 1988; Alislail and Bartels, 1990).

The effect of salt stress on N nutrition in plants has been studied for various crops. The results are still contradictory. Increased N-fertilization may overcome some inhibitor effects of salinity (Mohanty *et al.*, 1999; Heimann, 1958; Ravikovitch and Porath, 1967). Leon *et al.* (1974) stated that increased fertilization sometimes advocated to alleviate growth inhibition by salinity, with some emphasis on potassium but with major attention to P and N. Increased levels of N, P, or both, appeared to increase the salt tolerance of millet (*Setaria* sp.) and clover (*Trifolium* sp.). Total N content in roots of 31day old barley decreased with increased salinity, though the content in shoots increased (Helal and Mengel, 1979; Choon-So, 1999). Bernstein *et al.* (1974) found that despite decrease in total N uptake, leaf N concentration of some grain and vegetable crops increased with increasing salinity at all N fertilization levels. Khalil *et al.* (1974) noted that fertilizing with N increased the sensitivity of corn and cotton (*Gossypium hirsutum* L.) to salinity and Ogo and Morikawi (1965) observed similar effects with rice (*Oryza sativa* L.) and wheat.

Although literature on the effects of N fertilizing saline soils appears contradictory many workers have reported that external application of N has positive effects on salinity tolerance of some crops. Moreover, insufficient information exists on the role of external application of N on growth responses of mungbean under saline condition. Thus, this study was undertaken to clarify the role of N application on the growth responses and mineral ions accumulation in mungbean under saline conditions.

MATERIALS AND METHODS

The experiment was carried out at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna during summer (April to June 2004). The experimental site is in the Ganges Tidal Flood Plain (AEZ 13).

Climate

The weather data including temperatures, rainfall, and humidity during the experimental period is presented in Appendix 1.

Collection of soil

Salt free soil used in the pot was collected from (Jessore sadar upazilla) Jessore district which is under High Ganges River Floodplain (AEZ 11).

Analysis of soil

The physical and chemical properties of the soil samples used in the pots were analyzed at the Soil Resources Development Institute (SRDI) at Daulotpur, Khulna. The initial physical and chemical properties of the soil are given in the Table 1.

Table 1. Physical and chemical properties of the experimental soil

Soil properties	Analytical value
Sand (%)	7.74
Silt (%)	76.88
Clay (%)	15.38
Texture	Silty loam
p ^H	8.4
Total nitrogen (%)	0.095
Available P (mg /100 g dry soil)	21.58
Exchangeable K (µg/100 g dry soil)	0.30
Mg (µg/100 g dry soil)	1.7
Ca (µg/100 g dry soil)	19.00
Organic matter (%)	1.33
Salinity (ds m ⁻¹)	1.71

Materials

Variety BARI mung 5 was used in this experiment. This is a high yielding variety released from Bangladesh Agricultural Research Institute (BARI).

Treatments

Factor A. Salinity levels

Saline water was prepared artificially by dissolving calculated amount of pure NaCl salt with tap water to make 75 mM NaCl solution. The salinity level was selected based on Raptan *et al.* (2001) and Kabir (2002).

Factor B. Nitrogen levels

Three levels of nitrogen were used in the experiment: of them, lower level (N₁), which was 33% of the recommended dose (0.15 g pot⁻¹), higher level (N₃), which was 200%

of the recommended dose (0.90 g pot^{-1}) and the recommended dose was 40 kg ha^{-1} (0.45 g pot^{-1}) and designated as N_2 . Phosphorus and potassium were applied at the rate of 60 and 40 kg ha^{-1} , respectively, for all the treatments.

Experimental Design

The design used in this experiment was completely randomized design (CRD). There are six treatment in the experiment and each treatment replicate four times so there are 24 pots in an experiment.

Pot filling with soil

Each plastic pot ($22\text{cm} \times 25\text{cm}$) was filled-up with 10 kg air-dried soil treated with 10% formalin solution. The respective amount of nutrients was incorporated with the soil before seed sowing. The compost was $1/3^{\text{rd}}$ of the soil by volume.

Seed sowing

Pre-soaked five bold seeds were sown in each pot on 8 April 2004. After sowing, the pots were watered for good germination.

Intercultural operations

Keeping two uniform and healthy plants in each pot, extra plants were uprooted at the 2nd trifoliate leaf stage. Weeding and other plant protection measures were done as and when necessary.

Treatment imposition

Tap water was used in all pots up to the seedlings emergence . After seedling establishment, tap water was applied in control pots and 25 mM NaCl solution was applied in salt-treatment-pots as first irrigation up to three days and 50 mM NaCl solution as 2nd irrigation for the next three days for hardening of seedlings before applying actual treatments. When the first trifoliate leaf appeared i.e. ten days after emergence the required amount of

salt solution was applied in 4 pots per treatment. Plants in control were irrigated with tap water. The salt solutions were applied till maturity.

Measurement of plant water status

Four mungbean plants from each treatment were carefully selected. Fully expanded third trifoliate leaf from the top was separated. After taking fresh weight the leaves were kept immersed in distilled water for one hour at room temperature in the dark. The turgid weights of the leaves were then measured. Afterwards all the leaves were oven-dried at 72°C for 48h to take dry weights. Finally the fresh, turgid and dry weights of the leaves were used to determine the following parameters:

$$\text{Relative Water Content (RWC)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

$$\text{Water Saturation Deficit (WSD)} = (100 - \text{RWC})$$

$$\text{Water Retention Capacity (WRC)} = \frac{\text{Turgid weight}}{\text{Dry weight}}$$

$$\text{Water Uptake Capacity (WUC)} = \frac{\text{Turgid weight} - \text{Fresh weight}}{\text{Dry weight}}$$

Dry matter accumulation

Plants were harvested at maturity. The plants were partitioned into leaf, stem, petiole and pod. Except pod the partitioned organs were oven dried at 72°C for 48 hours. Weight of individual components was taken to calculate relative growth of the individual plant parts. Pods were sun dried properly to adjust at 12% moisture content.

Yield and yield components

At the final harvest, data were recorded on the following parameters :

- 1) Leaves, stem, petiole and total dry matter weight
- 2) Pods per plant

- 3) Seeds per pod
- 4) 1000-grain weight, and
- 5) Grain yield per plant

Laboratory analysis of plant samples

Oven dried plant materials (leaves + stem + petiole + pod shell and grain) at final harvest were ground with a Willey grinding machine (cap/small 1029-8, Yoshida Seisakusho Co. Ltd.) for the estimation of different mineral ions.

Total N analysis

Estimation of total nitrogen from the sample of whole plant was done by colorimetric method following Linder (1944). Plant sample was digested in Kjeldahl digestion flask with salicylic sulfuric acid and digestion catalyst. After digestion, color of the solution was developed with four different reagents. Then absorbance of the solution was measured at 625 nm wavelength with Double Beam Spectrophotometer (Model 200-20).

Total P analysis

Total P was determined by nitric-perchloric acid digestion method as described by Yamakawa (1992). The absorbance was measured at 440 nm with Double Beam Spectrophotometer (Model 200-20).

Na and K analysis

Sodium and potassium were determined following Hitachi Ltd. (1986). Dry plant sample was digested with nitric-perchloric acid solution. After digestion the sample was diluted with distilled water. Then the absorbance of the respective ions was measured with atomic absorption spectrophotometer (Model 41170-30 Hitachi).

Statistical Analysis

The data recorded on different parameters were statistically analyzed by the help of "MSTAT-C" program. The differences between treatment means were compared by LSD (Least Significant Different) test at 5% level of significance after performing ANOVA.

RESULTS AND DISCUSSION

Water Relations

Relative Water Content

The relative water content (RWC) indicates the water content of plants. Salinity decreased the RWC in mungbean. RWC increased with the application of N from N_1 to N_3 levels both under control and saline conditions, although the increase was nonsignificant (Table 2). The highest RWC (91.82%) was depicted from N_3 applied under control condition and the lowest (81.01%) was under saline condition with N_1 . A positive relationship existed between RWC and N levels (Fig. 1. $R^2 = 0.9189$ at control and $R^2 = 0.8979$ at 75 ds m^{-1}). The decreased RWC under saline condition was reported in different crops viz. Sayed and Gadallah (2002) in sunflower; Serraj and Drevon (1998) in alfalfa; Nandwal *et al.* (2000) and Kabir (2002) in *Vigna radiata*. There is scarce information on the status of RWC due to N application under saline condition. The result of the study showed that application of N has some beneficial effect on water uptake, which was reflected with the higher RWC. But it is not clear that how increased amount of N influences on the uptake of higher amount of water both under saline and non-saline conditions.

Water Saturation Deficit

Water saturation deficit (WSD) indicates the degree of water deficit in plants. WSD was higher in saline condition than that of control in mungbean (Table 2). The lowest WSD (8.18%) was observed from N_3 applied under control condition and the highest (18.99%) was under saline condition with N_1 . A significant relationship existed between WSD and N levels (Fig. 2. $R^2 = 0.8979$ at control and $R^2 = 0.9189$ at 75 ds m^{-1}). Salinity increased the water saturation deficit of mungbean as reported by Kabir (2002). Therefore, higher levels of N exerted beneficial effect on plant water relation. Probably the better water status in the plant resulted due to a

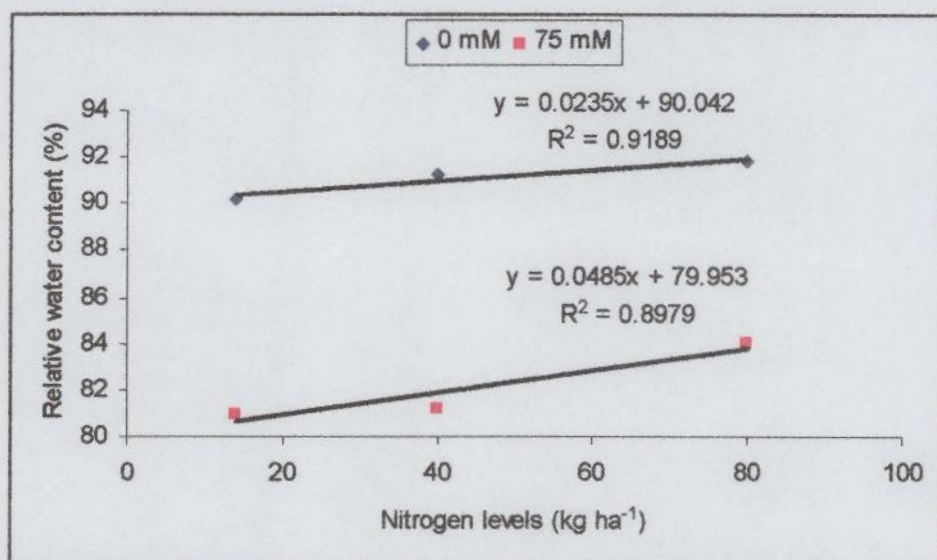


Fig. 1. Relationship between nitrogen levels and relative water conteny of mungbean under saline condition.

