

**MORPHO-PHYSIOLOGY OF BLACKGRAM AND MUNGBEAN AS
INFLUENCED BY SALINITY**

13

A Thesis

By

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**MASTER OF SCIENCE
IN
AGRONOMY**

**BANGABANDHU SHEIKH MUJIBUR RAHMAN AGRICULTURAL UNIVERSITY
SALNA, GAZIPUR**

WINTER 2001

**MORPHO-PHYSIOLOGY OF BLACKGRAM AND MUNGBEAN
AS INFLUENCED BY SALINITY**

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Registration no. 99-08-819



A Thesis

Submitted

to the

Bangabandhu Sheikh Mujibur Rahman Agricultural University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Agronomy

Winter, 2001

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THESIS ABSTRACT

MORPHO-PHYSIOLOGY OF BLACKGRAM AND MUNGBEAN AS INFLUENCED BY SALINITY

By

Md Sohikul Islam

Growth, yield, and physiological mechanisms of salinity tolerance of blackgram (*Vigna mungo*) and mungbean (*V. radiata*) were analyzed at the Bangabandhu Sheikh Mujibur Rahman Agricultural University. One blackgram (BARImash 2) and one mungbean (BARImung 3) varieties were grown in pots and subjected to 0, 50, and 100 mM NaCl salinity. Salinity affected seriously the synthesis of leaf chlorophylls (chl.), viz. chl. a, b and total chlorophyll. The salinity induced relative reduction of chl. was little higher in blackgram than in mungbean. Photosynthetic rate (Pn) was increased with the increasing photon flux densities (PFDs) irrespective of salt concentration. Pn of control plants showed light saturation at $1200 \mu \text{mol m}^{-2} \text{s}^{-1}$ while salt affected plant showed the saturation at much lower PFD. Mungbean (at control) showed higher Pn than blackgram. At 100 mM NaCl, however, blackgram had faster Pn than mungbean. Both stomatal resistance and intercellular CO_2 concentration were increased due to salinity. Relative water content (RWC), water saturation deficit (WSD), water retention capacity (WRC), water uptake capacity (WUC) and exudation rate were affected by salinity. The water relation in mungbean was affected more than that in

blackgram. Salt treated mungbean plants showed higher content of Na^+ than salt treated blackgram. Salinity decreased the accumulation of K^+ and blackgram showed larger reduction than mungbean. Under saline conditions leaf showed an increasing while roots a decreasing pattern of Mg^{2+} accumulation. Mg^{2+} content was little higher in mungbean than in blackgram. Leaf showed an increasing while roots a decreasing pattern of Ca^{2+} accumulation under saline conditions. Mungbean showed higher accumulation of Ca^{2+} than blackgram. Salinity induced reduction in dry matter production was conspicuously higher in mungbean than in blackgram. Salinity inhibited pod set more in mungbean than that in blackgram. Number of seeds per pod was, however, higher in mungbean than in blackgram at all salinity levels. Salinity also decreased 1000-grain weight more in mungbean than in blackgram. At 50 and 100 mM NaCl the grain yield reduced to only 81 and 35 percent in blackgram while that was 34 and 10 percent in mungbean, respectively. It was concluded that under saline conditions the relatively less reduction in Pn , maintenance of better water relations and less accumulation of Na^+ ion in blackgram compared to mungbean contributed to the high salt tolerance of blackgram than mungbean.

BIOGRAPHICAL SKETCH

The author is identified as **Md. Sohiful Islam** and was born in a noble family on April 19, 1967 in Vill. Dodangi, P.O. Kaligram, P.S. Manda, Dist. Naogaon, Bangladesh. He is the third son of Md. Ahad Ali Pramank and Mrs. Alepful Begum.

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Winter, 2001

The Author

ACKNOWLEDGEMENT

All praises and thanks are due to the Almighty and Merciful Allah who has out of infinite Mercy enabled the author to pursue his education in agriculture discipline and to complete the degree of Master of Science in Agronomy.

It is a matter of dignity and pride for the author to express his heartiest gratitude and profound respect to his honourable teacher, research supervisor and major professor Dr. Abdul Karim, Professor, Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur for his scholastic guidance, undaunted inspiration, valuable instruction, constructive criticism and overall supervision throughout the study and genius help for the preparation of this manuscript.

The author also finds a great pleasure in expressing his sincere and immense indebtedness to his respected teacher Dr. Abdul Hamid, Professor and Head, Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, for his valuable advice and encouragement and for providing facilities from Agronomy Department to conduct the research program.

The author expresses his heartfelt indebtedness and deep sense of respect and gratitude to his venerable teachers and members advisory committee Dr. Qazi Abdul Khaliq, Professor, Department of Agronomy; Dr. Jalal Uddin Ahmed, Professor, Department of Crop Botany and Dr. A. R. M. Solaiman, Professor, Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna,

Gazipur, for their valuable suggestions, criticism and generous help to improve the manuscript.

The sincere gratitude is extended to his honourable teachers Dr. Md. Moynul Haque, Associate Professor and Mr. Md Nasimul Bari, Assistant Professor, Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, for their kind co-operation and valuable suggestions.

The author extends his personal gratitude to Mr. Md. Farukh Hossain Mollah, Demonstrator, Department of Agronomy; Mr. Md. Abdul Latif, Demonstrator, Department of Soil Science and all staff of the Department of Agronomy who helped him in the field and laboratory for the study.

The author feels proud to respectfully his departed grandfather Md. Abdul Jabbar Pramanik, loving parents Md. Ahad Ali and Mrs. Alepful Ahad, brothers and sisters for their blessing encouragement which opened the gate paved the way to his higher studies.

The author also thankfully remembers his well wishers Kennedy bhai, Jhumy bhabi, Katha-moni, Mahatab, Kafil, Momin, Azam, Piash, Mainuddin, Kamal bhai, Siraj, Mustofa, Tusher, Masud, Nazu, Sumi, Noni, Dollar and others who directly or indirectly helped the author to complete this study successfully. Special thanks are also extended to Masuma who always helped during the study period.

Winter, 2001

The Author

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INTRODUCTION

CHAPTER I

INTRODUCTION

The problems of salinity in the irrigated agriculture of the tropics and subtropics are increasing at an increasing rate. Since the intensity of salinity problem is associated with temperature and water stress, the problem might be more serious with the global climate change (Maas and Hoffman, 1977; Abdulrahman and Williams, 1981).) There might be a shift in cropping pattern in the tropics due to increase in saline area. (Most of the high yielding salt sensitive crops might become unsuitable for cultivation in the existing cropping pattern. Serious attempt should therefore be undertaken to search for tolerant crops or variety of a crop to keep agriculture in the salt affected area economically viable.)

(Blackgram (*Vigna mungo* L.) and mungbean [*V. radiata* (L.) Wilczek] are two important grain legumes in the tropics and sub-tropics.) Seeds of these two legumes are an excellent source of protein. These legumes are consumed in many different forms including dhal (soup), bean sprouts, noodles, bean curd, dahl cake etc. (Due to increasing demand for cereals, farmers are interested to allocate good soils for cereals instead of legumes. Consequently legume cultivation is pushing to the problem soils including saline soils.)

*(In Bangladesh about 3 million ha of land in the southern part is affected by different degrees of salinity (Anon., 1998; Maniruzzaman and

Rahman, 2001). Farmers are growing summer legumes like mungbean in that area. Salinity levels in summer become low due to monsoon rain but the soil is not yet free from salinity. The yield level of legume is thus much lower in that soil compared to salt-free soil.)

(A plant under saline conditions encounters three inevitable factors, viz. i) water stress arisen from low osmotic potential in root media, ii) specific ion toxicity due to excess accumulation of Na^+ or Cl^- in plant cells, and iii) imbalanced accumulation and distribution of essential nutrient elements (Blum, 1988).) In several studies photosynthesis was also found to sharply decrease due to salinity (Karim *et al.*, 1993; Khan *et al.*, 1997). The decreased photosynthesis under saline condition was the resultant effect of decreased stomatal conductance, low light absorptance, feed back effect due to slower translocation and decreased synthesis of photosynthetic pigments (Sharma *et al.*, 1990, Hamada and El-Enany, 1994; Singh *et al.*, 1994). Usually tolerant crop or tolerant variety of a crop shows better water relations, low accumulation of Na^+ , less imbalance in the accumulation of nutrient elements, higher photosynthesis and finally better growth than salt sensitive ones.

(Blackgram is reported to be a relatively salt tolerant crop, than mungbean (Raptan, 2000). The two crops belong to the same genus, *Vigna*. The existence of a variation in salt-tolerance ~~between the two crops~~ would be useful for crop improvement program for the saline soils. For that reason it is necessary to have clear understanding on the physiological mechanisms

✓
of salt tolerance of ~~both~~ blackgram, and mungbean. Although mineral ions accumulation pattern in *Vigna spp.* was studied (Raptan, 2000; Paliwal and Maliwal, 1980), the water relation and other physiological responses of these crops to saline environment are insufficiently addressed.) Periodic analyses of growth characters along with water relations, photosynthetic response and mineral element accumulation in the two *Vigna* crops might help to clarify the physiological reasons for the variation in salinity tolerance between blackgram and mungbean. (This study was initiated with the following specific objectives:

- i) to analyse periodically relative growth characteristics of blackgram ~~and mungbean~~ to affirm ^{its} ~~their~~ comparative salt tolerance, and
- ii) to analyse water relation, mineral ion accumulation and light dependent gas exchange characteristics of blackgram and mungbean to elucidate their physiological mechanisms of salinity tolerance.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

(Blackgram and mungbean are two important grain legumes in the tropics and subtropics.) With the scarcity of good land, due to increasing demand for cereal based food, the legume cultivation is pushing to the marginal soils including saline soils. (In Bangladesh more than two million hectares of coastal and offshore areas are affected by different degrees of salinity) Grain legumes are cultivating there in a legume-rice cropping pattern (Khan *et al.*, 1997; Raptan, 2000). However, a little research attention has been paid for the improvement of legumes as well as for the development of their production practices in the saline soils. (The available literatures pertinent to growth, physiology, yield and yield components of blackgram and mungbean under saline conditions are presented hereunder.)

Leaf Chlorophylls

The physiological basis of salt tolerance of two cultivars of blackgram, cv. Candhari Mash and Mash 654 was assessed in a salinized sand culture. It was found that increasing NaCl concentration in the rooting medium significantly decreased the chlorophyll a, chlorophyll b and total chlorophyll (Ashraf, 1989). Maas and Hoffman (1977) also reported earlier that salinity affects seriously the synthesis of chlorophyll pigments in glycophytes. *Vigna radiata* cv. Plant Moong-2 was grown with 0, 4 and 8

dS/m salinity and both chl. a and chl. b contents were found to decrease with the increasing levels of salinity (Singh *et al.*, 1994). Chlorophylls and carotenoids in *Vicia faba* were not reduced upto 80 mM NaCl but decreased sharply afterwards (Hamada and El-Enany, 1994). Sharma *et al.* (1990) found a reduced content of chlorophyll and protein in leaves in two mungbean cultivars grown under saline conditions.

Leaf gas exchange characters

In Egypt Hamada and El-Enany (1994) noticed that transpiration of *Vicia faba* and peas were decreased sharply with an increasing salinity upto 100 mM NaCl. The concentrations of chlorophyllus and carotenoids in leaves remained more or less unchanged upto 80 mM NaCl though at higher concentration a significant decrease in the contents were observed. A stimulation in the net photosynthetic rate of peas was observed at low levels of NaCl, but at the high levels an inhibitory effect of salinity was recorded (Hamada and El-Enany, 1994). In *V. faba* NaCl even at low concentration inhibited photosynthetic activity. Dark respiration of both plant species was stimulated by salinity (Hamada and El-Enany, 1994). Datta *et al.* (1990) noticed a decreased chlorophyll content in chickpea due to chloride salinity. Photosynthetic rate was also reduced with increasing salinity levels. Respiration was stimulated even by 6 dS/m salinity. This result was supported by the findings of Manchanda and Sharma (1990), and Sharma *et al.* (1990) in chickpea.

Concentrations of ions in plant parts

Sodium

Generally sodium accumulation in different plant parts increases with increasing salinity levels. Raptan (2000) noticed that *Vigna mungo*, the relatively salt tolerant legume, accumulated high amount of Na^+ compared to *Vigna radiata*, the salt sensitive *Vigna spp.* Salt tolerant variety accumulated less amount of Na^+ in most of the plant parts compared to susceptible one, except roots as reported by Lauchli and Wieneke (1979) for soybean and Karim *et al.* (1992) for triticale. This is in agreement with the results of Sharma *et al.* (1993) in chickpea. Among the plant parts, roots retained maximum Na^+ , which was lower in stem and the lowest in leaf in chickpea genotypes (Hye, 2000).

Dhingra and Sharma (1993) reported that Na^+ content increased in mungbean seedlings with the increasing levels of salinity. Similar results were reported by Ashraf and Karim (1990) for blackgram, and Salim (1989) for *Vigna radiata*, sunflowers, *phaseolus vulgaris*, tomatoes and *Atriplex spongiosa*.

Potassium

In general, K^+ was decreased by salinity in most of the plant parts in both blackgram and mungbean. Blackgram accumulated less K^+ than mungbean (Raptan, 2000). K^+ concentration in root tissue was decreased

though Na^+ and Cl^- concentrations were generally increased with an increasing salinity level in the soil medium of *Vigna radiata*, Sunflowers, *Phaseolus vulgaris*, tomatoes and *Atriplex spongiosa* (Salim, 1989). Sudhakar *et al.* (1990) observed in horsegram and greengram that K^+ concentration in roots decreased and in shoots increased under salt stress conditions. It is reported that under saline conditions plant cells utilize K^+ as a metabolite to maintain turgor to escape from osmotic shock (Blum, 1988; Greenway and Munns, 1980). The tolerant genotypes of peas showed increasing while the sensitive ones showed decreasing trend in potassium accumulation under saline conditions (Rao *et al.*, 1990).

Magnesium

Hamada and El-Enany (1994) noticed that Mg^{2+} content in shoots of both *Vicia faba* and peas and in roots of only *V. faba* decreased with the increasing salinity levels (0-100 mM NaCl). A decreased Mg^{2+} content with an increasing salinity was reported by Lal and Bhardwaj (1984) in peas, Paliwal and Maliwal (1980) in pearl millet, sorghum, greengram and blackgram.

Murumkar and Chavan (1989) demonstrated that Mg^{2+} concentration after 5 weeks treatment in chickpea crop tended to decrease with increasing salinity. Leaf magnesium concentrations remained unaffected with increasing salinity in pigeon pea genotype (salt tolerant species), while in most of the sensitive species it was decreased. Patil *et al.* (1995) did not find

any influence of salinity on Mg^{2+} accumulation in greengram. With the increasing salinity Mg^{2+} accumulation was increased in leaves while that was decreased in roots of *Vigna spp.* and the total Mg^{2+} accumulation was little higher in mungbean than that in blackgram though blackgram is relatively salt tolerant than mungbean (Raptan, 2000).

Calcium

In general, calcium uptake was decreased with the increase in saline water irrigation in *Vigna spp.* In a study Raptan (2000) demonstrated that salinity increased the Ca^{2+} accumulation in all plant parts except roots of blackgram and mungbean. Mungbean accumulated higher Ca^{2+} than blackgram. The concentrations of Na^+ , Ca^{2+} and Cl^- in roots and shoots were increased due to salinity as reported by Lal and Bhardwaj (1984) in pea, and Sudhakar *et al.* (1990) in horsegram and greengram. On the other hand, calcium uptake was decreased with the increase in salinity in the study of Al-Niemi (1981) with sorghum, corn and soybean, Paliwal and Maliwal (1980) with pearl millet, sorghum, greengram and blackgram, Nakamura *et al.* (1990) with mungbean, Patil *et al.* (1992) and Patil *et al.* (1995) with greengram. Nakamura *et al.* (1990) reported that addition of Ca to the external medium alleviated the inhibition of root elongation by salt stress and the plant under such condition maintained a high intracellular concentration of K^+ in the elongation region of the roots by encountering NaCl stress. These findings indicate that Ca^{2+} prevents the leakage of

intracellular K^+ and thereby supports the elongation of roots under salt stress.

✓ Plant morphological characters

Effect of salinity on plant growth.

Plant height

(Salinity induced reduction in plant height is well known. Egeh and Zamora (1992) applied salinity of 1, 3, 5, 7 dS/m on *Vigna radiata*, *V. ^{black gram} unguiculata* and *Glycine max*, and observed that plant height of these crops were decreased with the increasing levels of salinity.) In a study in Vietnam, Duong *et al.* (1988) also noticed a reduction in plant height of mungbean varieties due to salinity. Maliwal and Paliwal (1982) also noticed a decrease in plant height in *Vigna radiata*, *V. mungo* and *Cyamopsis tetragonoloba* with increasing salinity levels from 3-18 mS/d. (Raptan (2000) conducted pot experiment at BSMRAU with 4 levels of salinity (0, 50, 75 and 100 mM NaCl) considering blackgram (Barimsh-1 & Barimash-2) and mungbean (Barimung-3 & Barimung-4) as test crops. He observed that plant height of ~~both~~ the crops significantly decreased with increase in salinity) and mungbean was more sensitive to salinity than blackgram. A similar result was reported by Hug and Larher (1983), Hug *et al.* (1983) and Shi *et al.* (1997) for mungbean.

