Crop Response under Groundwater Salinity Stress
- A Controlled Environment Study -

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1. Introduction

In dry saline soils, plants are exposed to increased level of water and osmotic stresses, because of the metric potential and the osmotic potential decrease simultaneously with decreasing soil moisture (Glenn and Brown, 1998). Salinity affects crop growth by decreasing water availability to roots due to osmotic effect of external salt and by toxic effects with in the plant (Munns, 1993). It creates interference with crop growth when exceeds their tolerance limits of the crop (ASCE, 1990; Karim et al., 1990).

Sustainable saline agriculture has received little attention, especially groundwater salinity (GWS) induced affect on productivity, and therefore become imperative to exploit more the potential of these marginal lands having saline shallow groundwater in order to meet ever increasing food demands globally.

2. Experimental Design and Procedure

This experimental study was conducted in a Biotron (control chamber) to maintain the climatic effects uniform using long cylindrical column (micro-lysimeter) of length and diameter as 60cm and 20cm, respectively. Each column was connected to mariot siphon to maintain constant watertable at 55 cm depth through hydrostatic pressure (Fig.1). Drainage was not considered, as the objective was to keep constant watertable depth. Wheat (Spring-type) was selected for the experiment because of its relative tolerance to salinity and importance as main staple food for most of the countries, producing 420 million tones from 325 Mha (FAO, 1979). Sieved sand soil (2.0 mm mesh) brought from Yamagata city was used to grow crop. Sandy soil is generally easy to use for sub-irrigation due to its hydraulic conductivity.

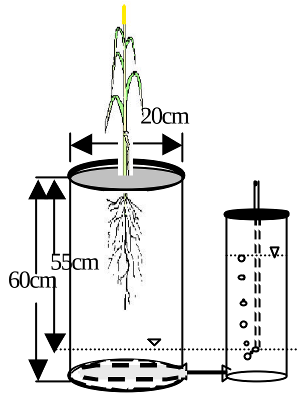

Fig. 1. Apparatus Design

Two treatments with one controlled value were designed as; controlled (C-1) ECw=0.2dS/m, (C-2) ECw=3dS/m, and (C-3) ECw=6dS/m with three replications. Equivalent amount of salt (NaCl) to fresh water were added to obtain required GWS (ECw) levels. Nursery was developed by sowing health seeds in sand trays, providing normal irrigation water to field capacity of soil. Four best seedlings of uniform height per column were selected and transplanted carefully, 10 days after sowing (DAS). Three times uniform nutrient solution were provide (during vegetative, flowering and yield formation stages) through fertilizers at the ratio of N-P-K:10-3-3 to all treatments. Room temperature was controlled at 25 °C during daytime, and 20 °C during nighttime. Relative air humidity was maintained at 60%. No surface water was provided after transplantation. Statistically, two-factor factorial completely randomized design (CRD) was adopted for the experiment analysis.

The measurements / observations carried out during the experiment are the following parameters; i) pan evaporation, ii, evapotranspiration, iii) crop phonological visual observations during different growth stages. The relative impact of constant brackish groundwater table was analyzed against controlled treatment for the following crop growth/productivity parameters like; plant height, dry biomass, grain yield, and number of spikelets/kernels, measured just after the harvest (103 DAS) of the crop. All columns were sampled at each 5 cm from surface to 50 cm depth for soil profile salinity (ECe), Moisture content and dry bulk density using soil core samplers, adopting a method as described by Blake and Hartge (1986). Soil extract of 1:5 was used for soil salinity measurements using a mechanical shaker (Method 3c, U.S. Salinity Lab. Staff, 1954). A well known gravimetric method was adopted for measuring soil-moisture content (Gardner, 1986). The statistical analysis was performed to see the crop response induced with GWS using MSTAT software by ANOVA and LSD-test at probability level of $P \leq 0.05$.