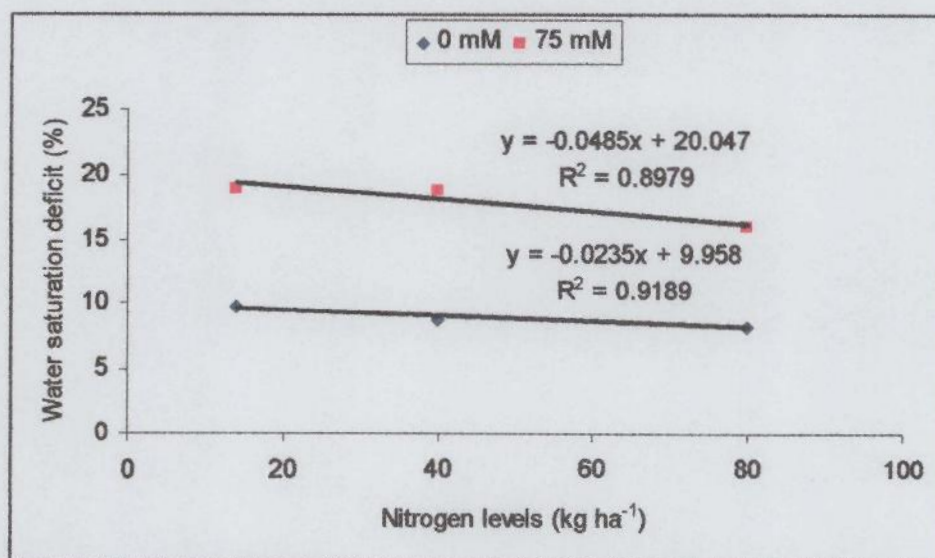


Fig. 2. Relationship between nitrogen levels and water saturation defisit of mungbean under saline condition.

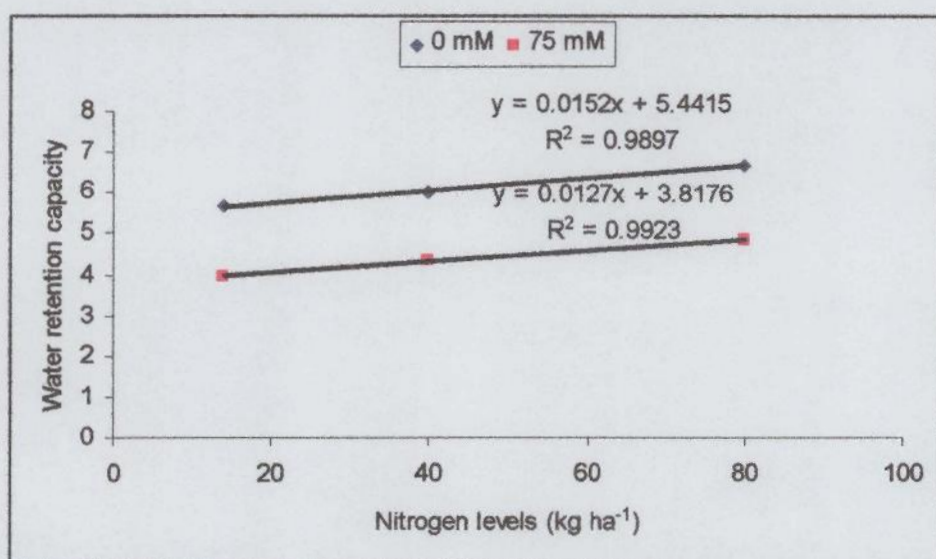


Fig.3. Relationship between nitrogen levels and water retention capacity of mungbean under saline condition.

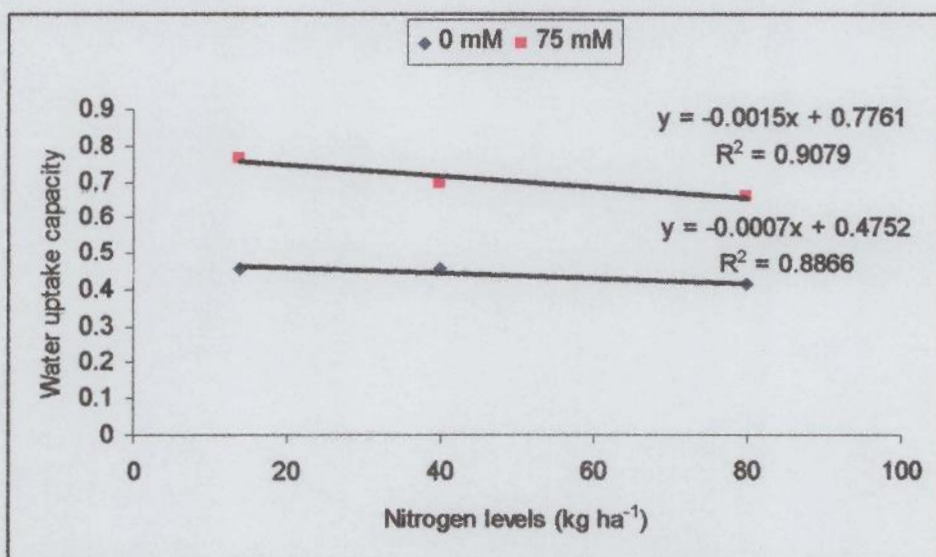


Fig. 4. Relationship between nitrogen levels and water uptake capacity of mungbean under saline condition.

Table 2. Effect of salinity and nitrogen levels on Relative Water Content, Water Saturation Deficit, Water Retention Capacity and Water Uptake Capacity of mungbean

Salinity levels (mM)	Nitrogen levels (kg ha ⁻¹)	Relative water content (%)	Water saturation deficit (%)	Water retention capacity	Water uptake capacity
0	14	90.21	9.79	5.69	0.459
	40	91.25	8.75	5.99	0.456
	80	91.82	8.18	6.68	0.413
75	14	81.01	18.99	3.97	0.766
	40	81.27	18.73	4.37	0.697
	80	84.08	15.92	4.82	0.662
LSD _(0.05)	-	NS	0.052	NS	NS
CV (%)	-	3.49	1.56	5.96	11.58

relatively better nodule dry weight, leghaemoglobin content of nodule and less ethylene production as reported by Nandwal *et al.* (2000).

Water Retention Capacity (TW: DW)

The turgid weight : dry weight (TW : DW) illustrates the water retention capacity of plants. Salt stress did not reduce the Water Retention Capacity (WRC) significantly compared to that of control. Application of nitrogen also increased this ratio insignificantly both in control and salt treated plants (Table 2). The highest ratio (6.68%) was observed from N₃ applied under control condition and the lowest (3.97%) was under saline condition with N₁. A positive relationship existed between WRC and N levels (Fig. 3. $R^2 = 0.9897$ at control and $R^2 = 0.9923$ at 75 ds m⁻¹). Under saline condition the highest ratio was observed at the highest level of N indicated the plants capacity to absorb moisture increased to some extent with the increased level of N application under salinity though it was non-significant. WRC increased with higher level of nitrogen fertilization in mungbean under saline condition also reported by Kabir (2002).

Water Uptake Capacity

The water uptake capacity (WUC) denotes the capacity of plants to absorb water per unit of dry weight in relation to turgid weight. A higher water uptake capacity indicates that plants are subjected to a greater degree of moisture stress as these plants would absorb a greater quantity of water to reach turgid weight (Sangakkara *et al.*, 1996). Salinity increased the water uptake capacity (WUC) insignificantly in mungbean plants. The WUC decreased gradually due to application of N (Table 2). The highest WUC (0.766) was depicted under saline condition with N₁ and the lowest (0.413) was observed under control condition with N₃ level. A significant relationship existed between WUC and N levels (Fig. 2. $R^2 = 0.9097$ at control and $R^2 = 0.8866$ at 75 ds m⁻¹). A higher WUC under saline condition means a plant is subjected to water stress to a

greater degree and addition of N in soil helped to maintain better water relation under both saline and non-saline condition. Similar result was found by Kabir (2002) in mungbean under saline condition.

Dry Matter Production in Different Plant Parts

Leaf Dry Weight

Salinity decreased the leaf dry weight of mungbean compared to that of control. Leaf dry weight increased with the application of N both under control and saline condition (Fig.5). Salinity reduced the leaf dry weight of mungbean reported by Ashraf and Rasul 1987 and Kabir, 2002. Highest leaf dry weight ($5.93 \text{ g plant}^{-1}$) was recorded under control condition at the highest level of nitrogen (N_3) and the lowest ($2.60 \text{ g plant}^{-1}$) in saline condition at N_1 level of nitrogen. Salinity induced reduction in leaf dry mass as observed in this study is in general agreement with the results obtained by Ashraf and Rasul (1987) in mungbean, Ram *et al.* (1989) in chickpea, Ashraf and Karim (1990).

Stem Dry Weight

Stem dry matter also decreased due to salinity. Stem dry matter showed increasing tendency with the increased application of N. Highest stem dry weight ($6.51 \text{ g plant}^{-1}$) was recorded under control condition at the highest level of nitrogen (N_3) and the lowest ($2.52 \text{ g plant}^{-1}$) in saline condition at N_1 level of nitrogen (Fig. 5). Reduction in stem dry weight under saline condition was also observed in mungbean by Maas and Hoffman (1977), Gill (1988) and Kabir (2002); Patil *et al.* (1996); in mungbean and blackgram by Raptan *et al.* (2001); in cowpea by Silverla *et al.* (1999); in cowpea and mungbean by Balasubramanian and Sinha (1976). Ali *et al.* (1998) showed that substantial increase in biomass production of leaves and shoots were observed with increasing rates of N in the saline media. Kabir (2002) also reported that N fertilization increased stem dry matter production under saline condition.

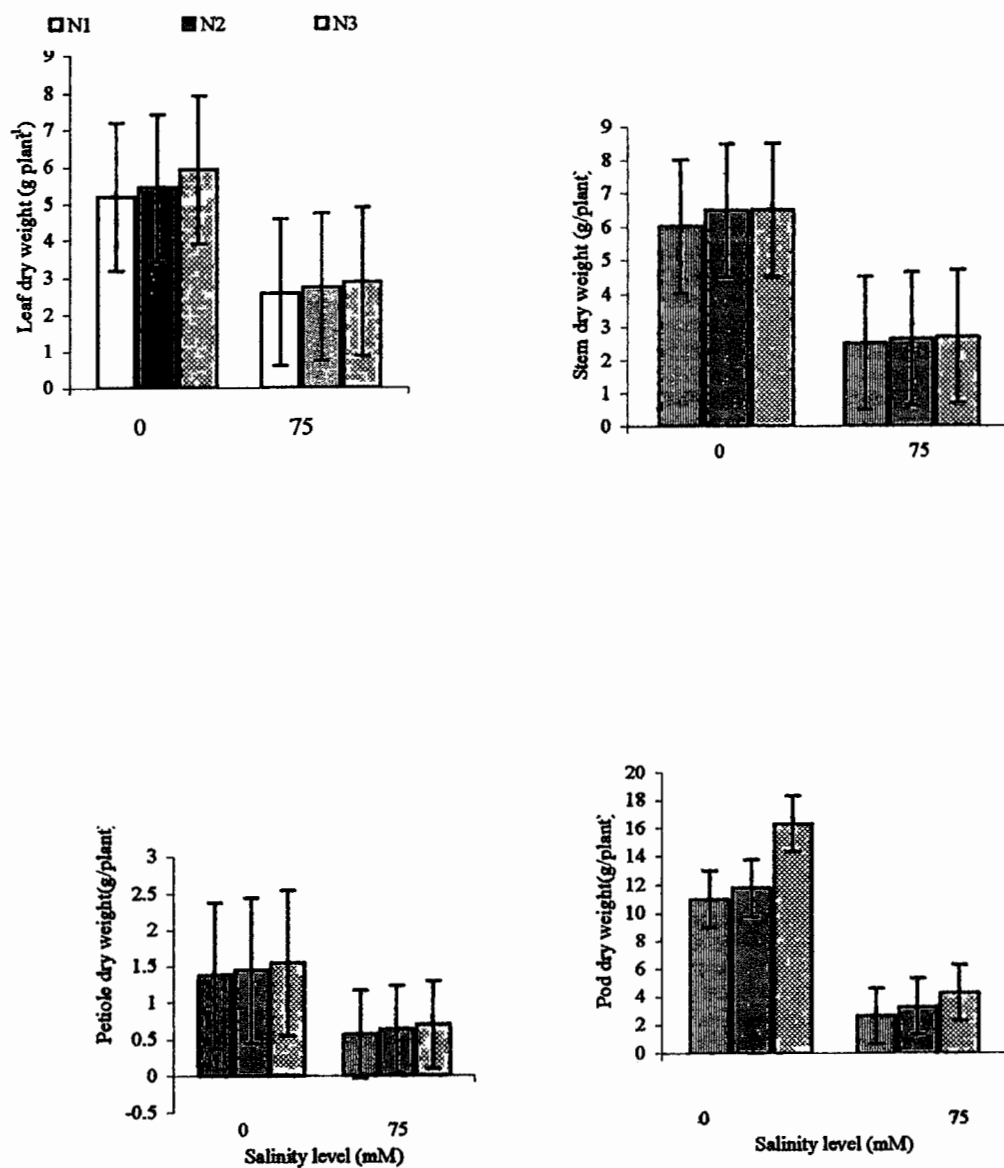


Fig. 5. Effect of salinity and nitrogen levels on Leaf dry weight, Stem dry weight, Petiole dry weight, Pod dry weight and Total dry weight of mungbean. Vertical bar indicate ($\pm$ SE). N₁, N₂, and N₃ = 14, 40 and 80 kg nitrogen ha⁻¹, respectively.