Green leaf area

(Balasubramanian and Sinha (1976) reported that salinity retarded leaf growth in mungbean and cowpea. Plant showed necrosis when subjected to salinity, which reduced the photosynthetic area.) The necrosis was probably caused by the effect of excessive accumulation Na^+ as well as Cl^- and due to hydration of protein and protoplasm to some extent (Mangal and Lal, 1988).
(A long term exposure of salinity leads to premature leaf senescence and thus reduces the photosynthetic area in barley (Cramer *et al.*, 1991). Munns and Termat (1986) disclosed that because of long term exposure to salinity a large amount of salt is transported into shoot, specially into old leaves which caused leaf senescence.)

Crop phenology

(There is a general view that the crop maturity period is shortened by environmental stresses due to reduction in source size due to leaf senescence (Levitt, 1992). However, Raptan (2000) did not observe any influence of salinity on the days to flowering in ~~either blackgram or mungbean varieties.~~)
In general both the crops took more or less similar time to flowering, though blackgram took longer time to mature than mungbean. In contrast, (Siddique and Kumar (1985) observed that flowering of pea was delayed and intensity of flowering and pod setting were reduced by salinity.) Pigeonpea also took longer time to flower (Promila and Kumer, 1982).

Dry matter accumulation

Leaf dry matter

(Ashraf *et al.* (1990) assessed salt tolerance of 27 local and exotic accessions of mungbean, and noticed that in all accessions the leaf dry weight decreased with the increasing salinity levels.) Similar results were found by Ashraf and Rasul (1987) and Chowdhury (1992) in mungbean, Ram *et al.* (1989) in chickpea and Raptan (2000) in blackgram and mungbean.

Stem dry matter

(Ashraf and Rasul (1987) assessed the salt tolerance of two cultivars of mungbean [*Vigna radiata* (L.) Wilczek], AuMg 588 and Mg 6601. They found that increasing salt concentration significantly reduced the dry matter weight of stems in both the cultivars.) Reduction in stem dry weight under saline condition was confirmed in mungbean by Gill (1988) and Patil *et al.* (1996), and in cowpea and mungbean by Balasubramanian and Sinha (1976). (Salinity decreased the stem dry mass irrespective of species (blackgram and mungbean) or varieties and longer the exposure to salinity higher was the damage (Raptan, 2000).)

Root dry matter

Salinity has a direct influence on plant biomass production of a crop. Kumar and Bhardwaj (1981) reported that root elongation as well as root

biomass was significantly reduced in some mungbean genotypes due to salinity. Similar results were observed by Balasubramanian and Sinha (1976) for cowpea and mungbean.

Siddique and Kumar (1985) stated that both shoot and root growths were significantly reduced with the increasing salinity levels in pea. Sudhakar *et al.* (1990) evaluated the effect of salinity at the early seedling stage of horsegram. The study revealed that the root yield was decreased with the increasing salinity levels. Roots of mungbean were found to be damaged more than those of blackgram (Raptan, 2000).

Total dry matter

(Salinity decreases plant dry matter at all stages of plant growth. In a study Hafeez *et al.* (1988) applied 1.4, 5.0, 7.5 and 10.0 dS/m levels of salinity on blackgram, and observed that dry matter accumulation was decreased significantly with an increasing salinity regardless of stages of plant growth.) They also opined that soil salinity of 7.5 dS/m caused a 50-60% decline in dry matter yield of mungbean plant and that of 10.0 dS/m was almost toxic. Total dry matter at all growth stages in mungbean was reduced due to salinity (Patil *et al.*, 1996). (Reduction in total dry matter production under saline condition was also reported by a number of workers,) eg, in mungbean (Salim and Pitam, 1987; Duong *et al.*, 1988; Gill, 1988; Patil *et al.*, 1992; Singh *et al.*, 1994), in mungbean, cowea and soybean (Egeh and Zamora, 1992), in cowpea and mungbean (Hug *et al.*, 1983), in

horsegram and greengram (Sudhakar *et al.*, 1990), in pea (Siddique and Kumar, 1985), in *Vicia faba* and *Phaseolus vulgaris* (AbdelGhaffar *et al.*, 1982) and in *Glycine wightii* (Wilson, 1970).

Yield and yield components

Pods per plant

(Increasing salinity led to a significant reduction in number of pods per plant over control and blackgram had higher number of pods per plant than that of mungbean (Raptan, 2000), Ram *et al.* (1989) observed that increasing salinity significantly reduced pods per plant in chickpea.) However, Hafeez *et al.* (1988) noticed that mild level of salinity did not reduce pods per plant significantly in *Vigna radiata*. Similar result was also found by Patil *et al.* (1996) in mungbean.

Seeds per pod

(In mungbean number of seeds were reduced due to salinity though in blackgram the number remained unaffected (Raptan, 2000). Earlier work in mungbean (Hafeez *et al.*, 1988), blackgram (Ashraf and Karim, 1990) and pea (Siddique and Kumar, 1985) indicated that salinity reduced seeds per pod at a higher concentration.)

1000-grain weight

(The 1000-grain weight decreased significantly with increasing salinity levels (0-100 mM NaCl) and a greater reduction was observed in

mungbean than in blackgram (Raptan, 2000). Siddique and Kumar (1985) reported that pea seeds were shrunked at 75 and 100 mM NaCl salinity levels and thus the 1000-grain weight was reduced seriously. Similar results were also found by Malik *et al.* (1977) in pea, Lauter and Munns (1981) in chickpea and cowpea, and Ashraf and Karim (1990) in mungbean.

Grain yield

A negative relationship between grain yield and salinity levels was evidenced in mungbean (Gill, 1988). Such inverse relationship between salinity and grain yield was deduced in blackgram and mungbean varieties (Raptan, 2000). Hafeez *et al.* (1988) noticed that grain yield of *Vigna radiata* was about 60% lower at salinity level of 7.5 dS/m compared to 1.4 dS/m, while it was completely depressed at 10.0 dS/m. *Vigna radiata* was subjected to salinity levels of 0.5 (control), 2.0, 4.0 and 6.0 dS/m and the corresponding average seed yields were 977, 906, 540 and 370 kg/ha, respectively (Singh *et al.*, 1989). Reduction in grain yield per plant under saline condition was also reported by Salim and Pitam (1987), Duong *et al.* (1988), Gill (1988) in mungbean; Ram *et al.* (1989), Ashraf and Karim (1990), and Hye (2000) in chickpea; Siddique and Kumar (1985) in pea and Egeh and Zamora (1992) in mungbean, cowpea and soybean.



MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur during May to July, 2000. The location of the experimental site was at 24°05 North latitude and 90°25 East longitude (Centre of Madhupur Tract) with an elevation of 8.4 meters above the sea level and about 40 km north of Dhaka, the capital of Bangladesh.

Climate

The weather data including temperature, rainfall, relative humidity and sunshine hours during the period of experimentation recorded as the BSMRAU meteorological station and BRRI crop physiology laboratory are presented in Appendix I.

Collection of soil

The soil used in the pot was collected from Kodda area of Bashon Union Porishad, Joydebpur, Gazipur. This soil belongs to Kodda series, under Madhupur tract (AEZ 28).

Analysis of soil

The soil samples used in the pots were dried, powdered and mixed thoroughly. The physical and chemical properties of the soil were analyzed

at the Soil Science Laboratory, BSMRAU, Salna, Gazipur. The initial physical and chemical properties of the soil are given in Table 1.

Table 1. Physical and chemical status of the experimental soil.

Soil properties	Status
Sand %	47.17
Silt %	42.77
Clay %	10.06
Texture	Sandy-loam
PH	6.9
Total nitrogen (%)	0.13
Available P (mg P/100g dry soil)	0.10
Exchangeable K (meq/100g dry soil)	0.32

Materials

One blackgram (BARImash 2) and one mungbean (BARImung 3) variety was used in the experiment. The varieties were released from Bangladesh Agricultural Research Institute. These are high yielding varieties with semi-synchronous fruiting pattern. They are well grown in Bangladesh.

Treatments

Saline water was prepared artificially by dissolving calculated amount of commercially available salt (NaCl) with tap water to make 50 and 100

mM NaCl solution. Tap water was used as control. The electrical conductivity (EC) of tap water and the respective solutions was equivalent to 0.1, 5 and 10 dS/m, respectively.



Pot filling with soil

Each plastic pot (24cm x 27cm) was filled-up with 12kg air-dried soil and kept inside vinyl-house under natural light. Compost ($1/4^{\text{th}}$ of the soil by volume) and 0.58, 0.79, and 0.22 g of Urea, TSP and MP per pot (@ 40-60-20 kg/ha of N, P_2O_5 and K_2O , respectively) were incorporated uniformly into the soil.

Seed Sowing

Pre-soaked six bold seeds were sown in each pot on May 19, 2000. After sowing, the pots were watered for easy germination.

Intercultural operations

Thinning was done at the appearance of the 2nd trifoliate leaf to keep two uniform and healthy plants in each pot. Weeding and plant protection measures (Nogos @ 1 ml per litre) were ensured as when needed.

Treatment imposition

Tap water was applied in all pots up to the emergence of seedlings. After seedling establishment tap water in control pots and 12.5 mM NaCl

solution were applied in salt-treatments-pots up to three days and 25 mM for the next three days for hardening of seedlings before applying actual treatments. When the first trifoliolate appeared i.e. ten days after emergence (DAE) required amount of salt solutions were applied in 16 pots per treatment. Plants in control groups were irrigated with tap water. The salt solutions were applied till maturity. Electrical conductivity (EC) of the respective treatments were monitored throughout the experimental period. Average EC (dS/m) of saturation extract from salinized soil during plant growth and development period was as follows:

Desired EC (dS/m)	Measured EC (dS/m)		
	30 DAE	40 DAE	At harvesting
0	0.1	0.1	0.1
5	5±0.1	5±0.3	5±0.5
10	10±0.2	10±0.4	10±0.8

Data collection

Chlorophyll estimation

Chlorophylls were measured on fresh weight basis extracting the leaf samples with 80% acetone by using Double Beam Spectrophotometer (Model 200-20). Different chlorophylls were estimated using the following equations (Witham *et al.*, 1986):

mg chlorophyll a/g tissue = $[12.7(D_{663}) - 2.69(D_{645})] \times [v/1000 \times w]$

mg chlorophyll b/g tissue = $[22.9(D_{645}) - 4.68(D_{663})] \times [v/1000 \times w]$

mg chlorophyll a+b/g tissue = $[20.2(D_{645}) - 8.02(D_{663})] \times [v/1000 \times w]$

where,

D= Optical density of the chlorophyll extract at the specific wave length

V= Final volume of the 80% acetone + chlorophyll extract

W= Fresh weight of leaf tissue

Measurement of leaf gas exchange

Leaf gas exchange was measured at flowering stage using a portable photosynthesis system (LICOR-6200) assembled with an Infra Red Gas Analyzer (IRGA) and data logger following the procedure described by Kubota and Hamid (1992). Gas exchange characteristics, viz. net photosynthetic rate (P_n), intercellular CO_2 concentration (C_i), stomatal resistance (r_s) and leaf temperature were recorded at 0, 100, 400, 800, 1200 and 1600 $\mu \text{ mol m}^{-2} \text{ s}^{-1}$ photon flux density (PFD) on fully expanded 2nd trifoliate from the top of the canopy. Each of the measurements was replicated 3 times. The light source was artificial halogen lamp (OSRAM, HQI-TS 150/NDL).

Measurement of plant water status

The shoot systems of five blackgram and five mungbean plants were carefully separated at 20, 30, 40 and 50 DAE. Fresh weight of fully expanded third trifoliate leaves from the top, petiole of the leaf and part of

stem were taken. The plant parts were kept immersed in distilled water for 24h at room temperature in the dark. The turgid weights of those plant parts were then measured. Afterwards all the materials were oven-dried at 80°C for 72h in order to take dry weight. The fresh, turgid and dry weights of the plant segments were used to determine the following parameters:

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

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

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

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



Exudation rate was measured at 5 cm above from the stem base. At first dry cotton was weighed. A slanting cut on stem was made with a sharp knife. Then the weighed cotton was placed on the cut surface. The exudation of sap was collected from the stem for 1h at normal temperature. The final weight of the cotton with sap was taken. The exudation rate was measured by deducting cotton weight from the sap containing cotton weight and expressed per hour basis as follows:

$$\text{Exudation rate} = \frac{(\text{Weight of cotton+sap}) - (\text{Weight of cotton})}{\text{Time (h)}}$$

Crop phenology

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

Laboratory analyses of plant samples

Oven dried plant materials (leaves and roots) at 20 and 40 DAE and at harvest were ground with a Willey grinding machine (cap/small 1029-8, Yoshida Seisakusho Co. Ltd.) for the estimation of different mineral ions.

Preparation of stock solution for estimating Na, K, Ca, Mg ions

Reagents:

1. Deionized distilled water
2. Hydrochloric acid, 2N HCl was prepared in batches of two litres at a time. Added 352 ml of concentrated HCl to 1648 ml of distilled water.
3. Lanthanum Chloride

Equipment: Atomic Absorption Spectrophotometer (Model,

Hitachi, 170-30) ((Yamakawa, 1992).

Labware: Crucible, volumetric flask (50ml), filter funnel, filter paper

(Whatman No. 1), pipettes, sand bath, vial graduated at 40ml tubes.

Procedure:

Five hundred mg plant samples were taken in crucible and dry-ashed in Muffle Furnace at 550°C for two hours. After ashing, 10 ml of 2N HCl was added in crucible and warmed to dissolve the constituents for some times at sand bath. Then the dissolved materials were filtered through Whatman No.1 filter paper in volumetric flask. Distilled water was added to prepare 50 ml stock solution.

Analyses of Na, K, Ca and Mg

At first 0.1 ml liquid sample was taken in a vial test tube from stock solution and 10 ml distilled water and 0.1 ml lanthanum chloride ($\text{LaCl}_3 \cdot 7\text{H}_2\text{O}$) were added. Absorbances of respective ions were measured with Atomic Absorption Spectrophotometer (Model 170-80, Hitachi).

Dry matter accumulation and partitioning

Five plants from each crop per treatment were harvested at 10 days interval beginning from 10 days after treatment imposition (20 DAE). From the sampled plants, data on plant height were recorded. Leaf area of each sampled plant was also measured with an automatic leaf area meter (Model AAM-7, Hayashi Dehnco Co. Ltd. Tokyo, Japan). The plants were partitioned into leaf, stem, petiole and reproductive organs and oven dried at 70°C for 72 hours. Weight of individual components was recorded.

Yield and yield components

Eight plants were harvested at maturity stage of each crop and the following data were recorded:

- i) Plant height (cm)
- ii) Leaves, stem, roots and total dry matter weight
- iii) Pods/plant
- iv) Seeds per pod
- v) 1000-grain weight and
- vi) Grain yield

Statistical analysis

Data were statistically analyzed with the help of MSTAT program. The difference between the treatment means was compared by Least Significant Difference (LSD) test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

Salinity induced comparative changes in growth and some physiological characteristics of blackgram and mungbean are discussed in this chapter.

Effect of NaCl on chlorophyll content and gas exchange characters in *Vigna spp.*

Leaf chlorophylls

Salinity affected seriously biosynthesis of leaf chlorophylls viz. chlorophyll a, chlorophyll b and total chlorophyll (a+b) as well as chlorophyll a/b ratio of blackgram and mungbean (Fig. 1). Leaf chlorophylls were significantly decreased with the increasing salinity in both the crops.

Chlorophyll a was higher in blackgram than in mungbean at all levels of salinity. However, the relative reduction in chl. a due to salinity was a little more in blackgram (35 and 53 % at 50 and 100 mM NaCl, respectively) than in mungbean (30 and 50 %). The highest chl. a content (1.73 mg/g in blackgram and 1.16 mg/g in mungbean) was recorded at control while the lowest (0.82 mg/g in blackgram and 0.58 mg/g in mungbean) was at 100 mM NaCl salinity. A linear but negative relationship existed between salinity levels and chlorophyll a content of blackgram and

mungbean, and expressed by the equation $y = -0.0091x + 1.6783$ ($R^2=0.9628$) and $y = -0.0058x + 1.14$ ($R^2=0.9859$), where R is highly significant (Fig. 1). Higher R value as found in mungbean than in blackgram indicated a stronger relationship between salinity levels and chlorophyll a in the former crop than blackgram.

Chlorophyll b also followed a decreasing pattern with the increasing salinity levels in both the crops (Fig. 1). Blackgram showed high chl. b than mungbean at all salinity levels. The relative reduction of the content was more or less similar for both the crops. A linear but negative relationship existed between salinity levels and chlorophyll b content of blackgram and mungbean, and expressed by the equation $y = -0.0045x + 0.795$ ($R^2=0.9643$) and $y = -0.0027x + 0.5117$ ($R^2=0.9887$), respectively, where R is highly significant (Fig. 1). Higher R value as found in mungbean than blackgram indicated a stronger relationship between salinity levels and chlorophyll b in the former crop than blackgram.

Total chlorophyll (a+b) was also decreased with the increasing salinity levels in both the crops. Higher amount of total chlorophyll (a+b) was recorded in blackgram than mungbean, though the relative reduction was also more at all levels of salinity in the former crop than mungbean. A linear but negative relationship existed between salinity levels and total chlorophyll content of blackgram and mungbean, and expressed by the equation $y = -0.0136x + 2.4733$ ($R^2 = 0.9633$) and $y = -0.0085x + 1.6517$

($R^2 = 0.9868$), respectively, where R is highly significant (Fig. 1). Higher R value as found in mungbean than in blackgram indicated a stronger relationship between salinity levels and total chlorophyll in the former crop than the blackgram. Ashraf (1989) reported that NaCl salinity in rooting medium decreased significantly chlorophyll a, chlorophyll b and total chlorophyll (a+b) in two cultivars of blackgram. According to Mass and Hoffman (1977) chlorophyll synthesis in blackgram was highly sensitive to salinity like other leguminous crops. Singh *et al.* (1994) observed in *Vigna radiata* that chl. a and chl. b contents decreased with increasing salinity (0 to 8 dS/m). However, chlorophyll and carotenoids of *Vicia faba* were not affected appreciably upto 80 mM NaCl though the pigments decreased significantly at higher concentration (Hamada and El-Enany, 1994).

The ratio of chlorophyll a/b increased due to salinity (Fig. 1). Salinity decreased chl. b more than chl. a and thus increased the ratio. A linear and positive relationship existed between salinity levels and chlorophyll a/b ratio of blackgram and mungbean, and expressed by the equation $y = -0.0009x + 2.2217$, ($R^2 = 0.9067$) and $y = -0.001x + 2.1033$ ($R^2 = 0.9494$), respectively, where R is highly significant (Fig. 1). Higher R value as found in mungbean than in blackgram indicated a stronger relationship between salinity levels and chlorophyll a/b ratio in the former crop than the later. In a study of Mishra *et al.* (1995) chlorophyll synthesis and accumulation was stimulated by mild level of NaCl salinity. The result of this experiment is partially in

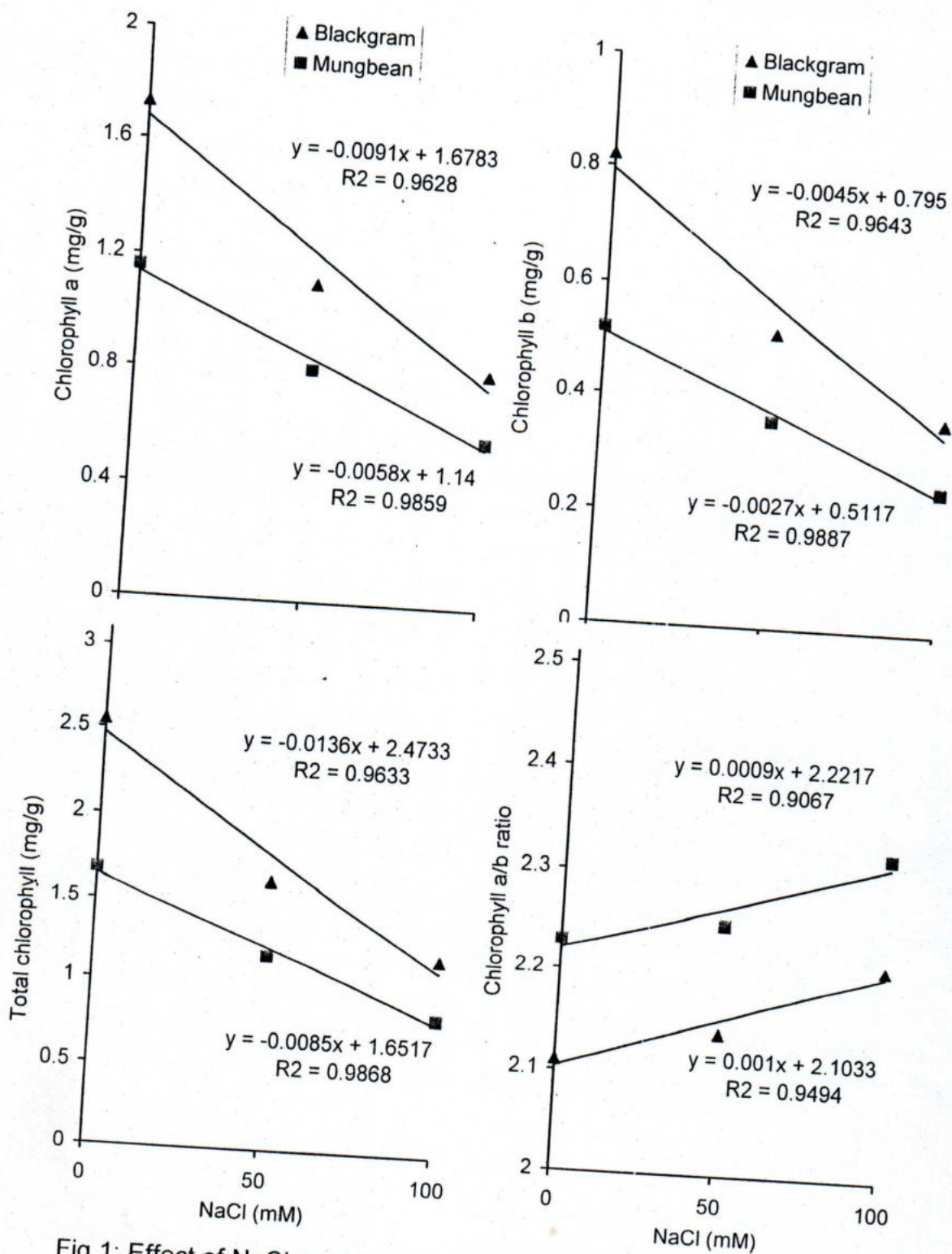


Fig.1: Effect of NaCl on chl. a, chl. b, total chl. (a+b) and chl. a/b ratio of blackgram and mungbean.

line with that of Singh *et al.* (1994) for *Vigna radiata* that chlorophyll a/b ratio increased with the increasing salinity levels. The less damaged chlorophylls in blackgram than mungbean by salinity was presumably contributed for maintaining higher Pn efficiency in the former crop than the later (Seemann and Critchley, 1985; Datta *et al.*, 1990).

Gas exchange characters at different light intensities

The gas exchange characters of blackgram and mungbean grown under different levels of salinity are presented in Fig. 2. The photosynthetic CO₂ assimilation rate (Pn), in general, increased with the increasing photon flux density (PFDs) in both the crops. However, salt affected plants showed less Pn at all PFD levels. Respiration rate measured at 0 PFD increased with the increasing salinity levels in both blackgram and mungbean. Blackgram showed higher respiration than mungbean. At the highest level of salt concentration, the maximum respiration rate was recorded ($5.67 \mu \text{mol m}^{-2} \text{s}^{-1}$) in blackgram, which was almost double than that in mungbean. Although there is scarce information on the influence of salinity on respiration in *Vigna spp.* Hamada and El-Enany (1994) and Datta *et al.* (1990) noticed an increased respiration due to salinity in *Vicia faba* and chickpea)

Mungbean plants showed higher Pn than blackgram at and above 400 PFD under control condition. The differences in Pn between the control and salt affected plants became wider with the increase in PFD. Photosynthesis of control plants of both mungbean and blackgram showed light saturation

at $1200 \mu \text{mol m}^{-2} \text{s}^{-1}$ light intensity, while the salt affected plants showed the saturation at much lower PFD. At 100 mM NaCl blackgram showed higher Pn than mungbean at all PFD levels. At that high NaCl concentration Pn in blackgram reduced to 32, 66, 60, 36 and 43 % and that in mungbean to 60, 76, 83, 48 and 70 % under 100, 400, 800 1200 and 1600 $\mu \text{mol m}^{-2} \text{s}^{-1}$ PFDs, respectively. There is lack of information on the photosynthetic light response of legumes under saline conditions. However, earlier reports indicate that salinity decreased Pn in glycophytes. The decreased Pn is the resultant effect of increased stomatal resistance, lowered transportation of photosynthates or even slower activity of some photosynthetic enzymes (Munns and Termat, 1986; Hamada and El-Enany, 1994; Khan *et al.*, 1997; Orcutt and Nilsen, 2000). The less reduction in Pn of blackgram at high salt concentration than mungbean was obviously helpful to maintain better growth in the former crop than the later one (Seemann and Critchley, 1985; Prasad, 1997).

Stomatal resistance (r_s) indicates the degree of exchange of CO_2 and water vapor between ambient and inner leaf. It is calculated from the transpiration rate and difference in vapor pressure between air and leaf. As observed stomatal resistance (r_s) increased with the increasing salinity levels in both blackgram and mungbean (Fig. 2). The r_s also increased with the increasing PFD, irrespective of crops and salinity levels. At all levels of salinity the r_s of blackgram was higher than the r_s of mungbean (Fig. 2).

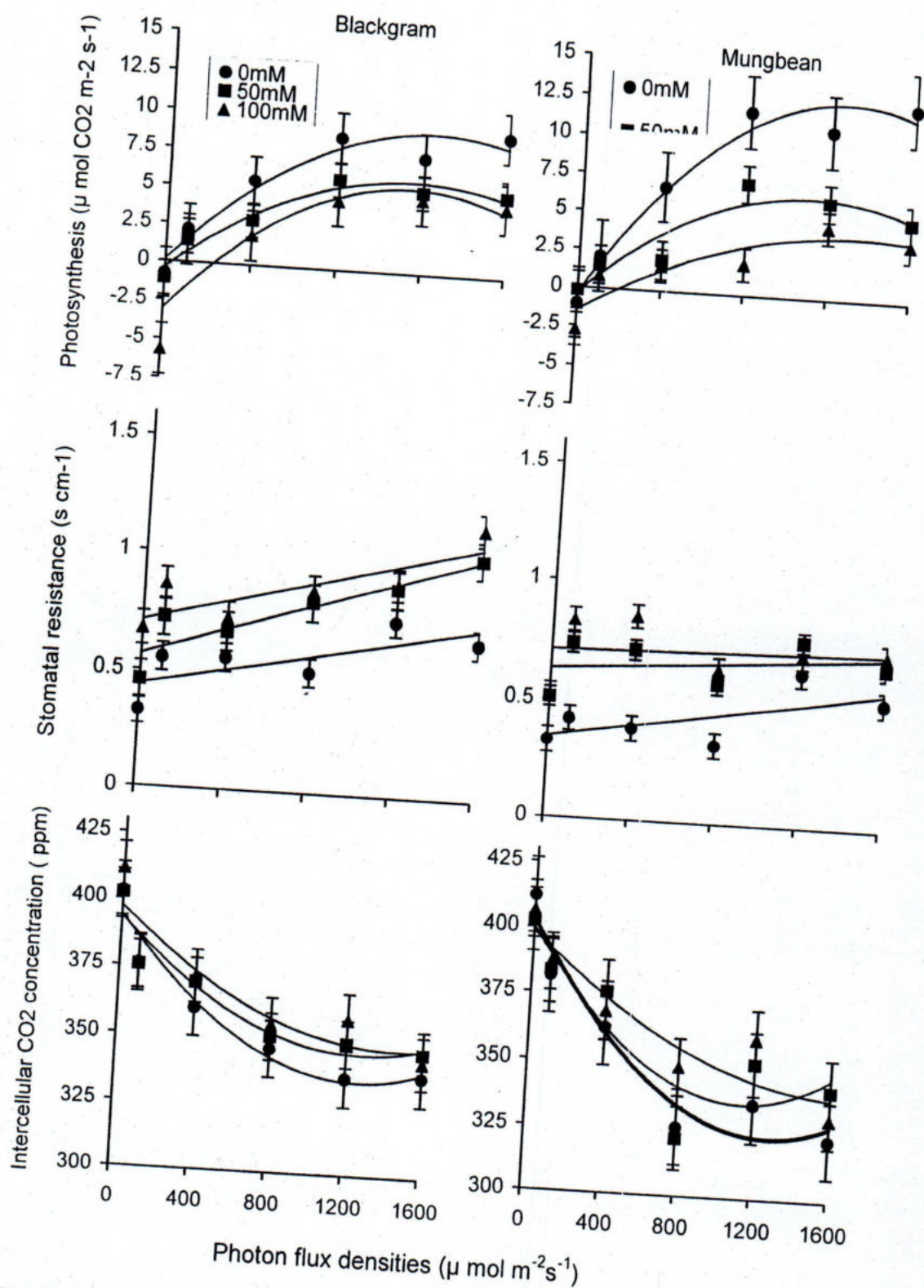


Fig. 2: Gas exchange characteristics of blackgram and mungbean at different photon flux densities (PFDs) as affected by salinity levels. Bars indicate SE ($\pm$).

Salinity induced increase in r_s was also found in other crops (Karim and Shigenaga, 1992; Khan *et al.*, 1997). The increased r_s under saline condition is the consequence of water stress as developed by salinity (Karim *et al.*, 1992; Gunes *et al.*, 1996; Prasad, 1997). It is interesting to note that despite higher r_s blackgram showed faster Pn than mungbean under saline conditions. The findings indicate that blackgram possesses better mechanism of CO₂ assimilation under a condition of partial stomatal closure than mungbean.

Salinity increased the intercellular CO₂ concentration (C_i) in both the crops. The differences in the C_i between the control and NaCl treated plants was sharpened at and above PFDs of 400 $\mu\text{mol m}^{-2}\text{s}^{-1}$. The C_i , however, decreased with the increasing PFD irrespective of levels of salinity. The two crops showed more or less similar C_i irrespective of levels of salinity (Fig. 2). Salinity inhibits the activity of photosynthetic enzymes such as RuBisCO that results in the increasing accumulation of C_i (Seemann and Critchley, 1985).

Effect of NaCl on water relations of *Vigna spp.*

Relative Water Content

The relative water content (RWC) in leaf, petiole and stem was measured at 10 days interval from 20 days after emergence (DAE) till maturity. The RWC decreased with plant age in both the crops (Fig. 3).

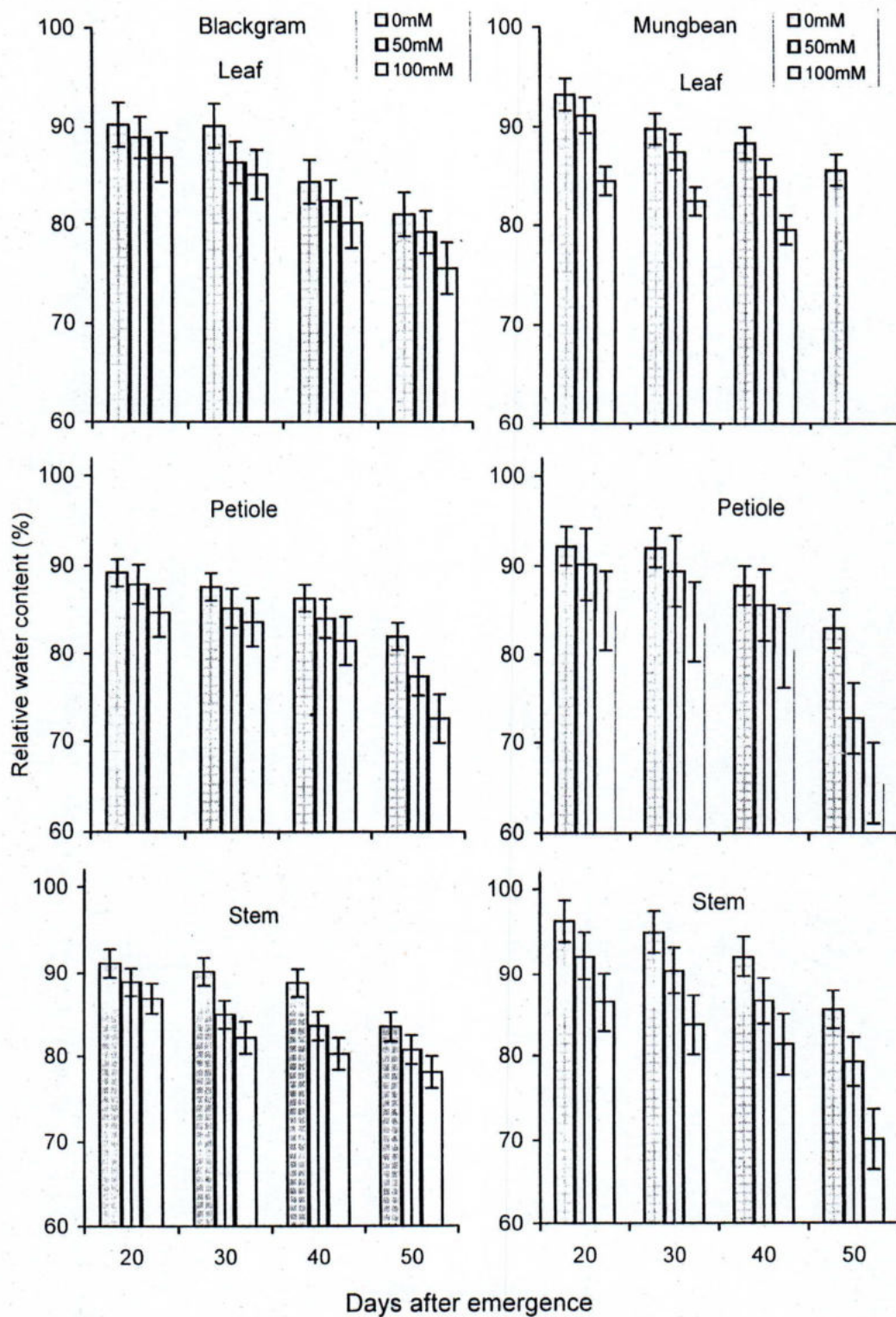


Fig.3: Effect of NaCl on relative water content in different plant parts of blackgram and mungbean measured at different days after emergence. Bars indicate SE($\pm$).