Petiole Dry Weight

Petiole dry weight decreased due to salinity. Application of nitrogen increased petiole dry matter under both control and saline condition (Fig. 5). The response was however statistically insignificant.

Pod Dry Weight

Salt stress decreased pod dry weight drastically. The pod dry weight increased significantly with the application of N both in the control and saline condition (Fig. 5). The highest pod dry weight (16.31 g) was found in the plants treated with highest amount of N (N_3) under control condition. Pod dry weight reduced under saline condition is also reported in blackgram and mungbean (Raptan *et al.*, 2001; Islam, 2001a) and in mungbean (Kabir, 2002). Perhaps, the physiological mechanisms associated to the photoassimilate partitioning were improved by N nutrition and helped to accumulate them in the pod of mungbean (Kabir, 2002).

Total Dry Matter

Salinity significantly reduced total dry matter (TDM) production in mungbean. TDM increased significantly due to increasing levels of N application both under control and saline condition (Fig. 6). Fauzia *et al.* (1988) found a 50-60% reduction of dry matter yield of *Vigna radiata* with 7.5 dS m⁻¹ salinity. Under saline condition high nitrogen played a positive role and interacted with all physiological mechanisms associated with growth and development of leaves, stems, reproductive organs, which finally contributed to increase total dry matter (Kabir, 2002). Mohanty *et al.* (1999) showed in rice that addition of nitrogen and phosphate fertilizers in various combinations worked as a remedial measure of the adverse effect of salinity. Reduction in growth and total dry matter production under saline condition was also reported for mungbean by Salim and Pitam, 1987; Duong *et al.* 1988; Gill, 1988; Patil *et al.*, 1992; Sing *et al.* 1994 and for mungbean and blackgram by Raptan *et al.*, 2001.

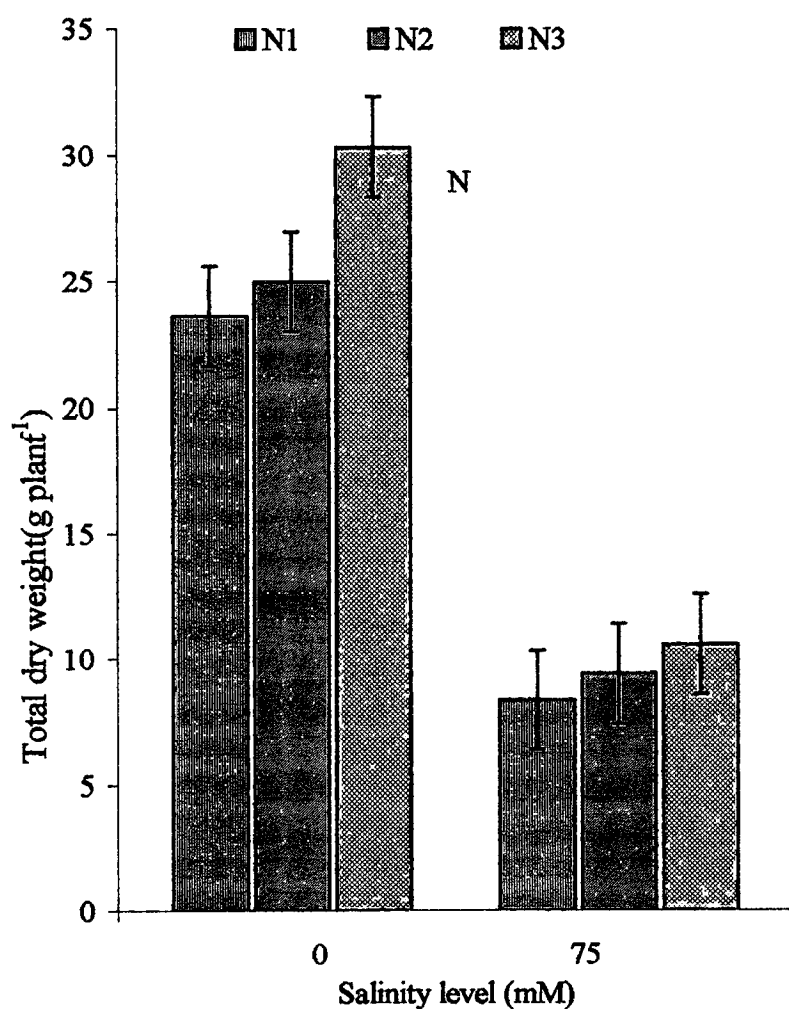


Fig. 6. Effect of salinity and nitrogen levels on total dry weight of mungbean. Vertical bars indicate ($\pm$ SE). N_1 , N_2 and N_3 = 14, 40 and 80 kg N ha⁻¹, respectively.

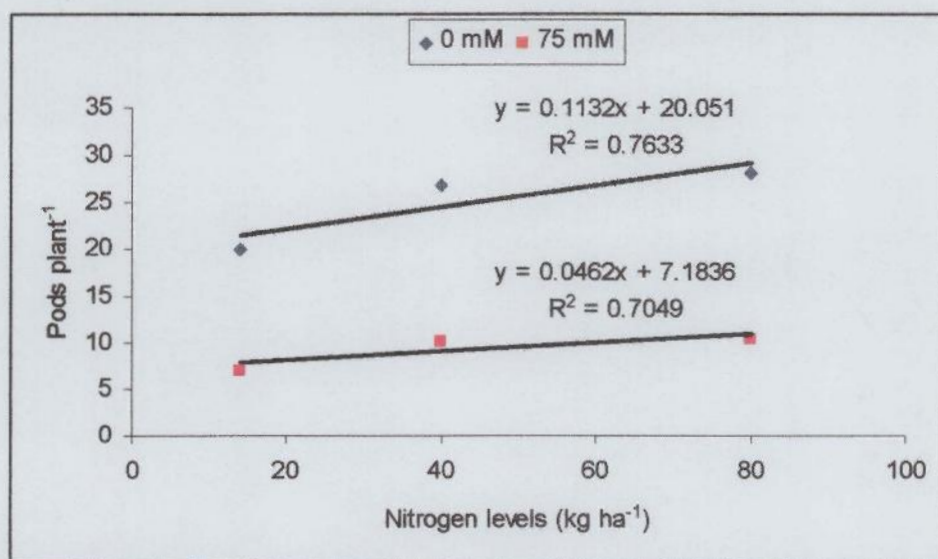


Fig. 7. Relationship between nitrogen levels and pods plant⁻¹ of mungbean under saline condition.

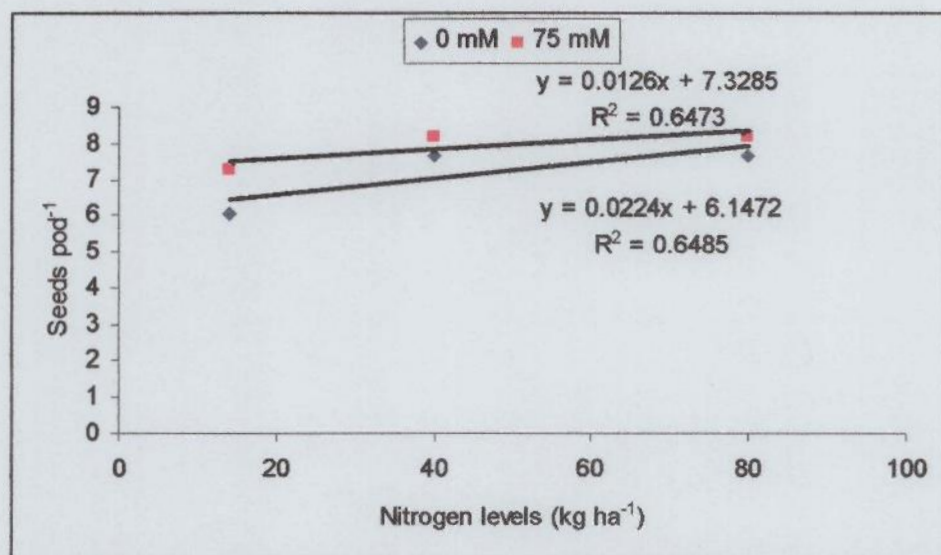


Fig. 8. Relationship between nitrogen levels and water seeds pods⁻¹ of mungbean under saline condition.

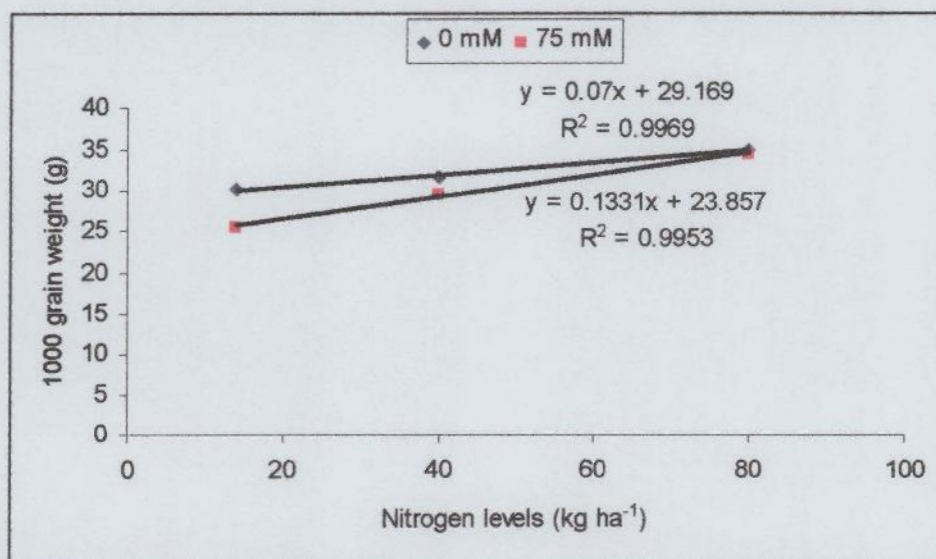


Fig. 9. Relationship between nitrogen levels and 1000 grain weight (g) of mungbean under saline condition.

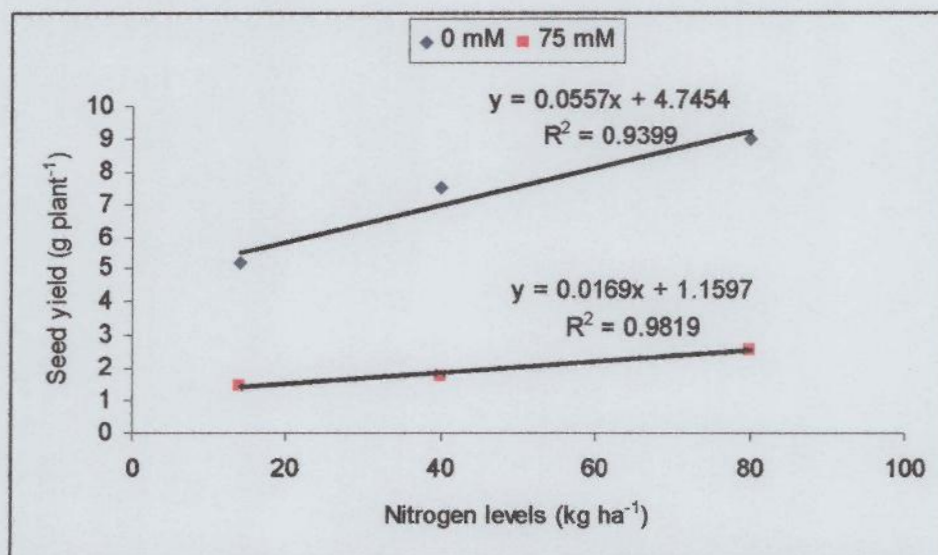


Fig. 10. Relationship between nitrogen levels and seed yield (g plant⁻¹) of mungbean under saline condition.

Table 3. Effect of salinity and nitrogen levels on pods plant⁻¹, seeds pod⁻¹, 1000-grain weight, seed yield of mungbean

Salinity levels (mM)	Nitrogen levels (Kg ha ⁻¹)	Pods plant ⁻¹	Seeds pod ⁻¹	1000-grain weight (g)	Seed yield (g plant ⁻¹)
0	14	20.18	6.08	30.24	5.20
	40	26.98	7.67	31.82	7.51
	80	28.16	7.69	34.83	8.99
75	14	7.14	7.29	25.51	1.45
	40	10.17	8.19	29.53	1.75
	80	10.43	8.20	34.37	2.55
LSD (0.05)	-	2.875	NS	2.099	0.796
CV (%)	-	8.23	7.01	4.55	8.54

and saline condition (Table 3). The maximum 1000-grain weight (34.83g) was observed from N₃ applied under control condition and the lowest (25.51g) was observed under saline condition with N₁. A significant relationship existed between 1000-grain weight and N levels (Fig. 9. $R^2 = 0.9969$ at control and $R^2 = 0.9953$ at 75 ds m⁻¹). According to Raptan *et al.* (2001) salinity slows down the mobilization of assimilates to the seeds that affect 1000-grain weight. A similar reduction in 1000-grain weight due to salinity was also reported by Malik *et al.* (1977) in pea, Lauter and Munns (1981) in chickpea and cowpea, Kabir (2002) in mungbean.

Seed Yield Plant⁻¹

The seed yield plant⁻¹ decreased significantly by salinity. Nitrogen application increased seed yield plant⁻¹ both in control and salt treated plant (Table 3). The maximum seed yield plant⁻¹ (8.99 g) was recorded under control condition with N₃ and the minimum (1.45 g) was recorded under saline condition with N₁. A significant relationship existed between seed yield plant⁻¹ and N levels (Fig. 10. $R^2 = 0.9399$ at control and $R^2 = 0.9819$ at 75 ds m⁻¹). Salinity induced reduction in seed yield was also reported by Singh *et al.* (1994), Hafeez *et al.* (1988), Salim and Pitam (1987), Duong *et al.* (1988) and Gill (1988) in *Vigna radiata*, Ram *et al.* (1989), Ashraf and Karim (1990), Kabir (2002). The higher seed yield plant⁻¹ due to application of N was due to higher number of seeds pod⁻¹ and greater seed size (Kabir 2002).

Effect on Uptake of Mineral Ions

Total Nitrogen

Salt stress decreased total nitrogen uptake significantly (Fig.11). Increased N fertilization enhanced the uptake of N insignificantly under both control and saline condition. Kabir (2002) also showed that increased nitrogen fertilization resulted in larger accumulation of total N in mungbean. Increasing N levels increased the pod production of *Hibiscus esculentus*, alleviating the adverse effect of salinity. Higher levels of N application

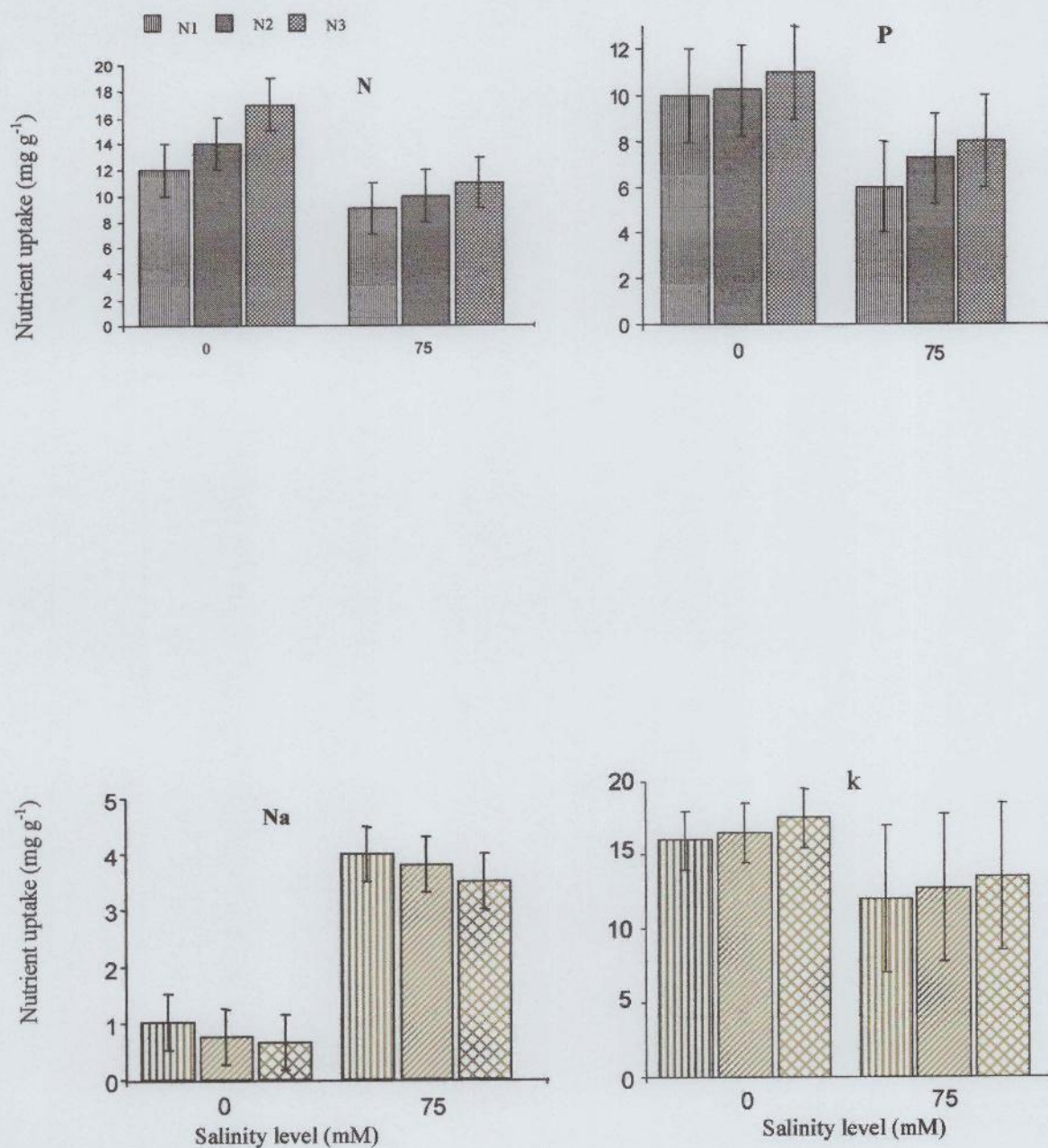


Fig. 11. Effect of N levels on uptake of different nutrients in mungbean under saline condition. Vertical bar indicate ($\pm$ SE). N₁, N₂, and N₃ = 14, 40 and 80 kg N ha⁻¹, respectively.

increased the contents and uptake of almost all nutrients (Singh, 1998). Reduction in total nitrogen due to salinity was also reported by a number of workers, viz. in chickpea (Ram *et al.*, 1989; Kumar and Promila, 1983), in mungbean (Hafeez *et al.*, 1998; Kabir, 2002; Patil *et al.*, 1995, Singh *et al.*, 1994), in blackgram (Paliwal and Maliwal, 1980), in pea (Lal and Bhardwaj, 1984), in cowpea and mungbean (Balasubramanian and Sinha, 1976), in mungbean, cowpea and soybean (Egeh and Zamora, 1992), in mungbean and blackgram (Raptan *et al.*, 2001).

Phosphorus

Salt stress decreased phosphorus uptake (Fig. 11). Increased level of nitrogen application increased P uptake significantly both in the control and salt treated plants. Salinity induced reduction in P was also reported by many workers. There is lack of information on the influence of N application on P uptake in mungbean but Khadrah *et al.* (1999) in wheat, Papadopoulos and Rending (1983) in tomato, Kumar *et al.* (1997) in wheat, Kabir (2002) in mungbean showed that increasing application of N increased P uptake under saline condition.

Potassium

Salinity decreased K uptake in mungbean plants (Fig. 11). The application of higher level of N showed an increasing tendency of K accumulation under both control and salt stressed condition. Raptan *et al.* (2001) and Islam (2001 a) reported that potassium deficiency occurred due to salinity in blackgram and mungbean. It was reported that high level of Na^+ can displace Ca^{2+} from root membranes, changing their integrity (Cramer *et al.*, 1985) and thus, affecting the selectivity for K^+ uptake (Kramer *et al.*, 1977). Although information on the influence of N application on K uptake is scarce for mungbean, Kabir (2002) showed in mungbean that increasing N rate increased K uptake under saline condition.

Sodium

Salinity increased the Na uptake in mungbean. Increasing levels of N application decreased the accumulation of Na at both control and saline treatments (Fig. 11). Therefore, N application might mitigate the harmful effect of Na⁺ in plant cell (Kabir 2002). Salinity induced uptake of excessive Na⁺ was reported by Nandwal *et al.* (2000) in *Vigna radiata* and Ullah *et al.* (1993) in faba bean, Raptan *et al.* (2001) in blackgram and mungbean. Although information on the influence of N application on Na uptake is scarce for mungbean, Kabir (2002) showed in mungbean that N application decreased Na content under saline condition. Leon *et al.* (1974) stated that increased fertilization sometimes advocated to alleviate growth inhibition by salinity, with some emphasis on potassium but with major attention to P and N. Increased levels of N, P, or both, appeared to increase the salt tolerance of millet (*Setaria* sp.) and clover (*Trifolium* sp.). Khalil *et al.* (1974) noted that fertilizing with N increased the sensitivity of corn and cotton (*Gossypium hirsutum* L.) to salinity and Ogo and Morikawi (1965) observed similar effects with rice (*Oryza sativa* L.) and wheat.

Experiment 2

INFLUENCE OF SALINITY AND PHOSPHORUS ON WATER RELATION, YIELD AND YIELD ATTRIBUTES OF MUNGBEAN (*Vigna radiata* (L.) Wilczek)

INTRODUCTION

Phosphorus plays a key role in different plant physiological processes. Phosphorus is an essential constituent of nucleoprotein, phospholipids, enzymes and other plant substances and it is needed for energy storage in and release from living cells. Phosphorus deficiency causes yield reduction by limiting plant growth (Poehlman, 1991). It influences nutrient uptake by promoting root growth, nodulation and specific nodule activity. Mungbean, a legume, responds favorably to P fertilization (Arya and Kalra, 1988).

Phosphorus is well known that salinity creates nutritional disorders and thus affects plant growth. However, literature on the role of external application of nutrients on crop salt tolerance are rather limited, though there is an indication that fertilizer application increases crop yield at mild level of salinity (Amer *et al.*, 1964; Luken, 1962; Lunin *et al.*, 1965). Irshad *et al.* (2002) reported that application of supra-optimal level of phosphate fertilizer increased salt tolerance in maize crop by increasing P uptake.