Salinity decreased RWC in all the plant parts. The relative reduction was greater at the later stages of plants which might be due to longer exposure to salinity. The leaf of mungbean showed higher RWC at the control treatment. However, at the high salt concentration all the plant parts of mungbean showed conspicuously higher reduction in RWC (% of the control) than those of blackgram. Particularly, petiole and stem of mungbean showed remarkable reduction in RWC compared to those organs of blackgram. Under saline conditions plant suffers from osmotic shock due to lower osmotic potential in the soil solution. (Greenway and Munns, 1985; Orcutt and Nilsen, 2000). Plant synthesizes different metabolites accross the tonoplast to maintain turgor. However, the plants must spend substantial energy to maintain turgor under water deficit conditions (Munns and Termat, 1986). The RWC signifies the water content in plants. In the present study mungbean was found to suffer more from water stress than blackgram. The better water relation in blackgram under saline condition obviously contributed to maintenance of higher plant growth in blackgram than in mungbean.

Water Saturation Deficit

Water saturation deficit (WSD) showed an inverse trend of RWC. WSD indicates the degree of water deficit in plants. WSD increased with the increase in plant age in both the crops. Salinity increased the WSD in all the plant parts studied, viz. leaf, petiole and stem (Fig. 4). At all the growth

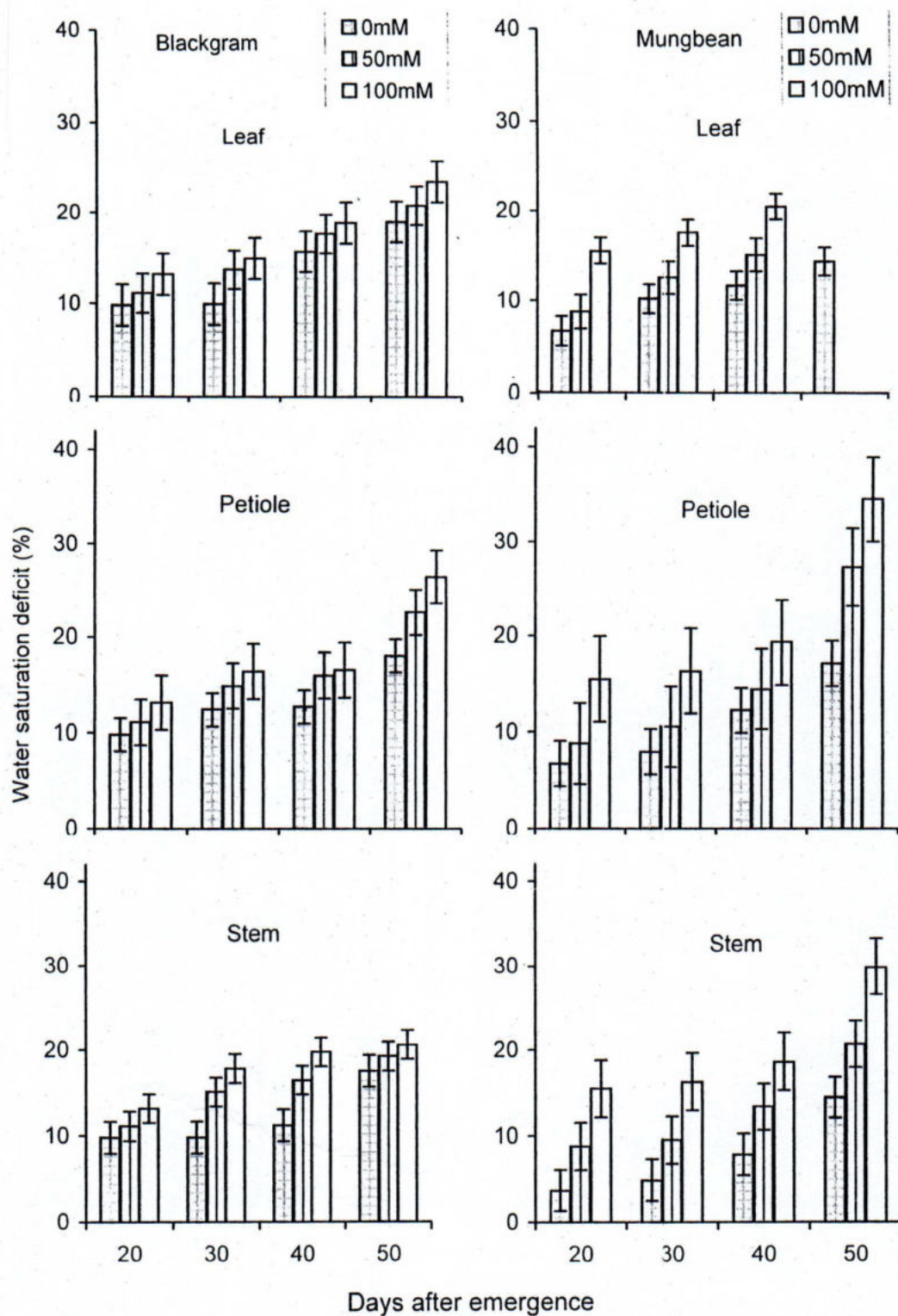


Fig.4: Effect of NaCl on water saturation deficit in different plant parts of blackgram and mungbean measured at different days after emergence. Bars indicate SE ($\pm$).

stages the different plant parts of salt treated plants of mungbean showed higher relative WSD (% of the control) than those in blackgram. This findings reveal that mungbean plants suffered more from water deficit specially at high salt concentration than blackgram (Greenway and Munns, 1985; Orcutt and Nilsen, 2000).

Water Retention Capacity

The turgid weight: dry weight ratio, termed as water retention capacity (WRC), illustrates the capacity of plant cell to retain water at a particular stage. WRC is determined by cell structures. WRC decreased with the increasing plant age in both the crops (Fig. 5). Salinity decreased the WRC irrespective of plant age and the reduction was greatest at the highest level of salinity (100 mM NaCl). On and above 30 DAE the relative reduction in WRC of mungbean was much higher than that of blackgram, especially in leaf. The higher reduction in WRC (% to the control) in mungbean than in blackgram indicates a greater damage in cell structure due to salinity in the former crop than the later (Sangakkara *et al.*, 1996; Islam, 2001).

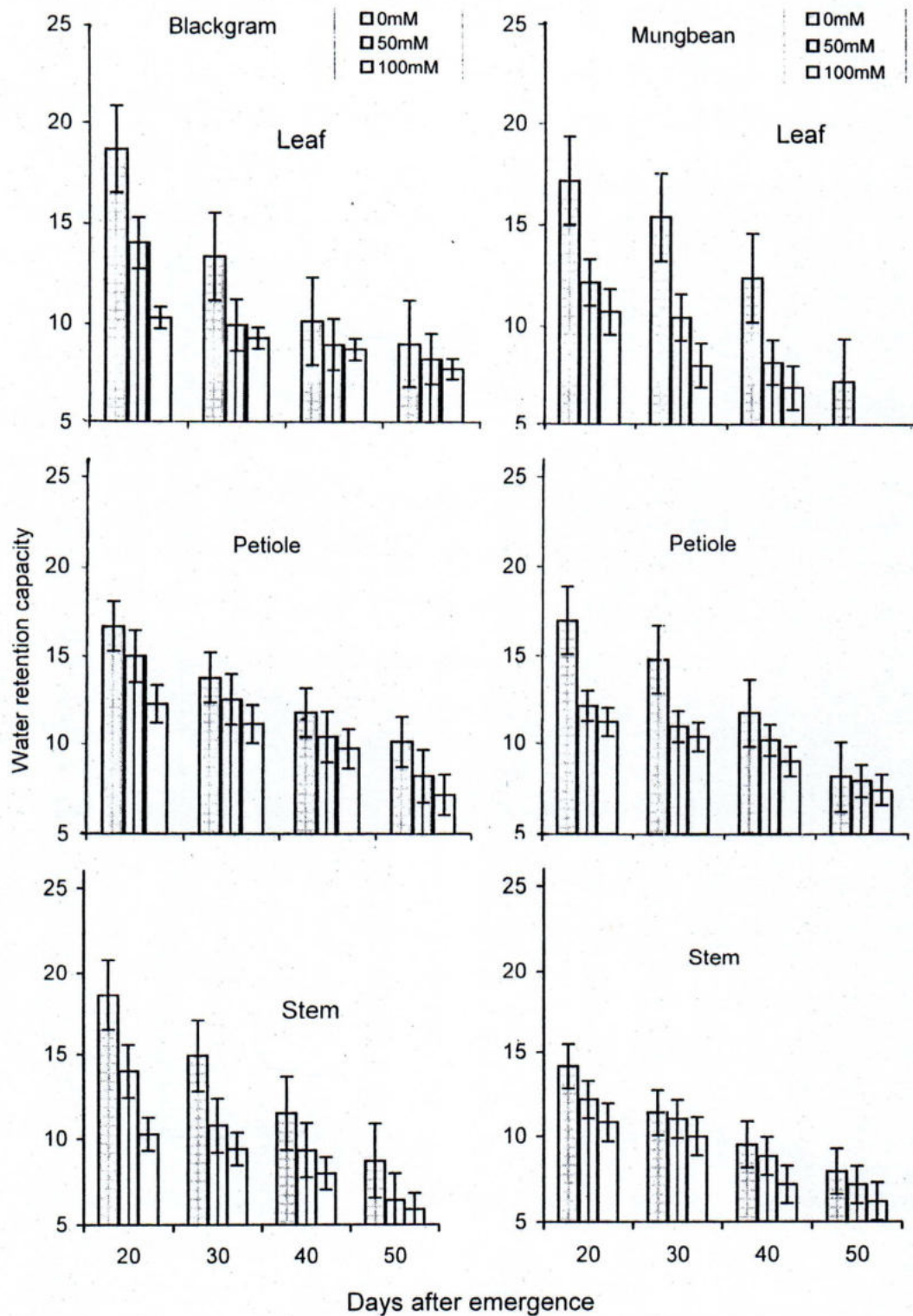


Fig.5: Effect of NaCl on water retention capacity in different plant parts of blackgram and mungbean measured at different days after emergence. Bars indicate SE ($\pm$).

Water Uptake Capacity

The water uptake capacity (WUC) quantifies the capacity of plant cells to absorb water per unit dry weight at a particular stage. A higher WUC 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. In general, WUC decreased with the increasing plant age in all the treatments. Salinity resulted in an increasing WUC in different plant parts viz. leaf, petiole and stem in both blackgram and mungbean (Fig. 6). Although blackgram showed a little higher absolute WUC than mungbean, the relative increase in WUC (% to the control) was greater in mungbean than blackgram. As mungbean plants suffered more with water stress. This trend was also observed in other parameters such as RWC, WRC and WSD, the crop had to uptake relatively more amount of water to reach turgidity than blackgram (Sangakkara *et al.*, 1996; Islam, 2001).

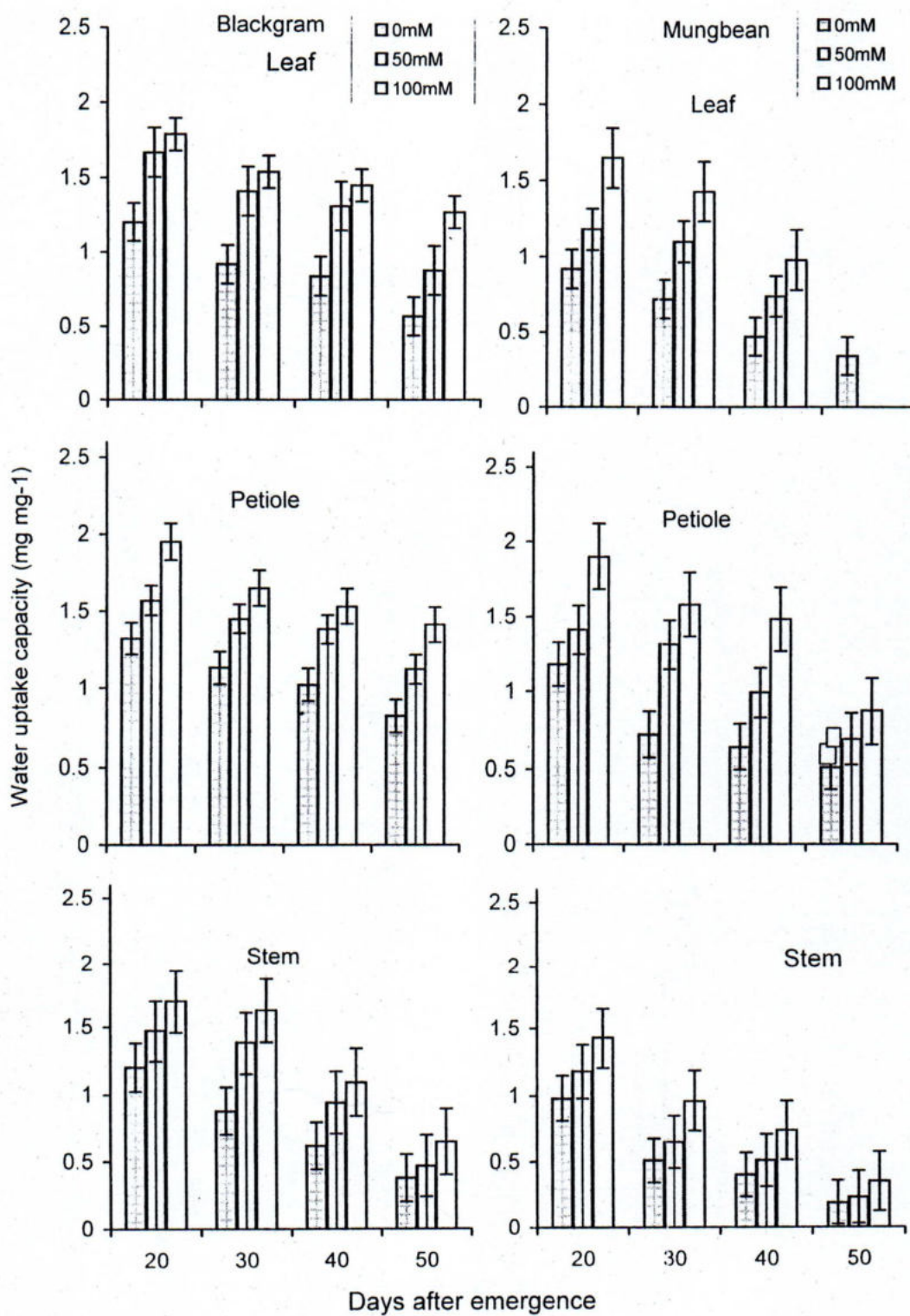


Fig.6: Effect of NaCl on water uptake capacity in different plant parts of blackgram and mungbean measured at different days after emergence. Bars indicate SE (±).

Exudation rate

The exudation rate of blackgram and mungbean measured at different growth stages (DAE) was decreased markedly with the increasing salinity levels. Control plants showed the highest exudation rate at 30 DAE, which decreased thereafter in both the crops (Table 2). However, salt treated plants showed the highest exudation rate at the early growth stage, 20 DAE, and the rate decreased with the increasing plant age. The exudation rate in salt treated mungbean plants was much lower than that in blackgram at all growth stages and at both 50 and 100 mM NaCl levels. Compared to control plants, exudation rates in blackgram plants treated with 100 mM NaCl were 46, 29, 7 and 9 %, and those of mungbean were only 40, 9, 6 and 5 % at 20, 30, 40 and 50 DAE, respectively. Exudation rate is directly associated with the flow of transpirational stream. Higher exudation rate means a plant can absorb more water from the soil solution than a plant with lower exudation rate. Higher exudation rates in blackgram than mungbean disclosed that blackgram plants maintained a better water relation than mungbean under saline condition (Sangakkara *et al.*, 1996; Islam, 2001).

Table 2: Effect of NaCl on exudation rate of blackgram and mungbean at different growth stages.

NaCl (mM)	Exudation Rate (mg/hour)							
	20 DAE*		30 DAE		40 DAE		50 DAE	
	BG*	MB*	BG	MB	BG	MB	BG	MB
0	104.0	87.0	142.40	155.8	95.0	134.2	77.4	118.4
50	60.20	40.60	57.80	20.80	20.0	12.80	12.8	11.20
	(58)	(47)	(41)	(13)	(21)	(10)	(17)	(9)
100	48.20	34.40	40.80	14.4	6.6	7.60	6.8	5.8
	(46)	(40)	(29)	(9)	(7)	(6)	(9)	(5)
LSD	19.53	13.66	15.71	14.18	12.67	11.61	8.23	15.45
CV(%)	15.50	11.51	14.29	10.18	9.56	12.66	14.76	9.24

- DAE: Days after emergence; BG: Blackgram; MB: Mungbean
Values in parentheses indicate percentage value to the control.