Lunin (1965) found that with a complete fertilizer (N, P, and K), though bean yields decrease with increasing salinity at all fertility levels, yields were much greater at a given salinity level at high fertility levels than that of low ones. Luken (1962) found that yield of wheat increased with increasing levels of P fertilization at low saline levels, but at very high saline levels the effect of P fertilization was negligible. Leon *et al.* (1974) stated that increased fertilization sometimes advocated to alleviate growth inhibition by salinity, with some emphasis on potassium but with major attention to P and N. Increased levels of N, P, or both, appeared to increase the salt tolerance of millet (*Setaria sp.*) and clover (*Trifolium sp.*). Contrary to this findings, reduction in salt tolerance with the elevated level of P application was also reported by many workers (Bernstein *et al.*, 1974; Cerda and Bingham, 1978).

Besides this controversy, information on the role of P on improving salt tolerance of mungbean is limited also. Hence, this study was undertaken to investigate the influence of P on growth, water relation, yield and mineral ion uptake in mungbean under saline conditions.

MATERIALS AND METHODS

The cultivation procedure, data collection and sample analysis of the crop used in this experiment have already been described in experiment 1.

Salinity levels

As described in experiment 1.

Phosphorus levels

Three levels of phosphorus were used in the experiment : lower level (P_1), which was 33% of the recommended dose i.e. 20 kg ha^{-1} (0.20 g pot^{-1}), higher level (P_3), which was 200% of the recommended dose i.e. 120 kg ha^{-1} (1.2 g pot^{-1}) and the recommended dose, 60 kg ha^{-1} (0.60 g pot^{-1}) and designated as P_2 . Nitrogen and potassium were applied at the rate of 40 kg and 40 kg ha^{-1} , respectively for all treatments.

RESULTS AND DISCUSSION

Relative Water Content (RWC)

Salinity decreased the RWC in mungbean (Table 4). The RWC increased insignificantly by the application of P. Though there was a positive relationship existed between RWC and P levels (Fig. 12. $R^2 = 0.6493$ at control and $R^2 = 0.9912$ at 75 ds m^{-1}). Reduction in RWC under saline condition was reported in different crops by many workers (Ghoulam *et al.*, 2002 in sugar beet; Sayed and Gadallah, 2002 in sunflower; Serraj and Drevo, 1998 in alfalfa, and Nandwal *et al.*, 2000 and Kabir, 2002 in mungbean). Kabir (2002) reported that under salt stress condition the application of different levels of P did not show any significant variation in RWC in mungbean plant.

Water Saturation Deficit

Water saturation deficit (WSD) increased by salinity in mungbean. The trend was just inverse of RWC. Salinity increased WSD at all levels of P (P_1 , P_2 and P_3) compared to those of corresponding levels of P under control condition. The WSD decreased significantly due to application of higher level of P (Table 4) and there was a significant relationship existed between WSD and P levels (Fig. 13. $R^2 = 0.9912$ at control and $R^2 = 0.6493$ at 75 ds m^{-1}). Similar result was also reported by Kabir (2002) in mungbean.

Water Retention Capacity (TW: DW)

The turgid weight: dry weight, termed as water retention capacity (WRC), illustrates the capacity of plant cell to retain water. WRC is determined by cell structure. Generally, salt stress decreased the ratio TW: DW. Application of P significantly increased WRC in saline condition (Table 4) though that was lower than that of control condition.

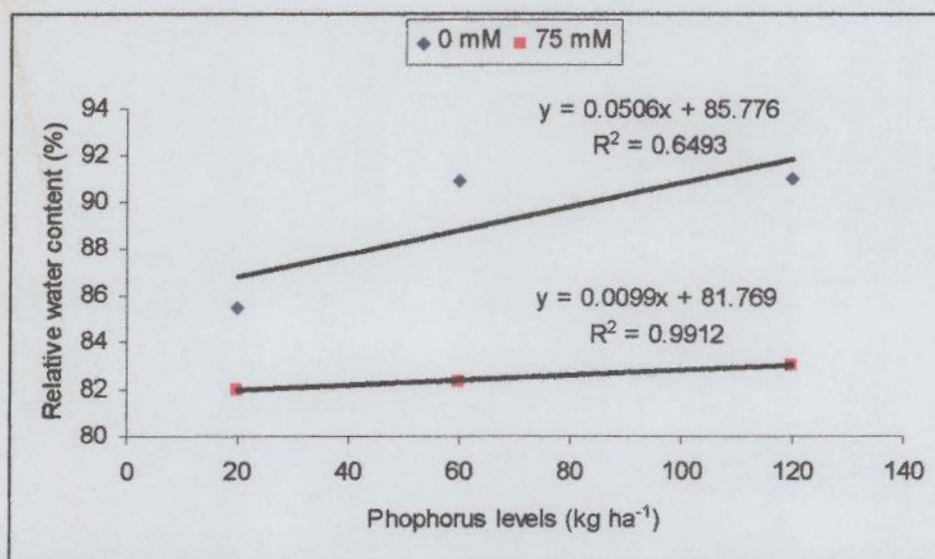


Fig.12. Relationship between phosphorus levels and relative water content of mungbean under saline condition.

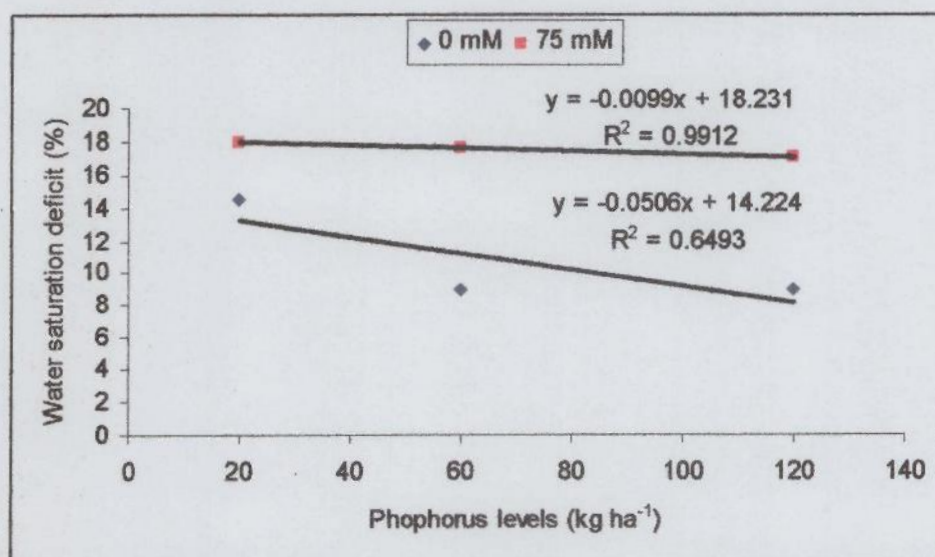


Fig. 13. Relationship between phosphorus levels and water saturation deficit of mungbean under saline condition.

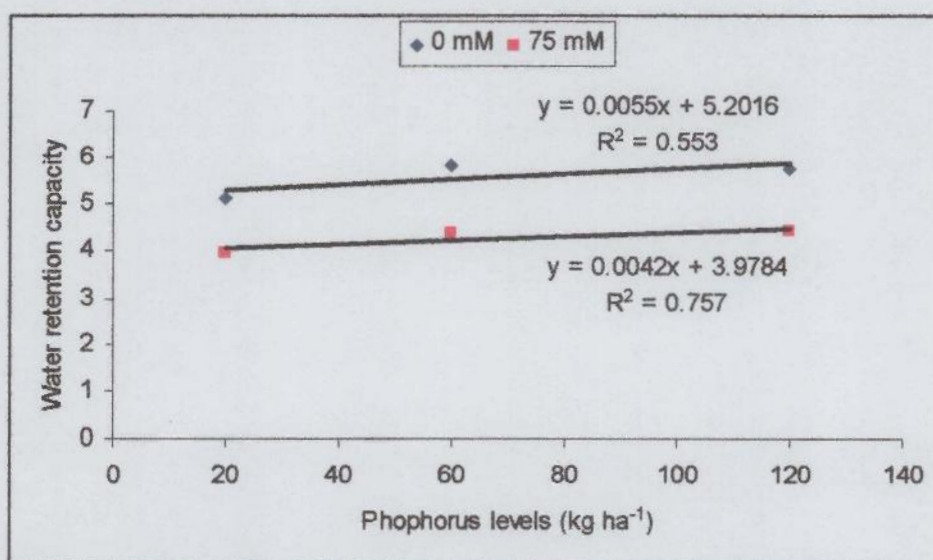


Fig. 14. Relationship between phosphorus levels and water retention capacity of mungbean under saline condition.

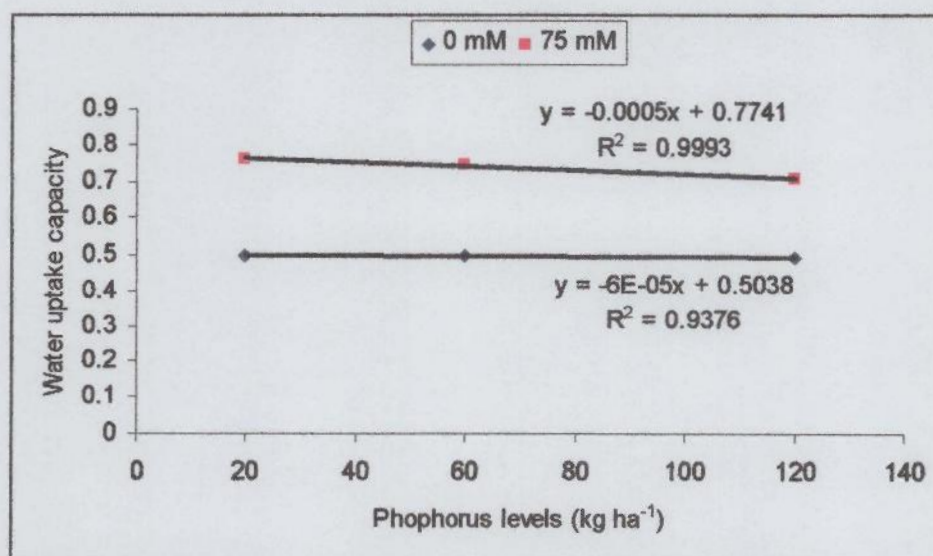


Fig. 15. Relationship between phosphorus levels and water uptake capacity of mungbean under saline condition.

Table 4: Effect of salinity and phosphorus levels on Relative Water Content, Water Saturation Deficit, Water Retention Capacity, Water Uptake Capacity of mungbean

Salinity levels (mM)	Phosphorus levels (kg ha ⁻¹)	Relative water content (%)	Water saturation deficit (%)	Water retention capacity	Water uptake capacity
0	20	85.50	14.5	5.14	0.502
	60	90.96	9.04	5.82	0.501
	120	90.99	9.01	5.75	0.496
75	20	82.00	18.00	3.98	0.763
	60	82.31	17.69	4.37	0.743
	120	82.98	17.02	4.43	0.710
LSD _(0.05)	-	NS	1.101	0.091	NS
CV (%)	-	2.88	1.14	0.96	10.76



There was a significant positive relationship existed between WRC and P levels (Fig. 14. $R^2 = 0.553$ at control and $R^2 = 0.757$ at 75 ds m^{-1}). The reduction in WRC (% to the control) indicates damages in cell structure due to water stress (Sangakkara *et al.*, 1996; Islam, 2001 b).

Water Uptake Capacity

The water uptake capacity (WUC) quantifies the ability of a plant to absorb water per unit dry weight in relation to turgid weight. A higher water uptake capacity under saline condition means a plant is subjected to water stress at a greater degree, because the plant would absorb more water to reach turgidity than a plant under control condition (Islam, 2001 b). Salinity in general increased the water uptake capacity. P fertilization decreased WUC under both control and saline condition. Though it was statistically insignificant (Table 4) but there was a negative relationship existed between WUC and P levels (Fig. 15. $R^2 = 0.9993$ at control and $R^2 = 0.9376$ at 75 ds m^{-1}).

Dry Matter Production

Leaf Dry Matter

Salinity decreased the leaf dry weight. Leaf dry matter production showed an increasing tendency by the application of P under both saline and control conditions. Although it was statistically nonsignificant (Fig. 15). Salinity induced reduction in leaf dry weight was observed by many workers in different crops, e.g. Ashraf and Rasul (1987) and Kabir (2002) in mungbean; Ram *et al.* (1989) in chickpea. Ashraf and Karim (1990), Raptan *et al.* (2001) and Islam (2001a) in mungbean and blackgram. Kabir (2002) observed in mungbean that leaf dry weight increased with increasing P-fertilization under saline condition.

Stem Dry Weight

Salinity also decreased the stem dry weight drastically. Levels of P insignificantly increased the stem dry weight both under saline and control condition (Fig 15). Salinity induced reduction in stem dry matter was reported earlier by many workers

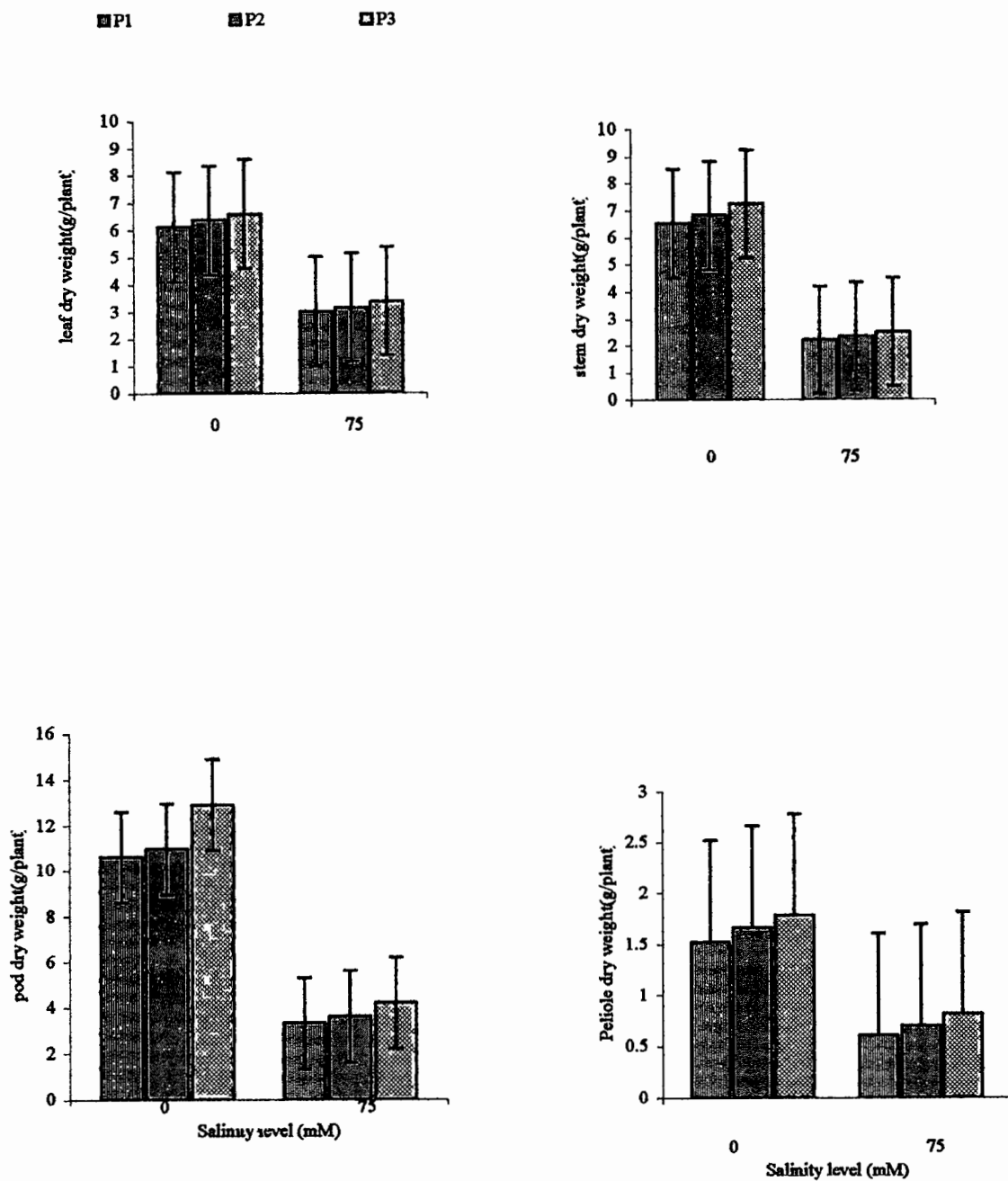


Fig. 16. Effect of salinity and phosphorus levels on leaf dry weight, stem dry weight, petiole dry weight and pod dry weight of mungbean.

(Gill, 1988 and Kabir, 2002 in mungbean; Patil *et al.*, 1996 in green gram; Raptan *et al.*, 2001 in mungbean and blackgram; Silveria *et al.*, 1999 in cowpea; Balasubramanian and Sinha, 1976 in cowpea and mungbean). P-fertilization increased stem dry matter in common bean under saline condition (Zeiter and Saade, 1993).

Petiole Dry Weight

Salt stress sharply decreased petiole dry weight (Fig.15). Increase in P fertilizer did not show any significant effect on petiole dry weight under control and saline conditions. Salinity decreased both leaf and stem dry matter and consequently reduced petiole dry matter. P-fertilization increased petiole dry matter in mungbean under saline condition also stated by Kabir (2002).

Pod Dry Weight

Salinity exerted very strong influence on pod dry weight. Pod dry weight under saline condition was about one-third of the control treatments (Fig. 15). Application of increasing levels of P increased insignificantly the pod dry weight in saline condition. Decreased pod dry weight under saline condition was reported by many workers (Raptan *et al.*, 2001; Islam, 2001a). Kabir (2002) showed in mungbean that pod dry weight increased with increasing P- fertilization under saline condition.

Total Dry Matter

Total dry matter (TDM) weight of mungbean plant decreased severely by salinity (Fig. 17). The level of P had no influence on TDM irrespective of levels of salinity. Fauzia *et al.* (1988) showed that *V. radiata* treated with salinity 7.5 dS m⁻¹ produced only 50-60% total dry matter compared to that of control plant. Salinity induced reduction in TDM was reported by many workers in different crops (Salim and Pitam, 1987 ; Duong *et al.*, 1988; Singh *et al.*, 1994 in mungbean and Gill, 1988 in mungbean; Egeh and Zamora, 1992 in mungbean and cowpea; Hug *et al.*, 1983 in cowpea and mungbean. Zeiter and Saade, (1993) showed in tepary and common bean cultivars that a significant increase in shoot and root growth and reduction in foliar injury with increased P application. Mohanty *et al.* (1999) showed that dry matter production of rice, which was reduced due to salinity,

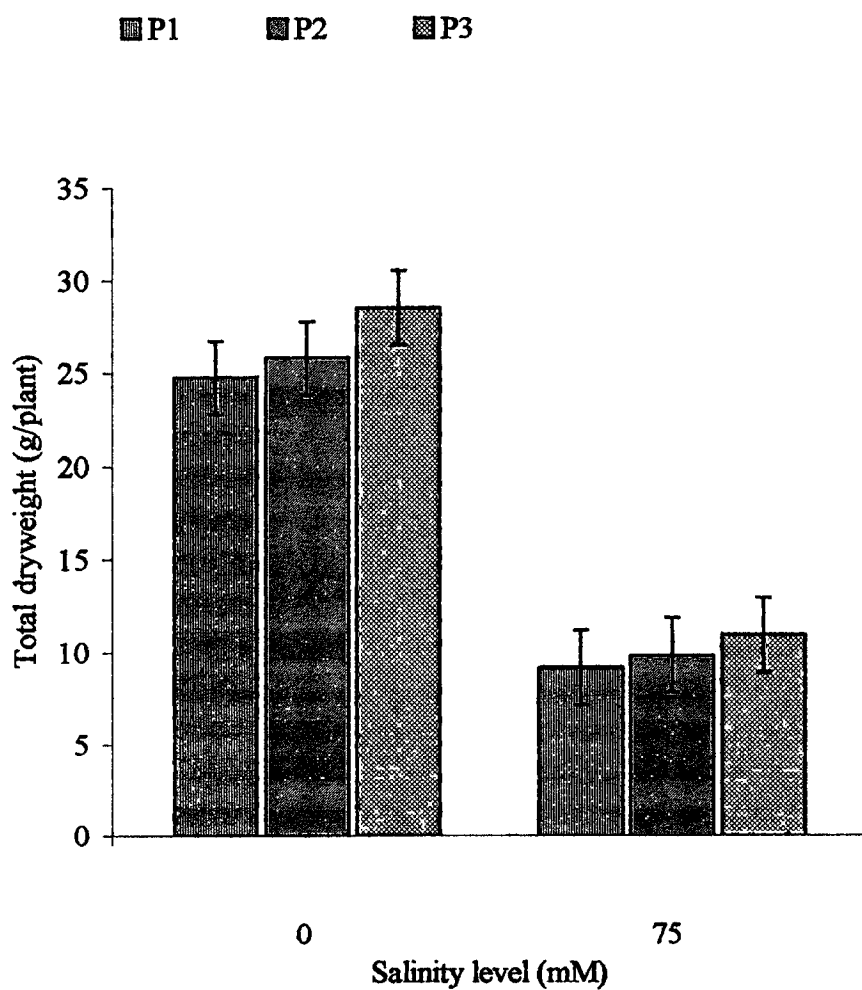


Fig. 17. Effect of salinity and phosphorus levels on total dry weight of mungbean. Vertical bar indicate ($\pm$ SE). P₁, P₂, and P₃ = 20, 60 and 120 kg P ha⁻¹, respectively

increased significantly by increased application of phosphorus. The dry matter production in different organs in salt affect mungbean plants showed an increasing tendency with the increasing of level of P fertilization (Kabir, 2002).

Yield and Yield Attributes

Pods Plant⁻¹

Salinity decreased the pod set per plant severely. The lowest number of pods (8.50) was counted when 7.5 dS m⁻¹ salinity was applied with P₁, and the highest (32.85) was counted under control condition with P₃ (Table 5). Application of increased level of P increased the pod set plant⁻¹ both saline and control condition. There was a significant positive relationship existed between pod plant⁻¹ and P levels (Fig. 18. R² = 0.999 at control and R² = 0.8029 at 75 ds m⁻¹). Kabir (2002) reported in mungbean that phosphorus fertilization increases pod set per plant under saline condition. Increased number and weight of pods per plant with the enhanced level of P application was shown by many workers for different crops under control condition (Dhage *et al.*, 1984 in blackgram; Samiullah *et al.*, 1981, Arya and Karla, 1988; Ahmed *et al.*, 1984 in mungbean; Ferdous, 2001 in pea; Ahlawat, 1996 in frenchbean; Phookan and Shadeque, 1994 in pea). Reduction in pods per plant under saline condition was also reported earlier (Raptan *et al.*, 2001 in mungbean and blackgram; Hafeez *et al.*, 1998 and Patil *et al.*, 1996 in *Vigna* spp.).

Seeds Pod⁻¹

The number of seeds per pod showed an increasing tendency with the increasing levels of P (Table 5) and there was a positive relationship existed between seeds pod⁻¹ and P levels (Fig. 19. R² = 0.7125 at control and R² = 0.7622 at 75 ds m⁻¹). A number of workers reported that salinity reduced the number of seeds per pod (Islam, 2001a; Raptan *et al.*, 2001 in blackgram and mungbean; Ram *et al.*, 1989 in chickpea; Patil *et al.*, 1996 in greengram; Hafeez *et al.*, 1998 and Kabir, 2002 in mungbean).