Effect of NaCl on mineral ions accumulation in leaves and roots of

Vigna spp.

Sodium accumulation

Compared to non-saline conditions Na^+ concentration increased with the increasing salinity in roots and shoots of both the crops (Fig. 7). Moreover, Na^+ accumulation increased with the plant age. Perhaps higher Na^+ accumulation at later stages was due to longer exposure of the crops to salinity. Under saline conditions, roots contained higher amount of Na^+ than the leaves in both the crops. Mungbean leaf as well as roots accumulated higher amount of Na^+ than those of blackgram. The highest Na^+ concentration (2.52%) was recorded in mungbean roots at maturity stage at 100 mM NaCl. High Na^+ retention in roots than shoot was also observed by Sharma and Kumar (1990) in chickpea. Similar to the findings of this experiment Blum (1988) also indicated that tolerant crop accumulated less amount of Na^+ than susceptible one. However, the findings of Lauchli and Wieneke (1979) in soybean, and Karim *et al.* (1992) in triticale revealed that tolerant cultivar maintained relatively larger amount of Na^+ in the roots and a smaller amount in the shoots compared to those in salt susceptible cultivar. In a study, Raptan (2000) observed that blackgram varieties (tolerant crop) accumulated higher amount of Na^+ than mungbean varieties. The reasons for dissimilar trend in accumulation of Na^+ in blackgram and mungbean between the findings of Raptan (2000) and the present study were not clear.

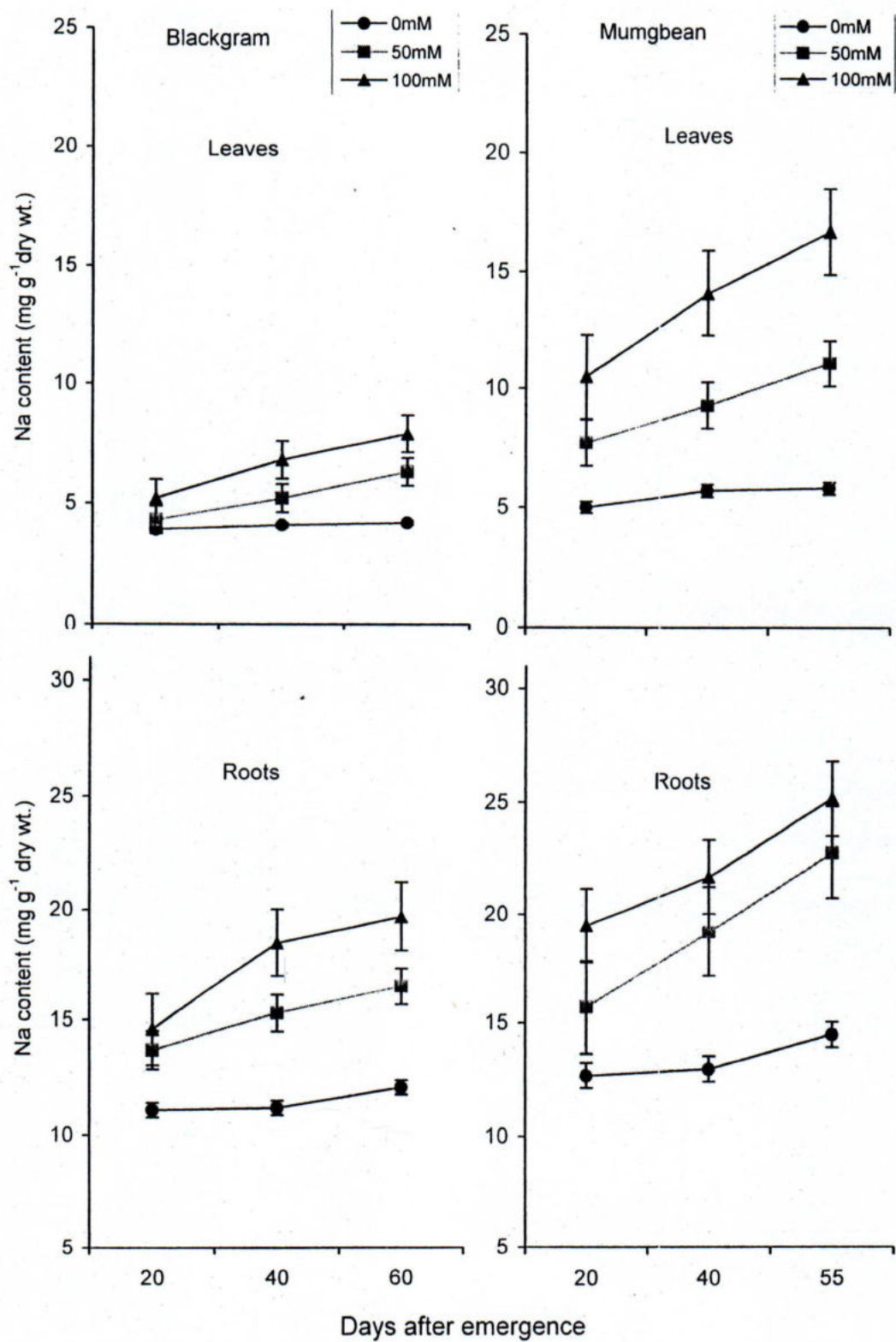


Fig. 7 : Change in Na⁺ content in leaves and roots of blackgram and mungbean measured with time. Bars indicate SE (±).

However, Raptan (2000) analysed Na^+ from composite samples (non replicated) and that made it complicated to make comparison between the results of the two studies. The excessive amount of Na^+ under saline conditions, as found in the present study, presumably caused harmful effect on plant growth, and mungbean was suffered more from Na^+ toxicity than blackgram (Blum, 1988; Mamo *et al.*, 1996).

Potassium accumulation

Accumulation of K^+ in leaves and roots of blackgram and mungbean grown under saline conditions are presented in Fig. 8. Under control conditions the K^+ accumulation at 20 DAE was almost similar to that at 55 or 60 DAE in both shoots and roots of the two crops. The accumulation pattern indicates that plant age did not have significant influence on K^+ accumulation in *Vigna spp.* Contrary, with the increase in salinity from 0 to 100 mM the K^+ content decreased in both leaves and roots in both the crops. Moreover, longer the exposure of plants to salinity higher was the reduction in K^+ accumulation. Mungbean accumulated higher amount of K^+ than blackgram at all levels of salinity (Fig. 8). The relative reduction in K^+ accumulation due to salinity was more in blackgram than that in mungbean though blackgram is more salt tolerant than mungbean. Raptan (2000) indicated that despite high salt tolerance of blackgram, the crop maintains lower K/Na ratio than mungbean. Salinity induced reduction in K^+ accumulation was also reported earlier in different crops such as barley

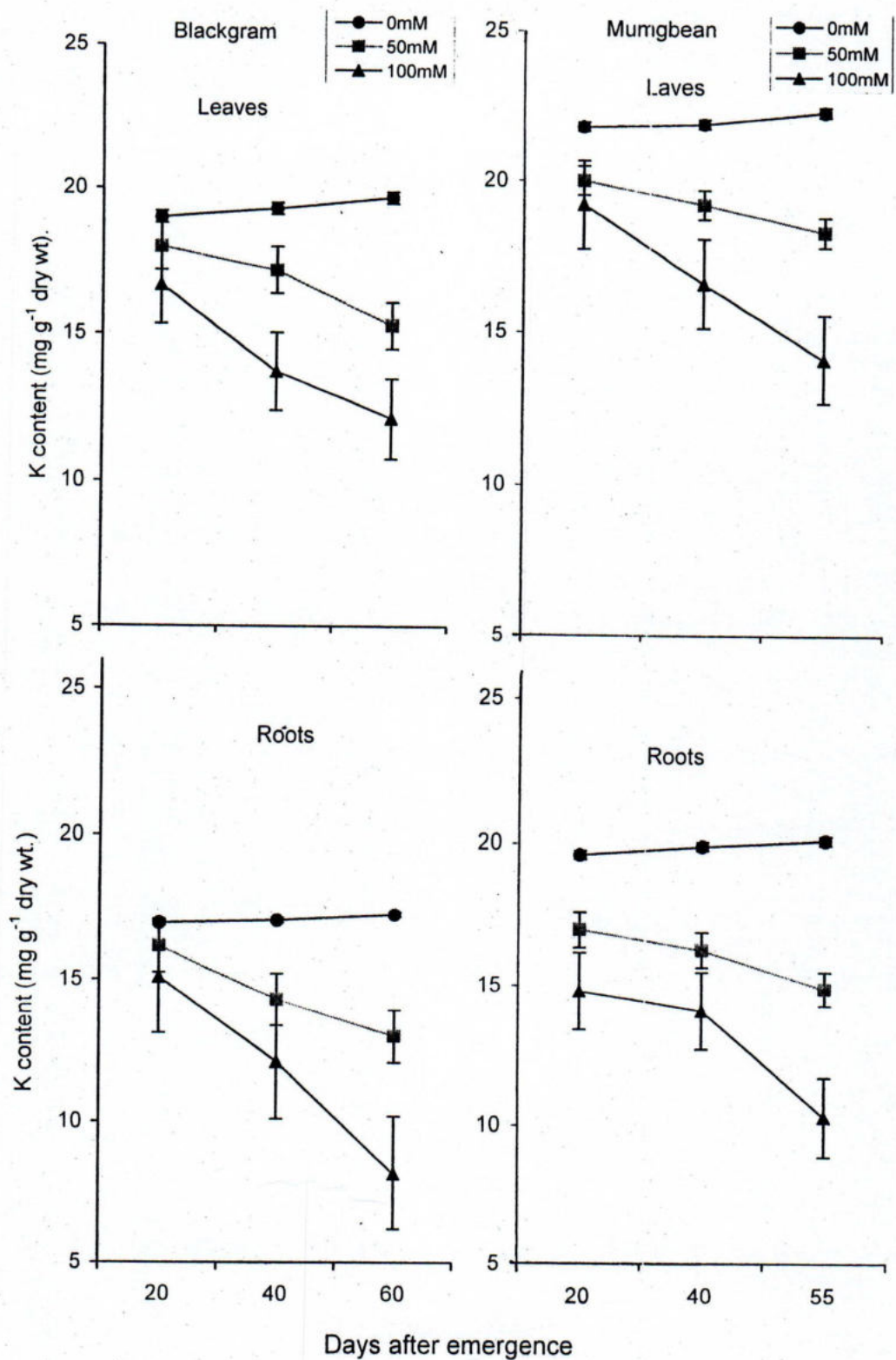


Fig.8: Change in K^+ content in leaves and roots of blackgram and mungbean measured with time. Bars indicate SE ($\pm$).

(Helal and Mengel, 1979), forage crops (Datta *et al.*, 1996), *Avicennia marina* (Forstk) Vierh. (Cherian *et al.*, 1999), chickpea (Singh and Singh, 1999) and blackgram and mungbean (Raptan, 2000). However, Hye (2000) reported that K^+ concentration in chickpea increased in leaves and roots with the increase in salinity. Perhaps chickpea possesses different mechanisms of K^+ accumulation than blackgram and mungbean. Sudhakar *et al.* (1990) observed in horsegaram and greengram that K^+ concentration in roots decreased while in shoots increased with salt stress. Under saline conditions, plant cells utilize K^+ as a metabolite to maintain turgor to escape from osmotic shock (Greenway and Munns, 1980; Blum, 1988). However, for the synthesis of metabolites the plant under salt stress has to use large amount of energy (Blum, 1980; Taiz and Zeiger, 1991). Although plant cell has the preference to absorb K^+ over Na^+ the enormous amount of NaCl in soil medium forced the plant cell to absorb large quantity of Na^+ and Cl^- compared to K^+ . The absorption of Na^+ , and Cl^- in large proportions upsets the accumulation pattern of major nutrients like K^+ (Lal and Bhardwaj, 1984).

Magnesium accumulation

Both leaves and roots in control plants showed an increasing accumulation of Mg^{2+} with the increase in plant age. However, under saline conditions leaves showed an increasing while roots a decreasing pattern of Mg^{2+} accumulation with time (Fig. 9). The Mg^{2+} accumulation was a little

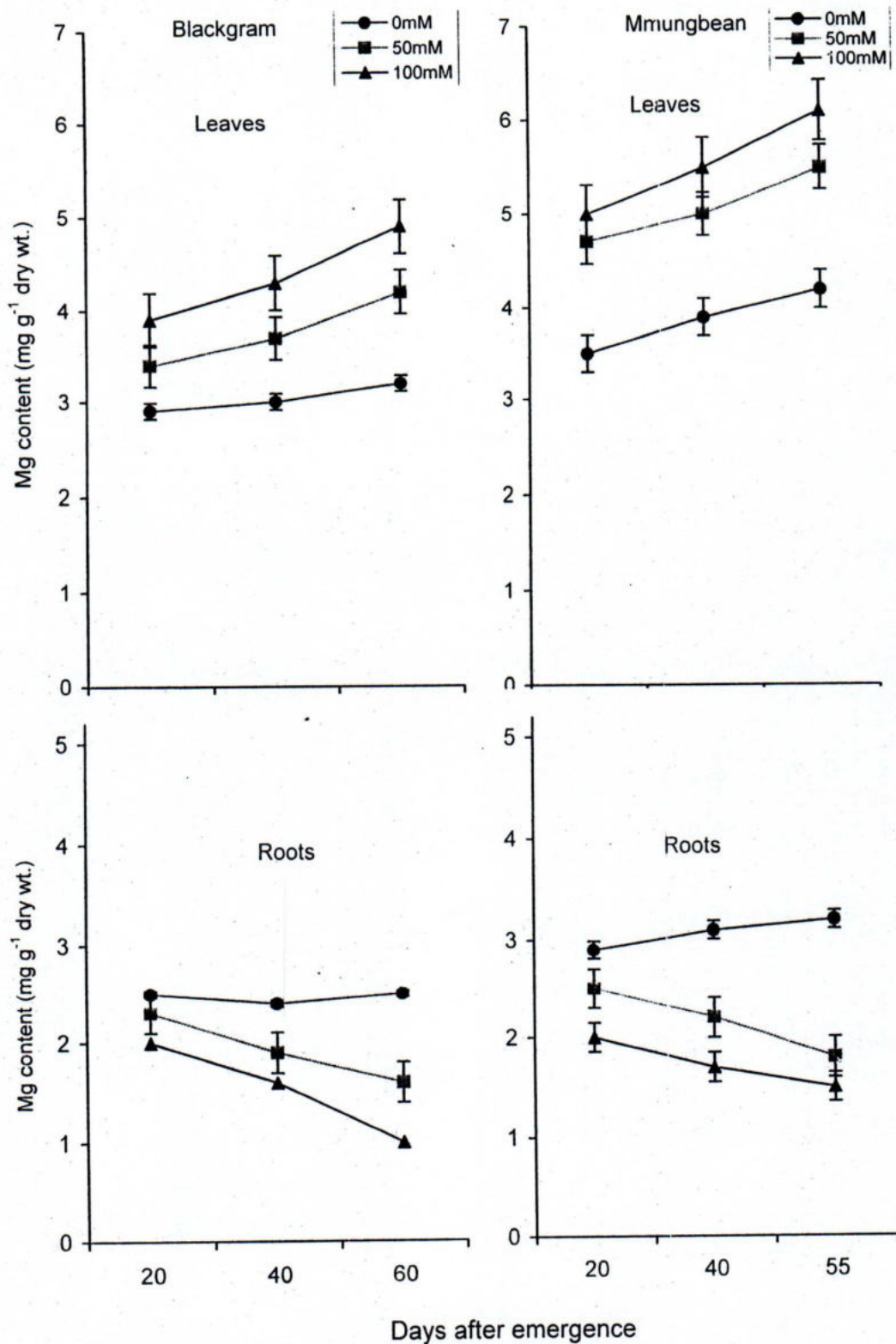


Fig. 9 : Change in Mg^{2+} content in leaves and roots of blackgram and mungbean measured with time. Bars indicate SE ($\pm$).

higher in mungbean than that in blackgram though blackgram is relatively salt tolerant than mungbean. In blackgram, leaves and roots accumulated 0.39 and 0.14% of Mg^{2+} at 20 DAE under high salinity level (100 mM NaCl) whereas that was 0.48 and 0.10% at maturity stage. Mungbean leaves and roots accumulated 0.50 and 0.20% at 20 DAE at 100 mM NaCl whereas 0.61 and 0.15% at maturity. There are controversial reports on the accumulation pattern of Mg^{2+} in plants under saline conditions. A decreased accumulation of Mg^{2+} was noticed by Lal and Bhardwaj (1984) in field pea, and Paliwal and Maliwal (1980) in greengram and blackgram. Similarly, Helal and Mengel (1979) observed a decreased content of Mg^{2+} in both shoots and roots of barley with the increase in salinity. Contrary, Patil *et al.* (1995) did not find any influence of salinity on Mg^{2+} accumulation in greengram. It is reported that accumulated Mg^{2+} in the source (leaf) of the plant was probably helpful to maintain osmoregulation to protect the plant cells from osmotic shock caused by salinity (Greenway and Munns, 2000).