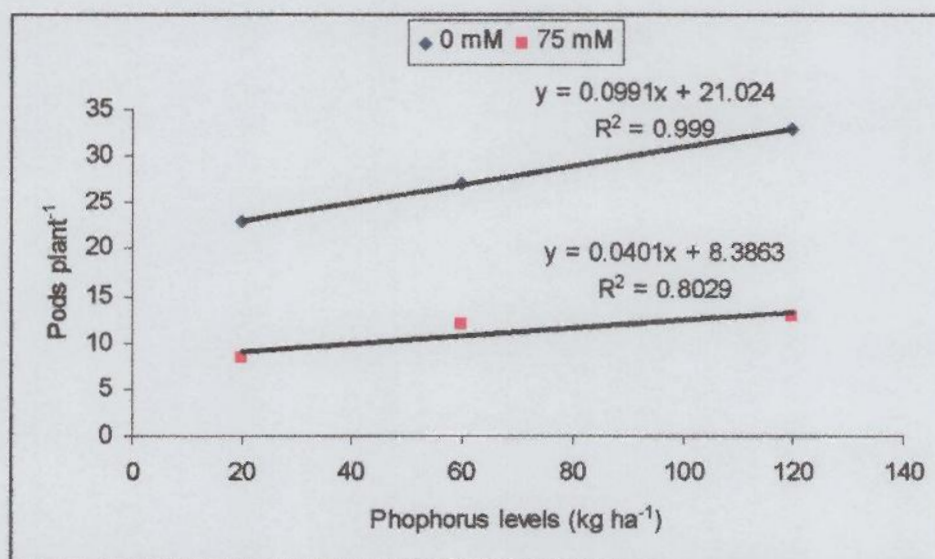


Fig. 18. Relationship between phosphorus levels and pods plant⁻¹ of mungbean under saline condition.

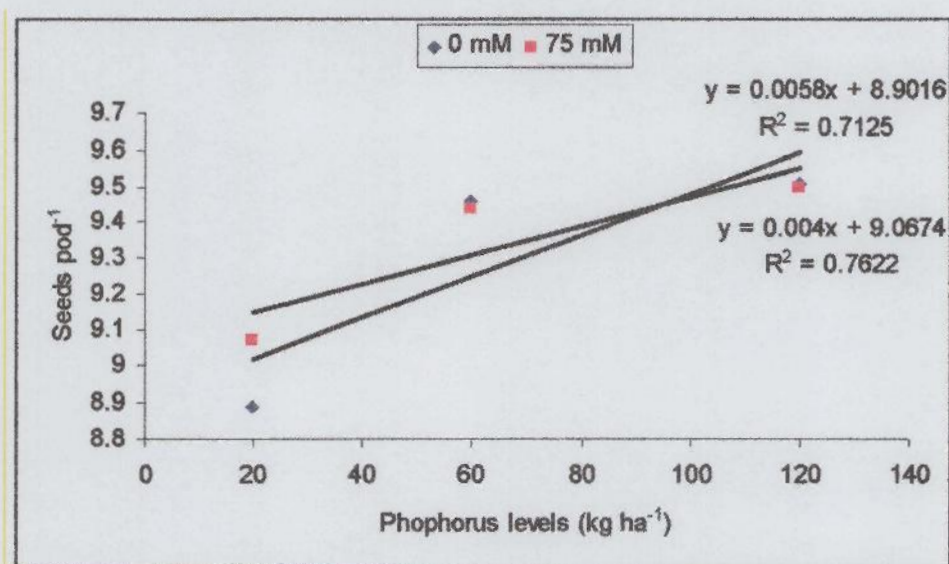


Fig. 19. Relationship between phosphorus levels and seeds pods⁻¹ of mungbean under saline condition.

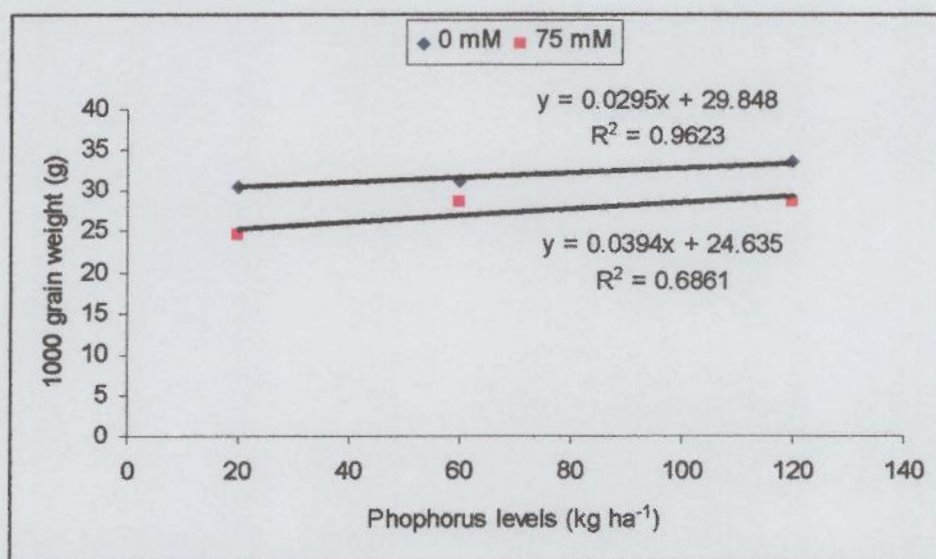


Fig. 20. Relationship between phosphorus levels and 1000 grain weight (g) of mungbean under saline condition.

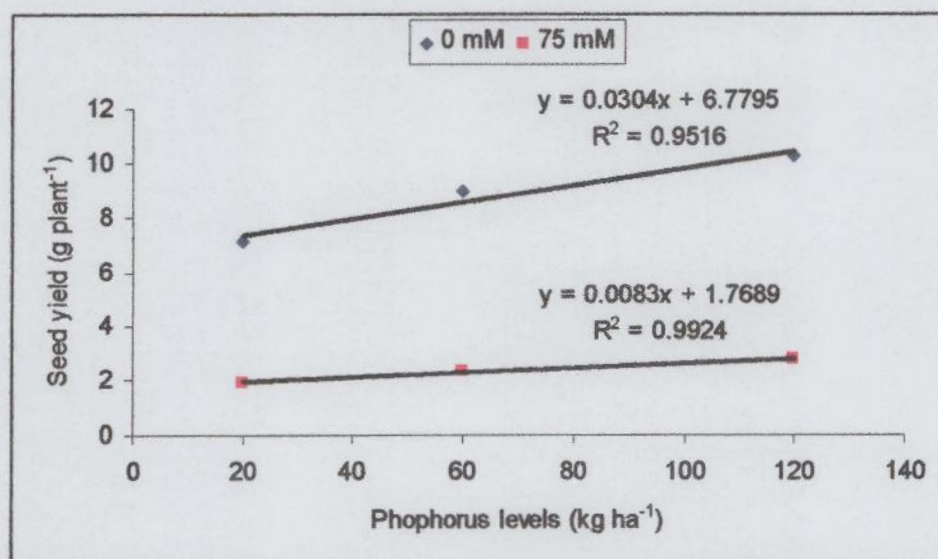


Fig. 21. Relationship between phosphorus levels and seed yield (g plant⁻¹) of mungbean under saline condition.

Table 5: Effect of salinity and phosphorus levels on pods plant⁻¹, seeds pod⁻¹, 1000-grain weight, seed yield of mungbean

Salinity levels (mM)	Phosphorus levels (kg ha ⁻¹)	Pods plant ⁻¹	Seeds pod ⁻¹	1000-grain weight (g)	Seed yield (g plant ⁻¹)
0	20	22.90	8.89	30.64	7.15
	60	27.15	9.46	31.28	9.00
	120	32.85	9.51	33.52	10.27
75	20	8.50	9.07	24.50	1.91
	60	11.94	9.44	28.54	2.31
	120	12.74	9.50	28.75	2.75
LSD _(0.05)	-	2.714	NS	NS	1.349
CV (%)	-	6.89	7.06	5.17	11.92

1000-Grain Weight

Salinity decreased the 1000-grain weight. Application of higher levels of P increased the 1000-grain weight at both saline and non-saline condition, although it was nonsignificant (Table 5). Though there was a positive relationship existed between 1000-grain weight and P levels (Fig.20. $R^2 = 0.9623$ at control and $R^2 = 0.6861$ at 75 ds m^{-1}).

Seed Yield Plant⁻¹

Seed yield plant⁻¹ decreased seriously by salt stress. The highest seed yield (10.27 g) was observed under control condition with P_3 and the lowest (1.91 g) was found under saline condition with P_1 level of phosphorus (Table 5). A positive Significant relationship existed between Seed yield plant⁻¹ and P levels (Fig.21. $R^2 = 0.9516$ at control and $R^2 = 0.9924$ at 75 ds m^{-1}). Salinity induced reduction in seed yield was observed by many workers, such as in mungbean by Singh *et al.* (1994), Hafeez *et al.* (1988), Salim and Pitam (1987), Duong *et al.* (1988) and Gill (1988); in chick pea by Hye (2000) and Ram *et al.* (1989); in blackgram by Ashraf and Karim (1990). Application of increased level of P increased seed yield per plant under saline condition in mungbean (Kabir, 2002). Although information on the influence of P on mungbean grain yield is scarce. Zeiter and Saade, (1993) showed in tepary and commom bean cultivars that a significant increase in shoot and root growth and reduction in foliar injury with increased P application. Reduction of turgor pressure due to osmotic shock might be the major cause of growth reduction as well as the accumulation of toxic levels of P in the plant tissue (Roberts *et al.*, 1984). Salt induced P-toxicity in a plant may be the result of poor growth and consequent accumulation of high P in the shoot cytoplasm. The effect of external P concentration exceeding the optimum under saline conditions may be the enhancement of P_i (P_i = inorganic phosphate) uptake and a resultant increased concentration of P_i in the cytoplasm of the shoot becoming toxic for growth and yield (Roberts *et al.*, 1984).