Calcium accumulation

Accumulation of calcium in leaves and roots of blackgram and mungbean at different growth stages is shown in Fig. 10. An increasing tendency in Ca^{2+} accumulation was observed in leaves while a decreasing tendency was in roots with the increasing salinity as well as with the age of crops. Apparently, leaves and roots of mungbean, the susceptible crop, accumulated higher concentration of Ca^{2+} than blackgram (tolerant one).

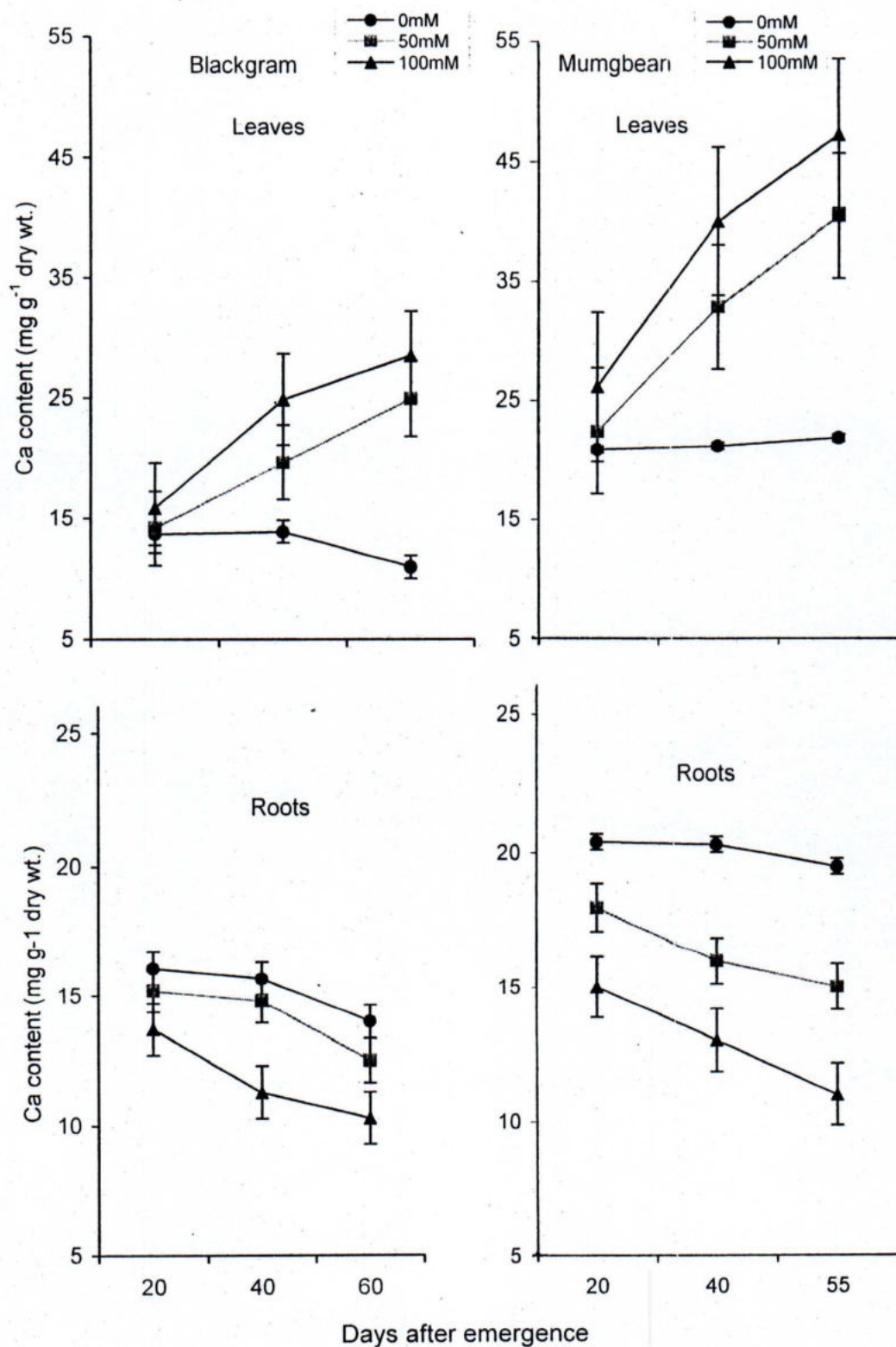


Fig.10: Change in Ca^{2+} content in leaves and roots of blackgram and mungbean measured with time. Bars indicate SE ($\pm$).

Exactly a similar finding was also observed by Raptan (2000) in blackgram and mungbean. Concentrations of Na^+ , Ca^{2+} and Cl^- in roots and shoots increased in fieldpea (Lal and Bhardwaj, 1984) and in horsegram and greengram (Sudhakar *et al.*, 1990). Contrary, Helal and Mengel (1979) in barley, Al-Niemi (1981) in sorghum, corn and soybean, Paliwal and Maliwal (1980) in pearl millet, sorghum, greengram and blackgram, Nakamura *et al.* (1990) in mungbean, Patil *et al.* (1992) and Patil *et al.* (1995) in greengram found that calcium uptake decreased with the increase in saline water irrigation. Nakamura *et al.* (1990) reported that addition of Ca^{2+} to the external medium alleviated the inhibition of root elongation by salt stress and the plant under such condition maintained a high intracellular concentration of K^+ in the elongation region of the roots by encountering NaCl stress. These findings indicate that Ca^{2+} prevents the leakage of intracellular K and thereby supports the elongation of roots under salt stress (Nakamura *et al.*, 1990; Raptan, 2000).

Effect of NaCl on plant morphological characters of *Vigna spp.*

Plant height

Salinity has a significant effect on plant height of both blackgram and mungbean. The plant height, measured at different growth stages, was always higher in mungbean than that in blackgram (Fig. 11). Plant height decreased progressively with the increasing salinity levels and the reduction

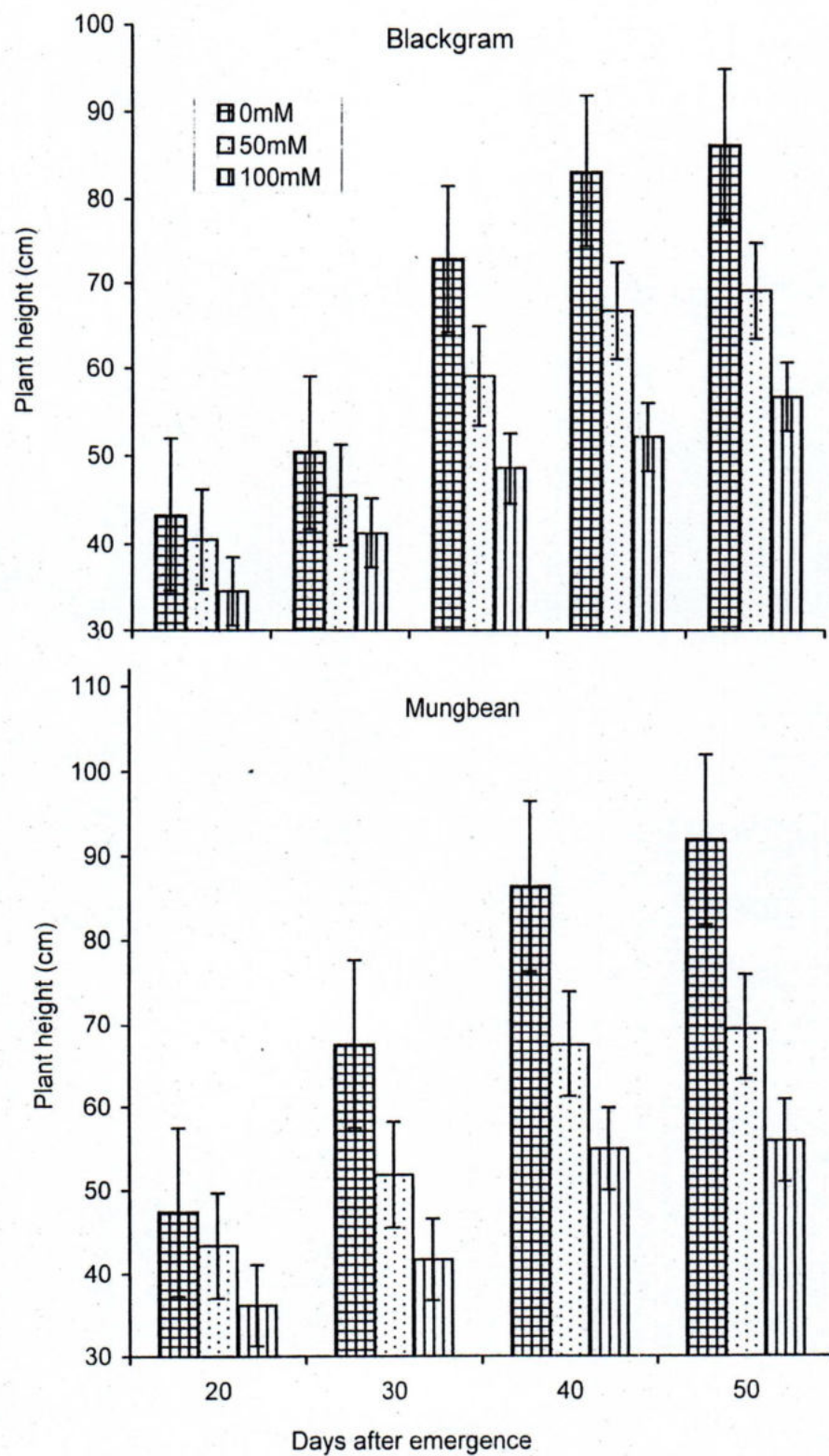


Fig.11: Effect of NaCl on plant height of blackgram and mungbean measured at different days after emergence. Bars indicate SE ($\pm$).

was conspicuously greater in mungbean than that in blackgram at all levels of salinity. Plant height increased rapidly upto 40 DAE and thereafter increased very slowly up to harvesting under saline conditions. The highest plant height (86.30 cm) was obtained at control condition and the lowest (54.84 cm) at high level of salinity in blackgram during harvesting stage which was 63 percent to the control. In mungbean, the highest plant height (93.60 cm) was obtained at control and the lowest (57.60 cm) at 100 mM during harvesting stage which was 61 percent to the control. Therefore, blackgram showed relatively high salt tolerance in plant height than mungbean. Salinity induced reduction in plant height was also reported by Egeh and Zamora (1992) for *Vigna radiata*, *V. unguiculata* and *Glycine max*. Duong *et al.* (1988) observed that plant height of mungbean adversely affected by salinity. Maliwal and Paliwal (1982) also found a similar result in *Vigna radiata*, *V. mungo* and *Cyamopsis tetragonoloba*. Raptan (2000) observed that plant height in mungbean decreased more than that in blackgram under saline condition. Therefore, the response of blackgram and mungbean to salinity as observed in this study was similar to the findings of Raptan (2000).

Green leaf area

Green leaf area per plant was measured up to 50 DAE in mungbean and 60 DAE in blackgram, because mungbean was matured earlier than blackgram. Green leaf area per plant increased up to 40 DAE in both the

crops and thereafter decreased in mungbean plant at all the treatments. In case of blackgram, it was increased up to 50 DAE at mild and high salt stress and then decreased (Fig. 12). Green leaf area per plant was higher in blackgram than in mungbean at all the treatments and the reduction due to salinity was also greater in mungbean than that in blackgram. Green leaf area per plant was reduced by 36 % and 59 % over the control at 40 DAE of blackgram and mungbean with 100 mM NaCl, respectively. Chlorosis on the leaves was observed at high salt concentration, which was observed within 10-12 days after imposition of salinity in mungbean but much later in blackgram. It indicated that leaves of mungbean were more sensitive to salinity than those of blackgram. Mangal and Lal (1988) reported that the necrosis, which was observed at high salt concentration, was probably due to toxic effect of excessive accumulation Na^+ as well as Cl^- due to hydration of protein and protoplasm to some extent. Cramer *et al.* (1991) stated that long term exposure to salinity leads premature leaf senescence and thus reduced the photosynthetic area in barley. Due to long term exposure to salinity a large amount of salt is transported into shoot, especially into old leaves, thus killing them (Munns and Termat, 1986).

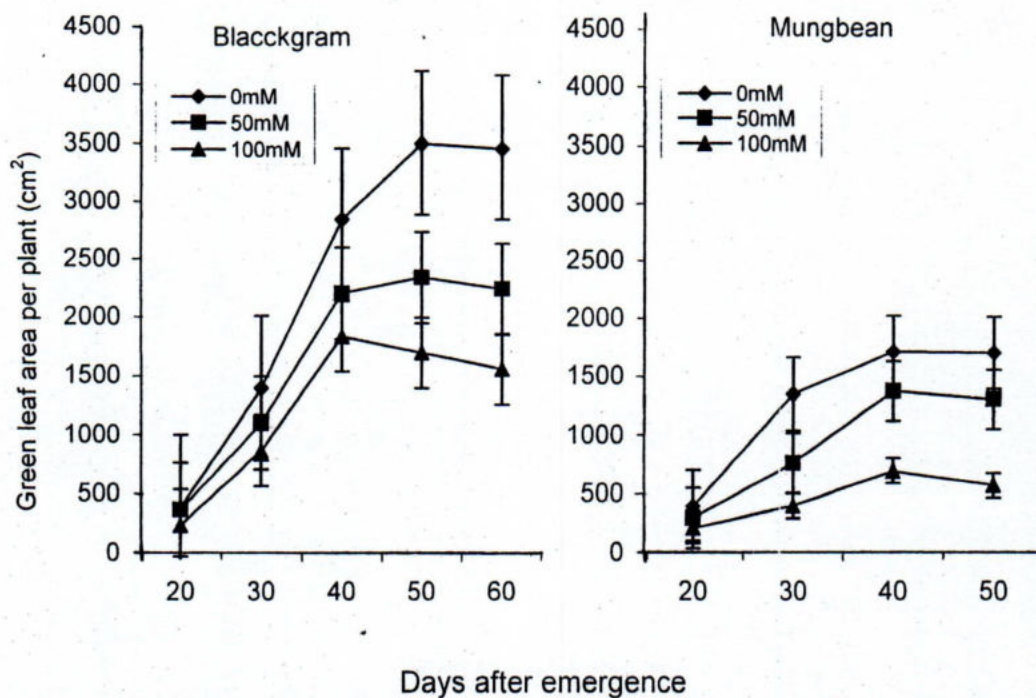


Fig.12: Effect of NaCl on green leaf area per plant of blackgram and mungbean measured at different days after emergence. Bars indicate SE ($\pm$).

Crop phenology

There is a general view that duration of crop is shortened by environmental stresses because of limited source size due to leaf senescence. Salinity reduced the crop duration of blackgram and mungbean (Table 3). Blackgram took longer time to flower and maturity than mungbean at all salinity levels. The shortest time (30 and 28 days) to flower was observed under 100 mM salinity levels, which was 81 and 82 percent of the control of blackgram and mungbean, respectively. Siddique and Kumar (1985) in pea and Promila and Kumar (1982) in pigeonpea also noticed an enhanced flowering time due to salinity. In contrast to this result, Raptan (2000) observed that salinity did not influence significantly the days to flowering in either blackgram or mungbean varieties. The dissimilar result of this study with Raptan (2000) might be due to influence of other environmental factors such as temperature which was not exactly same in both the year

Pod setting period was significantly reduced at 100 mM NaCl. The two crops took statistically similar time to pod setting at all levels of salinity. Days to maturity decreased progressively with the increasing salinity levels (Table 3) and the reduction was greater in mungbean than in blackgram. Moreover, the absolute days to maturity were higher in blackgram than in mungbean at all levels of salinity. Blackgram took 65 and 60 days to mature (96 and 88 % to the control) while mungbean took 54 and 50 days (90 and 83 % to the control) at 50 and 100 mM salinity, respectively.

Table 3: Effect of NaCl on crop phenology of blackgram (BG) and mungbean (MB).

NaCl (mM)	Days to 1 st flowering		Days to 1 st pod setting		Days to Maturity	
	BG	MB	BG	MB	BG	MB
0	37	34	39	37	68	60
50	34	32	37	35	65	54
	(92)	(94)	(95)	(95)	(96)	(90)
100	30	28	34	31	60	50
	(81)	(82)	(87)	(84)	(88)	(83)
LSD	3.10	1.97	3.05	2.81	2.72	3.56
CV (%)	12.3	7.56	17.3	11.2	13.5	12.2

Values in parenthesis indicate percent values to the control.

Dry matter accumulation

Production of economic yield is determined by the proportion of assimilates partitioned to reproductive organ (Singh and Yadav, 1989). Thus it is important to understand the dry matter accumulation pattern and its partitioning to different plant organs for the improvement of yield level in saline soils. The effect of salinity on the pattern of dry matter accumulation and the partitioning in leaves, stem, reproductive organ and roots are described hereunder.