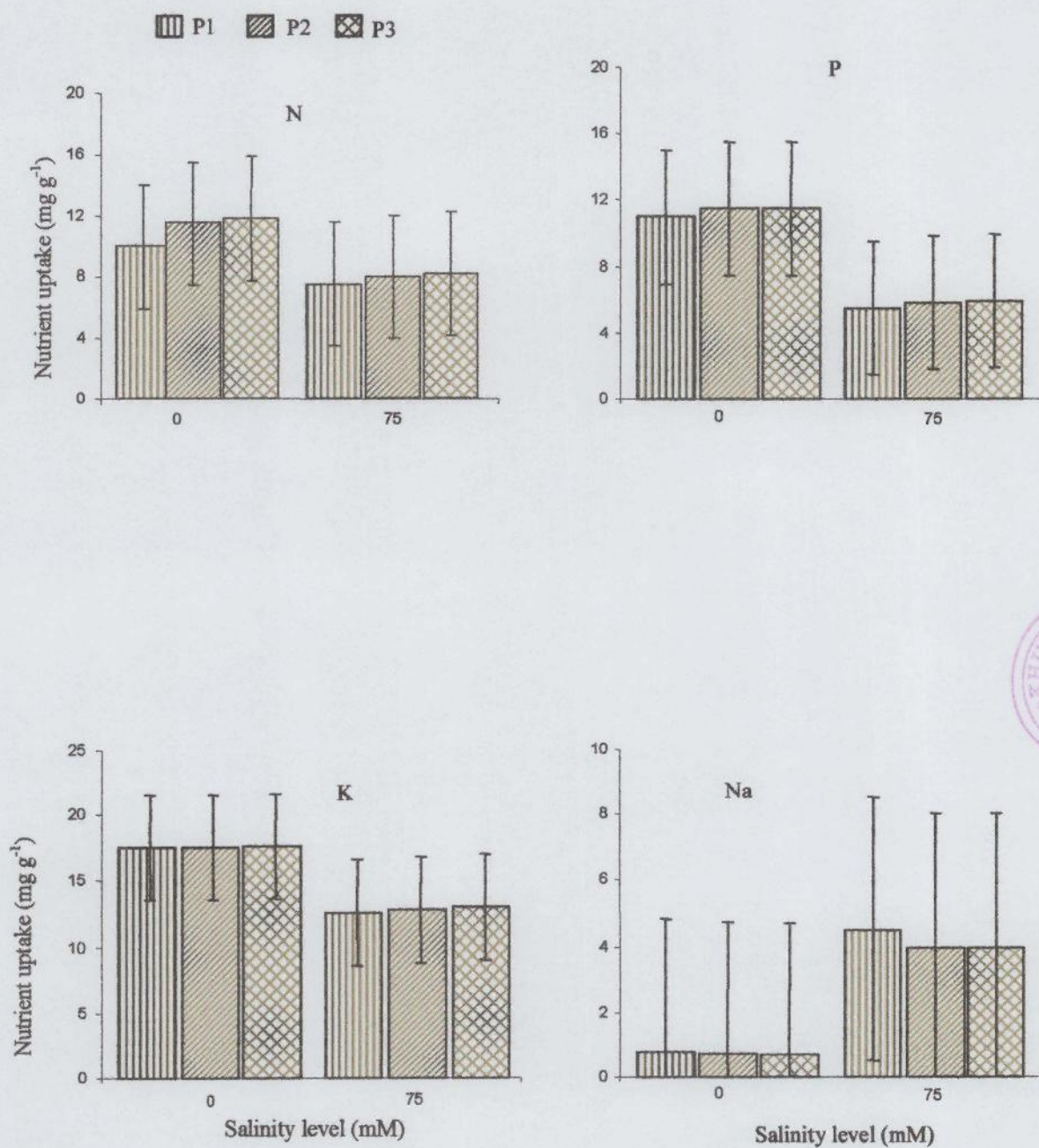


Fig. 22. Effect of P levels on uptake of different nutrients in mungbean under saline condition. Vertical bars indicate ($\pm$ SE). P₁, P₂, and P₃ = 20, 60 and 120 kg P ha⁻¹, respectively.

Effect on Uptake of Mineral Ions

Total Nitrogen

Salinity decreased the total N uptake in mungbean plants (Fig. 22). Higher levels of P increased the uptake of N insignificantly. Salinity induced reduction in total N uptake was reported earlier in chickpea (Ram *et al.* 1989; Kumar and Promila, 1983), in mungbean (Hafeez *et al.*, 1998; Patil *et al.*, 1995, Singh *et al.*, 1994), in blackgram (Paliwal and Maliwal, 1980), in pea (Lal and Bhardwaj, 1984), in cowpea and mungbean (Balasubramanian and Sinha, 1976), in mungbean, cowpea and soybean (Egeh and Zamora, 1992). Kabir (2002) showed that increased amount of P fertilizer increased total N uptake in the mungbean plant at 7.5 dS m⁻¹ level of salinity.

Phosphorus

Salt stress decreased P uptake. It was 50% lower than that of control (Fig. 22). Application of increased level of P did not affect P uptake both under control and saline condition. Chhabra *et al.* (1980) showed that the available phosphorus sharply decreases with depth in salt affected soils. Kabir (2002) reported that in saline condition P uptake increased by higher level of P fertilization.

Potassium

K uptake decreased due to salinity. Application of higher level of P increased K uptake nonsignificantly (Fig. 22). Raptan *et al.* (2001) and Islam (2001a) reported in mungbean and blackgram that K⁺ uptake decreased due to salinity. Kabir (2002) reported that in saline condition K uptake increased by higher level of P fertilization.

Sodium

Salinity increased the uptake of sodium (Fig. 22). Na content in mungbean showed decreasing tendency with increasing P fertilizer under saline condition though there was no significant difference between P₂ and P₃ levels. Earlier reports also indicated the increased uptake of Na in different crops due to salinity, eg. Nandwal *et al.* (2000) in *Vigna radiata*, and Ullah *et al.* (1993) in faba bean.

SUMMARY AND CONCLUSION

Two separate experiments were conducted at the experimental site of Forestry and Wood Technology (FWT) Discipline at the Khulna University, Khulna during April to June 2004 to evaluate the role of nitrogen and phosphorus on growth, plant water status, mineral nutrient uptake and yield of mungbean under saline condition. In both experiments BARI mung 5 was grown in 10 L pot under 0 and 7.5 dS m⁻¹ NaCl salinity. The design used in this experiment was Completely Randomized Design (CRD) with two factors.

In the first experiment, three levels of nitrogen, viz. 14, 40 and 80 kg ha⁻¹ respectively, were applied under both 0 and 7.5 dS m⁻¹ saline condition. NaCl affected plant water status, all the morphological characters, yield and yield attributes of mungbean plants. Application of N fertilizer at higher doses improved some of the plant characters. Salt stress decreased RWC, WRC and increased WSD and WUC. N fertilizer increased RWC, WRC while decreased WSD and WUC under both for control and saline condition. But the combined effect of salinity and nitrogen levels on RWC, WSD, WRC and WUC of mungbean were nonsignificant.

Salinity affected dry matter distribution in all plant parts viz. leaf, stem, petiole, pod and total dry matter significantly. Application of N fertilizer at higher doses did not improve the dry weight of leaf, stem, petiole, but there were increasing trends in these parameters. The yield and yield contributing characters viz. pods plant⁻¹, seeds pod⁻¹, 1000-grain weight and seed yield plant⁻¹ decreased due to salinity. N fertilizer exerted significant effect on yield and yield attributes except the seeds pod⁻¹. Under saline condition seed yield was very low (2.55 g plant⁻¹ at higher nitrogen level) compared to that of control (8.99 g plant⁻¹ at higher nitrogen level).

Salinity decreased N, P and K uptake and increased Na uptake. With the increasing levels of N, the uptake of N, P and K increased and Na content decreased, but these change were non-significant among the different levels of N.

In the second experiment, three levels of phosphorus viz. 20, 60 and 90 kg ha⁻¹ respectively, were applied under both 0 and 7.5 dS m⁻¹ NaCl saline condition. Salt stress decreased RWC, WRC and increased WSD and WUC. P fertilizer did not affect significantly in RWC and WUC but increase of WSD and decrease in RWC was significant.

Dry matter production in all plant parts decreased due to salinity. Application of P fertilizer at higher doses improved dry matter production though it was nonsignificant. The yield and yield contributing characters decreased due to salinity. P fertilizer increased yield

and yield attributes significantly except the seeds pod-1 and 1000-grain weight. The uptake of N, P and K decreased and Na uptake increased due to salinity. Application of increasing levels of P there were no significant effect on the uptaking of mineral nutrients except Na. Na uptake decreased significantly after P application.

From this study, it may be concluded that yield and yield attributes of mungbean increased with the increase of N and P fertilizer levels. Irrigation with saline water decreased the yield and yield attributes of mungbean. Yield improvement of mungbean under saline condition through higher level of fertilization may be possible with further detailed studies. For this, a number of field experiments are necessary to assess the combined effect of fertilizers and salinity on yield and yield attributes of mungbean.

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APPENDICES

Appendix 1: Mean weather condition during the experimental period (April 2004-July 2004)
at Khulna University, Khulna, Bangladesh

Months	Air temperature ($^{\circ}$ C)		Relative humidity (%)		Rainfall (mm)
	Max	Min	Max	Min	
April	33.9	25.0	97.5	35.0	85
May	35.8	26.2	98.0	49.6	180
June	32.2	26.2	96.3	62.5	383
July	32.1	26.4	97.7	65.0	252

Appendix 2: Mean Sum of Square (MSS) of relative water content, water saturation deficit, water retention capacity, water uptake capacity as affected by salinity and nitrogen levels

Source of variation	Degree of freedom (df)	Mean sum of Square (MSS)			
		Relative water content (RWC)	Water saturation deficit (WSD)	Water retention capacity (WRC)	Water uptake capacity (WUC)
Nitrogen (A)	2	11.686	11.570 ^{**}	1.734 ^{**}	0.011
Salinity (B)	1	483.214 ^{**}	483.124 ^{**}	17.957 ^{**}	0.423 ^{**}
A×B	2	2.580 ^{NS}	2.579 ^{**}	0.028 ^{NS}	0.003 ^{NS}
Error	18	9.123	0.006	0.098	0.004
Total	23				
CV (%)	-	3.49	1.57	5.96	11.58

^{**} indicates significant at 1% level

^{*} indicates significant at 5% level

CV : Coefficient of variation

Appendix 3: Mean Sum of Square (MSS) of relative water content, water saturation deficit, water retention capacity, water uptake capacity as affected by salinity and phosphorus levels

Source of variation	Degree of freedom (df)	Mean sum of Square (MSS)			
		Relative water content (RWC)	Water saturation deficit (WSD)	Water retention capacity (WRC)	Water uptake capacity (WUC)
Nitrogen (A)	2	25.215*	24.478**	0.756**	0.002 ^{NS}
Salinity (B)	1	270.950**	275.201**	10.323**	0.341**
A×B	2	15.757 ^{NS}	16.180**	0.043**	0.001 ^{NS}
Error	18	6.121	0.026	0.002	0.004
Total	23				
CV (%)	-	2.88	1.14	0.96	10.76

** indicates significant at 1% level

* indicates significant at 5% level

CV: Coefficient of variation

Appendix 4: Mean Sum of Square (MSS) of pods per plant, 1000 grain weight and seed yield per plant as affected by salinity and nitrogen levels

Source of variation	Degree of freedom (df)	Mean sum of Square (MSS)		
		Pods per plant	1000 grain weight	Seed yield per plant
Nitrogen (A)	2	4.184**	89.031**	10.574**
Salinity (B)	1	3.345**	39.117**	169.538**
A×B	2	0.322 ^{NS}	10.005*	5.292**
Error	18	0.278	1.998	0.153
Total	23			
CV (%)	-	7.01	4.55	8.54

** indicates significant at 1% level

* indicates significant at 5% level

CV: Coefficient of variation

Appendix 5: Mean Sum of Square (MSS) of pods per plant, 1000 grain weight and seed yield per plant as affected by salinity and phosphorus levels

Source of variation	Degree of freedom (df)	Mean sum of Square (MSS)		
		Pods per plant	1000 grain weight	Seed yield per plant
Phosphorus (A)	2	100.914**	26.215**	7.889**
Salinity (B)	1	1664.052**	124.124**	252.202**
A×B	2	19.090**	5.850 ^{NS}	2.663*
Error	18	1.778	2.333	0.440
Total	23			
CV (%)	-	6.89	5.17	11.92

** indicates significant at 1% level

* indicates significant at 5% level

CV: Coefficient of variation



Appendix 6: Mean Sum of Square (MSS) of total nitrogen ions, phosphorus ions, potassium ions, sodium ions as affected by salinity and nitrogen levels

Source of variation	Degree of freedom (df)	Mean sum of Square (MSS)			
		Total Nitrogen ions	Phosphorus ions	Potassium ions	Sodium ions
Nitrogen(A)	2	24.650**	4.500**	4.542**	0.373**
Salinity (B)	1	113.100**	66.667**	92.042**	52.658**
A×B	2	4.650**	0.667**	0.042 ^{NS}	0.021 ^{NS}
Error	18	0.070	0.021	0.069	0.014
Total	23				
CV (%)		2.17	1.65	1.79	5.12

** indicates significant at 1% level

* indicates significant at 5% level

CV: Coefficient of variation