Leaf dry matter

Dry matter production of crop is mostly dependent on the magnitude of assimilatory system. Assimilatory system composes of all green area of plants. However, leaf is the largest component of the system (Nanda and Saini, 1989). Salinity influenced partitioning of leaf dry weight markedly in both blackgram and mungbean at all growth stages. The leaf dry matter per plant decreased significantly with the increasing salinity (Fig. 13). Blackgram had higher leaf mass than mungbean from 30 DAE till maturity at all levels of salinity. The reduction of leaf dry weight per plant due to salinity was higher in mungbean than that in blackgram. Under control and mild stress conditions leaf dry weight increased up to 50 and 60 DAE in mungbean and blackgram, respectively. Thereafter the dry matter weight decreased. The decrease in leaf dry weight at later part of growth may be due to leaf senescence and remobilization of stored materials to the

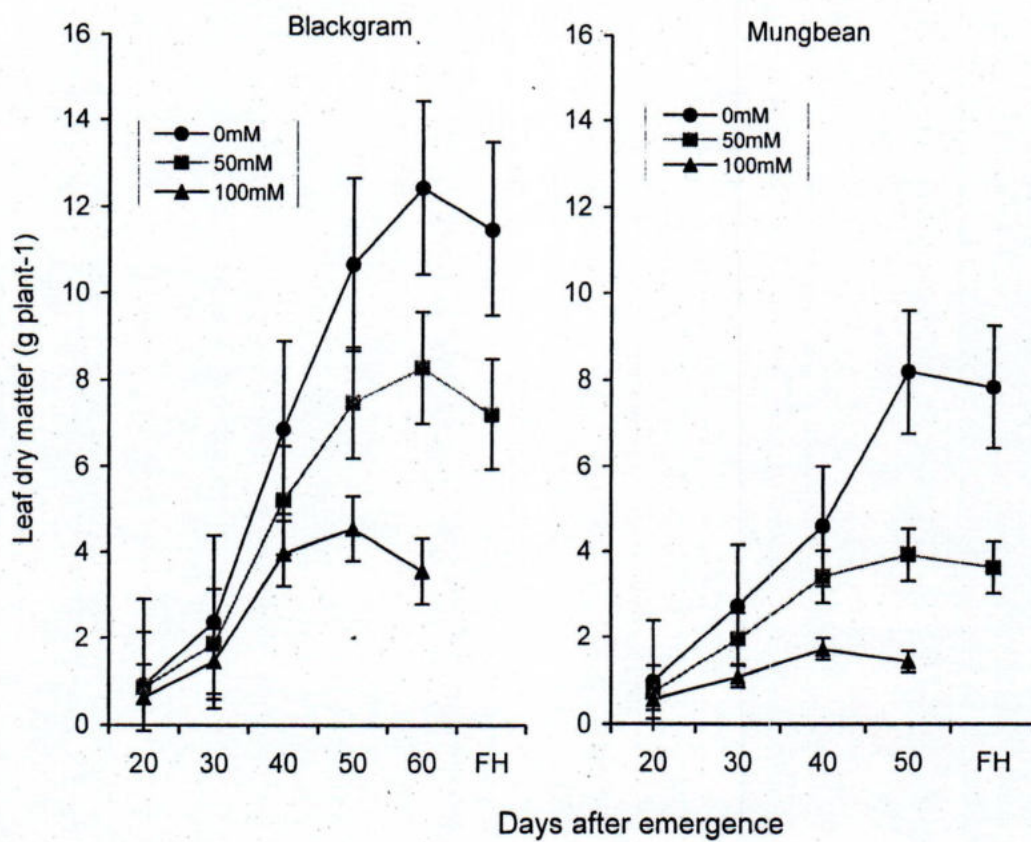


Fig.13: Effect of NaCl on leaf dry matter of blackgram and mungbean measured at different days after emergence. FH: indicates final harvest. Bars indicate SE ($\pm$).

reproductive organs (Chowdhury, 1992 and Khan, 2000). At control the highest leaf dry weight of blackgram was 11.27 g per plant while that was only 7.85 g per plant in mungbean. A strong relationship was also observed between leaf dry weight and total dry weight of blackgram and mungbean. During harvesting stage, the leaf dry matter production was 65 and 36 percent in blackgram and 45 and 30 percent in mungbean (% to the control) at mild and high salinity levels, respectively. 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 *et al.* (1990) in mungbean and Raptan (2000) in blackgram and mungbean.

Stem dry matter

Stem dry matter production per plant significantly reduced with salinity in both blackgram and mungbean. The reduction was higher in mungbean than in blackgram from 30 DAE till maturity (Fig. 14). Blackgram produced greater stem dry weight than in mungbean irrespective of salinity levels. Pattern of stem dry matter production was almost similar to that of leaf dry matter at all salinity levels. Stem dry matter weight in blackgram increased up to 60 DAE at control and 50 mM NaCl and thereafter decreased. At 100 mM, the stem dry matter increased to only 50 DAE. In mungbean the stem dry matter at control and 50 mM increased up to 50 DAE while that at 100 mM NaCl was up to 40 DAE. Blackgram was

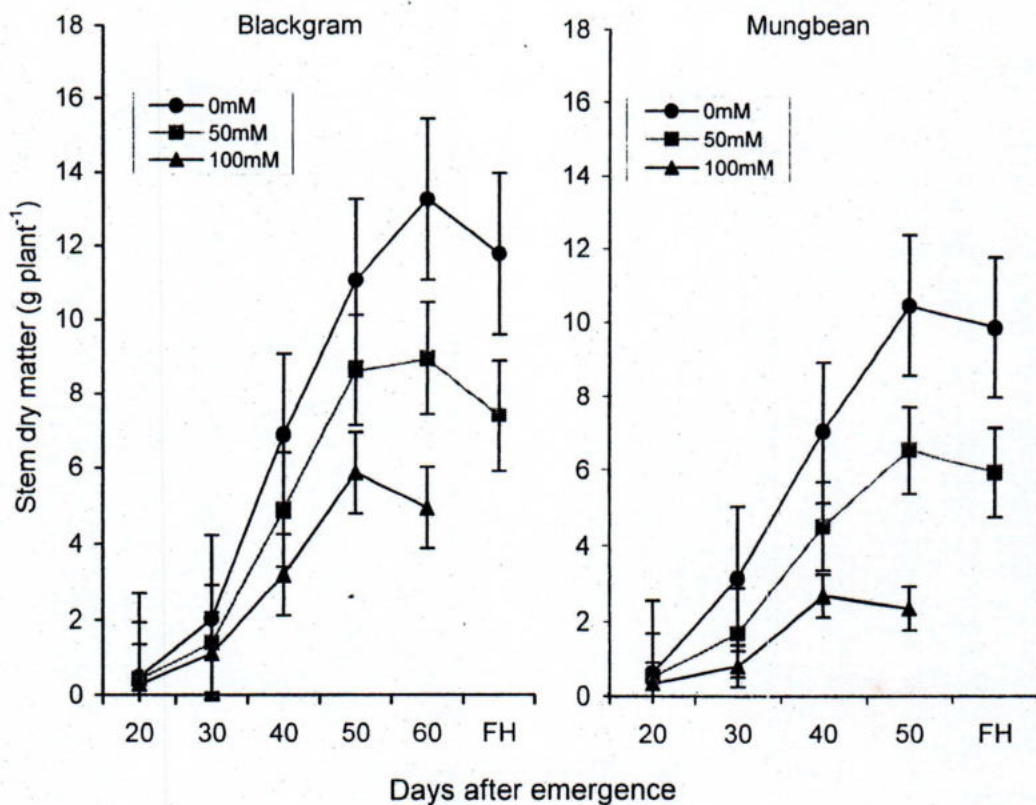


Fig.14: Effect of NaCl on stem dry matter of blackgram and mungbean measured at different days after emergence. FH: indicates final harvest. Bars indicate SE ($\pm$).

comparatively more tolerant than mungbean in terms of both absolute and relative stem biomass production (The result is in agreement with Ashraf and Rasul (1987) who noticed that increasing salt concentration significantly reduced the dry matter weight of stem in mungbean [*Vigna radiata* (L.) Wilczek]) Reduction in stem dry weight under saline condition was also observed in mungbean by Gill (1988) and Patil *et al.* (1996), and in cowpea and mungbean by Balasubramanian and Sinha (1976). Salinity decreased the stem dry mass irrespective of species (blackgram and mungbean) or varieties and longer the exposure to salinity higher was the damage as reported Raptan (2000).

Reproductive organ dry matter

Dry matter weight of reproductive organs was started to increase from 30 DAE, increased slowly up to 40 DAE and continued to increase sharply till harvest in all the treatments (Fig. 15). Salinity decreased the production of reproductive dry matter in both blackgram and mungbean) However, the reduction was much higher in mungbean than in blackgram. During harvesting stage, the maximum reproductive organ dry weight (13.22 g plant⁻¹) was produced by mungbean at control condition which was almost similar (12.74 g plant⁻¹) to blackgram at the same treatment. Reproductive organ dry matter at maturity stage was reduced to 17 and 59 percent in blackgram and 64 and 89 percent in mungbean under mild (50 mM) and high salt (100 mM) levels, respectively. It revealed that photoassimilate

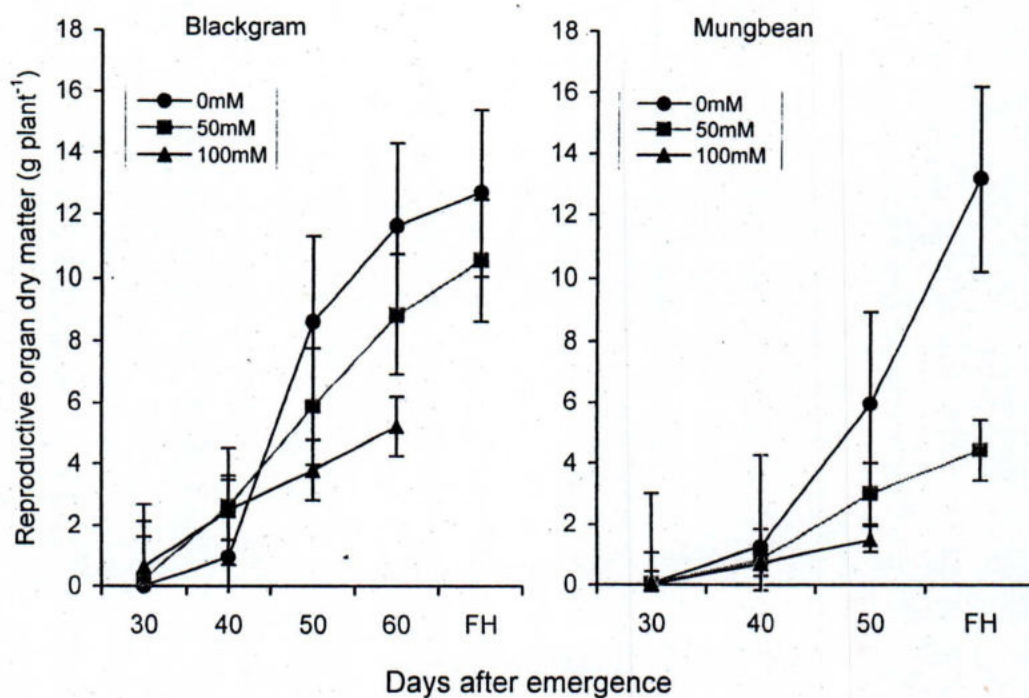


Fig. 15 : Effect of NaCl on reproductive organ dry matter of blackgram and mungbean measured at different days after emergence. FH: indicates final harvest. Bars indicate SE (±).

partitioning was influenced by salinity, and blackgram showed more salt tolerance than mungbean in the reproductive organ dry matter production. The findings reconfirmed the report of Raptan (2000) that salinity decreased the reproductive dry matter weight of mungbean more than that of blackgram.

Root dry matter

Root dry matter of blackgram increased up to 50 and 60 DAE at 50 and 100 mM NaCl levels, respectively and thereafter decreased. Under control condition it was increased till maturity (Fig. 16). In mungbean, root dry weight increased up to 40 DAE under saline condition and thereafter decreased. Under control condition the root mass increased till maturity. Salinity significantly reduced the root dry matter per plant in both blackgram and mungbean and longer the exposure to salinity higher was the damage of root biomass. The roots of mungbean, in general, were damaged more than that of blackgram. At 100 mM NaCl concentration blackgram produced $0.80 \text{ g plant}^{-1}$ root biomass while in mungbean it was only $0.43 \text{ g plant}^{-1}$ at final harvest (Table 4). Blackgram produced 60 and 30 percent (to the control) root dry weight under 50 and 100 mM NaCl levels while, mungbean produced only 49 and 28 percent to the control at the same treatments during harvesting stage. The higher root growth of blackgram than mungbean presumably contributed to higher shoot growth under saline condition. Salinity induced damage in root mass was also reported earlier by

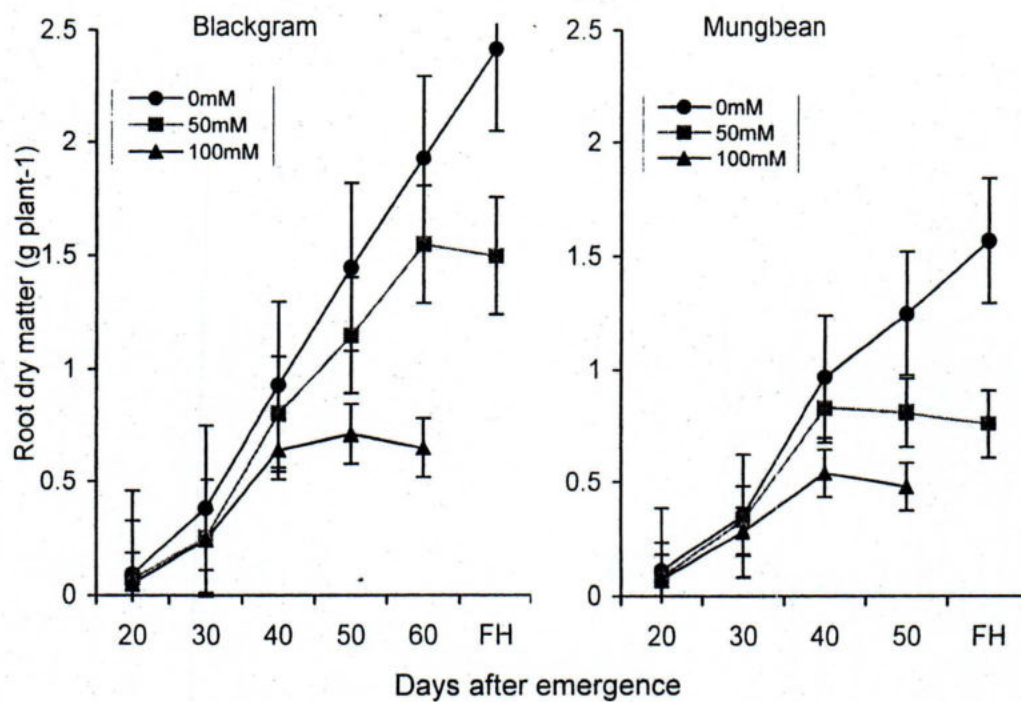


Fig.16: Effect of NaCl on root dry matter of blackgram and mungbean measured at different days after emergence, FH: indicates final harvest. Bars indicate SE (±).

Balsubramanian and Sinha (1976) in cowpea and mungbean, Kumar and Bhardwaj (1981) and Siddique and Kumar (1985) in pea, Gill (1990) in greengram, Sudhakar *et al.* (1990) in horsegram, and Raptan (2000) in blackgram and mungbean.

Total dry matter

Accumulation of total dry matter (TDM) per plant increased progressively over time and reached the highest at physiological maturity (Fig. 17). Dry matter production at high salt treatment resembled to that of leaf area development up to 40 DAE. The strong relationship ($r = 0.98$ and $r = 0.97$) between leaf area and dry matter production of blackgram and mungbean indicates the high influence of leaf mass on TDM production. At final harvest, TDM per plant decreased significantly with increasing salinity in both blackgram and mungbean (Table 4). The reduction in TDM was remarkable at 100 mM NaCl condition. The absolute amount of TDM was higher in blackgram than that in mungbean at all salinity levels. In general, TDM of mungbean decreased more remarkably compared to that of blackgram. At 100 mM NaCl, blackgram produced 41 percent TDM (% to the control) while mungbean produced only 26 percent (Table 4). This result is consistent with the findings of Raptan (2000) that mungbean is relatively salt sensitive than blackgram in TDM production. Hafeez *et al.* (1988) observed that dry matter yield decreased significantly with the increase in salinity regardless of the stages of plant growth. Patil *et al.* (1996) observed

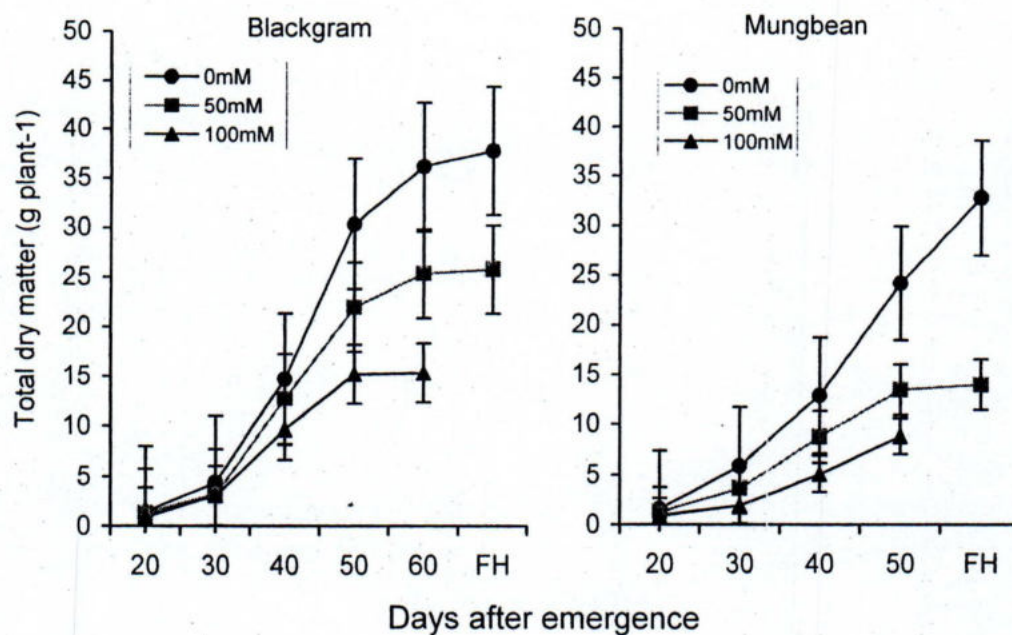


Fig. 17: Effect of NaCl on total dry matter production of blackgram and mungbean measured at different days after emergence. FH: indicates final harvest. Bars indicate SE ($\pm$).

✓ that total dry matter at all growth stages in mungbean was reduced by increasing salinity. Reduction in growth and total dry matter production under saline condition was also reported earlier in different legumes eg. in mungbean (Salim and Pitam, 1987; Duong *et al.*, 1988; Gill, 1988; Patil *et al.*, 1992; Singh *et al.*, 1994), in mungbean, cowpea and soybean (Egeh and Zamora, 1992), in cowpea and mungbean (Hug *et al.*, 1983), in horsegram and greengram (Sudhakar *et al.*, 1990), in pea (Siddique and Kumar, 1985), in *Vicia faba* and *Phaseolus vulgaris* (Abdel Ghaffar *et al.*, 1982) and in *Glycine wightii* (Wilson, 1970).

Table 4: Effect of NaCl on dry matter production (g/plant) in different plant parts of blackgram (BG) and mungbean (MB) at harvest.

NaCl (mM)	Dry wt. of different plants parts						Total dry matter/plant (g)			
	Leaves		Stems		Repro. Organ		Shoot		Root	
	BG	MB	BG	MB	BG	MB	BG	MB	BG	MB
0	11.08	7.85	10.79	9.87	12.74	13.22	34.61	30.94	2.68	1.52
50	7.21	3.57	7.44	5.94	10.58	4.44	25.23	13.95	1.60	0.75
	(65)	(45)	(69)	(60)	(83)	(34)	(67)	(44)	(60)	(49)
100	3.99	2.35	4.96	2.52	5.23	1.49	14.18	6.36	0.80	0.43
	(36)	(30)	(46)	(25)	(41)	(11)	(41)	(26)	(30)	(28)
LSD	2.94	0.51	2.54	2.01	4.57	3.24	8.24	5.36	0.29	0.21
CV(%)	12.57	9.52	10.10	13.20	14.21	7.54	12.36	6.58	11.25	8.52

Values in parenthesis indicate percent values to the control.

Effect of NaCl on yield and yield components of *Vigna spp.*

Total pods per plant

(Blackgram significantly produced higher number of pods per plant at control as well as at all salinity treatments. Salinity decreased the number of pods in both the crops) However, the reduction in mungbean was remarkable. In blackgram only 10 and 25 % pods were reduced whereas in mungbean the reduction was 68 and 85% at 50 and 100 mM NaCl, respectively (Table 5). The result reconfirms the findings of Raptan (2000) that salinity affected pod production more in mungbean than that in blackgram. Salinity induced reduction in pods per plant was also reported earlier by Hafeez *et al.* (1988) and Patil *et al.* (1996) in *Vigna spp.*)

Pods with grain per plant

(Irrespective of salinity blackgram had conspicuously higher number of pods per plant with grain, i.e. productive pod (Table 5). Salinity decreased the productive pods per plant in both the crops) However, the number of productive pods per plant was decreased severely in mungbean compared to that in blackgram. At 50 and 100 mM NaCl the number of productive pods in blackgram was 90 and 63 %, respectively, while that was only 35 and 13 % in mungbean. The findings of Raptan (2000) also revealed that the production of productive pods in mungbean was disturbed by salinity more in mungbean than that in blackgram. Earlier reports clearly

indicated that number of productive pods was decreased due to salinity in chickpea (Ram *et al.*, 1989) and mungbean (Hafeez *et al.*, 1988; Patil *et al.*, 1996).

Number of seeds per pod

Mungbean pods had remarkably higher number of seeds than blackgram in control as well as in salt treatments. Although statistically insignificant, the number of seeds per pod gradually decreased with the increasing salinity in both the crops. At 50 and 100 mM NaCl, blackgram produced 92 and 88% whereas mungbean produced 97 and 87% seeds per pod, respectively. Raptan (2000), however, observed that number of seeds per pod was significantly reduced by salinity in mungbean but not in blackgram.

1000-seed weight

(The 1000-seed weight was decreased significantly with the increasing salinity levels and a greater reduction was observed in mungbean than in blackgram (Table 5). At all levels of salinity 1000-seed weight was higher in blackgram than in mungbean. At control the 1000-seed weight in blackgram was 36.13g while that in mungbean was only 32.42g. When the plants were treated with 100 mM NaCl the 1000-seed weight reduced to 24.49g and 21.02g in blackgram and mungbean, respectively.) Thus, 100 mM NaCl salinity reduced the 1000-grain weight to 68 and 65 percent in

blackgram and mungbean, respectively. The significant reduction of 1000-seed weight in both the crops clearly indicated that salinity slowed down the mobilisation of assimilates to the seeds. Siddique and Kumar (1985) reported that pea seeds were shrunked at 75 and 100 mM NaCl salinity and thus the 1000-grain weight was also reduced seriously. These results are in general agreement with the findings of Raptan (2000) in *vigna spp.*, Malik *et al.* (1977) in pea, Lauter and Munns (1981) in chickpea and cowpea and Ashraf and Karim (1990) in mungbean that salinity impairs seriously the normal growth of seeds that ultimately affect the individual grain size.

Grain yield per plant

(Grain yield is the function of number of productive pods per plant, seeds per pod and 1000-seed weight. Change in any one of the characters will be reflected on grain yield production) At control, the two crops produced significantly similar grain yield (9.68 and 9.15 g/plant in blackgram and mungbean, respectively) (Table 5) (Salinity decreased the grain yield in both blackgram and mungbean.) However, the reduction was frustrating in mungbean compared to blackgram. (At 50 and 100 mM NaCl the grain yield reduced to 81 and 35 percent in blackgram) while that was 35 and 10 percent in mungbean, respectively. The serious reduction in pod sets per plant as well as 1000-grain weight was mostly responsible for the salinity induced reduction in grain yield in the *Vigna spp.* (The findings of this study reconfirm the report of Raptan (2000) that blackgram is more salt

tolerant) than mungbean. Reduction in grain yield per plant under saline conditions were also reported by Salim and Pitam (1987), Hafeez *et al.* (1988), Duong *et al.* (1988), Gill (1988) and Singh *et al.* (1994) in *Vigna radiata*; Ram *et al.* (1989), Ashraf and Karim (1990) and Hye (2000) in chickpea, Siddique and Kumar (1985) in pea; Egeh and Zamora (1992) in mungbean, cowpea and soybean. On the whole the results of this study revealed that under saline conditions the relatively less reduction in Pn, maintenance of water relation and less accumulation of Na⁺ ion in blackgram than in mungbean favoured the production of higher grain yield in blackgram than in mungbean.

Table 5: Effect of NaCl on yield and yield components of blackgram (BG) and mungbean (MB).

NaCl (mM)	Total pods/plant		Pods with grain/plant		Seeds/pod		1000-seed wt. (g)		Grain yield/plant (g)	
	BG	MB	BG	MB	BG	MB	BG	MB	BG	MB
0	58.2	40.6	54.0	31.80	5.00	9.80	36.13	32.42	9.68	9.15
50	52.4	13.2	48.60	11.20	4.60	9.60	32.41	27.18	7.85	3.14
	(90)	(32)	(90)	(35)	(92)	(97)	(90)	(83)	(81)	(34)
100	44.1	6.0	34.20	4.00	4.40	8.60	24.49	21.02	3.40	0.95
	(75)	(15)	(63)	(13)	(88)	(87)	(68)	(65)	(35)	(10)
LSD	16.2	4.1	13.40	11.19	NS	NS	3.32	5.22	1.64	1.59
CV(%)	9.15	14.25	15.32	17.55	16.61	9.95	8.12	12.93	9.26	10.25

Values in parenthesis indicate percent values to the control.

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

Growth, yield and physiological mechanisms of salinity tolerance of blackgram (*Vigna mungo*) and mungbean (*V. radiata*) were analyzed in pot culture under semi-controlled conditions at the Bangabandhu Sheikh Mujibur Rahman Agricultural University during summer season of 2000. One blackgram (BARImash 2) and one mungbean (BARImug 3) variety were subjected to 0, 50 and 100 mM NaCl salinity from the appearance of trifoliolate to maturity stage. Different chlorophyll contents, photosynthetic light response curve, water relations and mineral ions accumulation in roots and shoot, and dry matter production were periodically analyzed.

Salinity affected seriously the biosynthesis of leaf chlorophylls, viz. chl. a, b and total chlorophyll. chl. a was higher in blackgram than in mungbean at all levels of salinity. However, the relative reduction in chl. a due to salinity was little higher in blackgram than in mungbean. Chl. b was also higher in blackgram than mungbean. The relative reduction in chl. b due to salinity was more or less similar in both blackgram and mungbean.) Total chlorophylls (a+b) were higher in blackgram than in mungbean at all levels of salinity. Salinity decreased the total chls. and the relative reduction (% to the control) due to salinity was higher in blackgram than mungbean.

Salinity increased the ratio of chl a/b and the ratio was higher in mungbean than blackgram.

The photosynthetic CO₂ assimilation rate (Pn) was measured at different light intensities (PFD), from 0 to 1600 $\mu\text{mol m}^{-2}\text{s}^{-1}$. The Pn increased with the increasing PFDs. Salinity decreased the Pn at all levels of salinity. Respiration measured at 0 PFD was higher in blackgram than that in mungbean. Salinity increased the respiration in both the crops. Mungbean showed higher Pn than blackgram at and above 400 PFD under control conditions. Photosynthesis of control plants of both blackgram and mungbean showed light saturation at 1200 $\mu\text{mol m}^{-2}\text{s}^{-1}$. The salt affected plants showed the saturation at much lower PFD. At 100 mM NaCl blackgram showed higher Pn than mungbean. Stomatal resistance (r_s) increased by salinity at all levels of salinity. The r_s was also increased with the increasing PFD irrespective of crops and salinity levels. The r_s was higher in blackgram than in mungbean at all levels of salinity. Salinity increased the intercellular CO₂ concentration (Ci) in both blackgram and mungbean. The Ci, however, decreased with the increasing PFD levels. The two crops showed more or less similar Ci at all the salt treatments.

Relative water content (RWC), water saturation deficit (WSD), water retention capacity (WRC), water uptake capacity (WUC) and exudation rate were measured at a regular interval starting from 20 DAE to maturity. Mungbean showed higher RWC than blackgram at the control. Salinity

decreased the RWC and mungbean showed greater reduction than blackgram. WSD showed an inverse trend of RWC. At all growth stages the different plant parts of salt treated mungbean plants showed higher relative WSD than that of blackgram. The turgid weight:dry weight ratio termed as water retention capacity (WRC) was decreased with the increasing plant age. Salinity decreased the WRC irrespective of plant age, and the reduction was greater in mungbean than in blackgram. The water uptake capacity (WUC) in general decreased with the plant age in all the salt treatments. Salinity increased the WUC in different plant parts of both the crops. Although blackgram showed a little higher WUC than mungbean the relative reduction of this character was higher in mungbean than blackgram. The exudation rate measured at different times was decreased greatly with the increasing salinity levels. The exudation rate of salt treated mungbean plant was much lower than that in blackgram at all growth stages. All the parameters related to water relations indicated that mungbean plant suffered more from water stress due to salinity than blackgram.

Sodium content increased in both roots and leaf with increasing salinity levels. Moreover, longer the exposure to salinity higher was the accumulation of Na^+ . Roots accumulated higher amount of Na^+ than leaf. Mungbean leaf as well as roots accumulated larger amount of Na^+ than those in blackgram. Presumably mungbean suffered more from Na^+ toxicity than blackgram. Plant age did not show significant influence on K^+ accumulation

as the K^+ content on 20 DAE was similar to that at harvest. Salinity decreased the accumulation of K^+ in both roots and leaf of blackgram and mungbean. Blackgram showed higher reduction in K^+ due to salinity than mungbean. Mg^{2+} accumulation was a little higher in mungbean than in blackgram. At control Mg^{2+} accumulation in roots and leaf of both blackgram and mungbean increased with plant age. Under saline conditions leaves showed an increasing while roots a decreasing pattern of Mg^{2+} accumulation with time in both blackgram and mungbean. Under saline conditions leaf showed an increasing while roots showed a decreasing tendency in Ca^{2+} accumulation. In general both roots and leaf of mungbean accumulated higher content of Ca^{2+} than those of blackgram. Perhaps the three mineral ions, potassium, magnesium and calcium, did not influence directly on the degree of tolerance between blackgram and mungbean.

(Growth responses of blackgram and mungbean to salinity were studied periodically. Plant height and green leaf area were affected seriously by salinity. Salinity induced reduction in plant height and green leaf area was much higher in mungbean than blackgram. Blackgram took longer time to flower as well as to mature than mungbean at all salinity levels.)

(Leaf dry matter was decreased substantially by salinity and the reduction was higher in mungbean than in blackgram. Stem dry matter weight was also decreased by salinity and the stem of mungbean was reduced more than blackgram. Dry matter accumulation in reproductive

organ started to increase from 30 DAE and increased slowly up to 40 DAE, then rapidly till the harvest of the two crops. Root dry weight of blackgram increased up to 50 and 60 DAE at 50 and 100 mM NaCl levels and that in mungbean increased up to 40 DAE, thereafter decreased. Under control condition the root mass increased till maturity. Accumulation of total dry matter (TDM) per plant increased progressively over time and reached the peak at maturity. TDM per plant decreased significantly with the increasing salinity in both the crops. However, the TDM of mungbean reduced more than the TDM of blackgram. At 100 mM NaCl blackgram produced 41 percent TDM (% to the control) while mungbean produced only 26%.

Blackgram produced remarkably higher number of pods per plant than mungbean. Salinity decreased the pod production and the reduction was higher in mungbean than blackgram. Contrary, the seeds per pod were higher in mungbean than blackgram irrespective of salinity treatments. Salinity did not inhibit significantly the pod production in blackgram though inhibits in mungbean. Salinity decreased 1000-seed weight, and blackgram produced larger seed (1000-seed weight) at all levels of salinity compared to that of mungbean. At all salinity levels the grain yield was higher in blackgram than in mungbean. Moreover, the salt induced reduction in grain yield was conspicuously higher in mungbean than in blackgram. At 50 and 100 mM NaCl the grain yield reduced to only 81 and 35 percent (% to the control) in blackgram while that was 34 and 10 percent in mungbean.

(Therefore blackgram was relatively salt tolerant) than mungbean in grain yield production.)

It was concluded from the study that, under saline conditions, the relatively less reduction in P_n , maintenance of better water relations and less accumulation of Na^+ ion in blackgram than mungbean contributed to the high salt tolerance of the former crop than the later one.

LITERATURE CITED

CHAPTER VI

LITERATURE CITED

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Uzamora

APPENDIX

Appendix 1. Meteorological data during May to July, 2000.

Month		Temperature (0°C)			Rainfall (mm)	Relative humidity (%)			Sunshine (hrs/day)
		Max	Min	Mean		Max	Min	Mean	
May	01-10	31.16	22.77	26.97	16.56	92.61	58.53	75.57	5.78
	11-20	34.83	26.58	30.71	7.29	91.20	54.40	72.80	6.31
	21-31	31.53	25.11	28.32	16.14	91.12	64.59	77.88	3.72
June	01-10	34.34	24.64	29.49	1.80	91.28	63.46	77.37	6.17
	11-20	33.42	25.22	29.32	12.67	91.70	59.46	75.58	4.88
	21-30	33.14	26.04	29.59	9.83	92.18	64.61	78.40	4.81
July	01-10	34.88	28.47	31.68	8.00	89.82	66.09	77.96	5.71
	11-20	34.18	27.35	30.77	12.24	90.15	68.91	79.53	4.05
	21-31	32.43	26.67	29.55	4.31	92.72	66.96	79.84	5.74

Source: BSMRAU weather station and BRRI crop physiology laboratory, Gazipur.