3. Results and Conclusions

The differences in water stress finally appear in terms of water consumption efficiency (ETc) presented in Fig.2 (periodic and accumulative values). Comparing to the average difference for a controlled (salt free)

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treatment. High ETc was observed for C-1, followed by gradual decrease in C-2 and severely to C-3 treatment. It was observed that GWS did not show considerable effect at initial growth stages for C-2 and C-3 compared to all later stages, caused decline in productivity due to salinity-stress (osmotic effect) to plant roots in water up-take.

The salt concentration (in-situ) was calculated by converting EC1:5 data, shown in Fig.3, presenting strength of salt concentration in real soil solution conditions. These results showed that treatments C-2, C-3 got high concentration on upper soil profile due to evaporation and capillary rise compared to lower rootzone. As the wilting point (WP) is equal to 15bar for most of the plants (equal about 30dS/m) as threshold value, both the treatments are still in safer side for the rootzone depth but if the same conditions prevails it may reach to that limit and plant can wilt. Treatment C-3 has more chances to approach critical value with in another crop-growing season, and therefore needs periodically extra leaching water from surface. The results can be converted in terms of osmotic potential (not shown here) as 10dS/m=4.9bar approx.

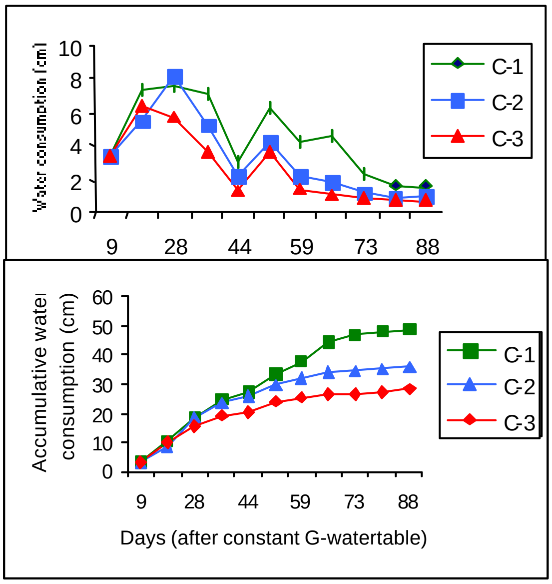

Fig. 2 Periodical and Cumulative difference in ETc.

Crop growth and yield parameters of spring wheat have been studied as one of the main objective to know the crop response on static watertable of different qualities. Means of each treatment has been compared by LSD test (Table 1) for saline and controlled conditions at 5% significant level. The results shows that the GWS variation is not significant with treatments C-1, C-2 but highly significant with C-3 in yield and dry biomass. No significant difference has been found in-terms of plant height but there is significant difference in no. of spikelets for C-3.

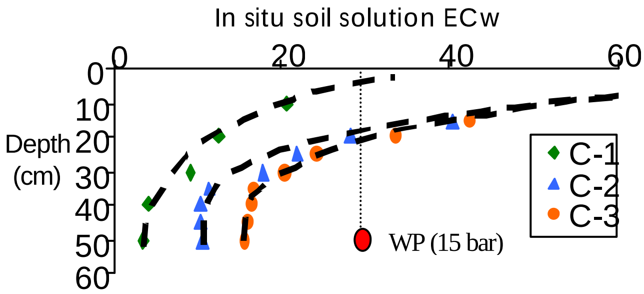

Fig. 3. In-Situ soil solution salt concentration in soil profile

Table1. Analysis of "variance" and "means" using LSD test

Treat.	Grain Yield (gm/p)	Dry Biomass (gm/p)	Plant Hight (cm)	No. of Spikelets
C-1	1.48 a	6.91 a	73.42 a	8.26 a
C-2	1.41 a	5.61 b	71.62 a	7.03 b
C-3	1.28 b	4.78 c	70.51 a	5.42 c
$P \leq 0.05$	**	**	N.S	***

It is observed that moderately tolerant crop like wheat can survive with shallow GWS, using as sub-irrigation, of ECe <4dS/m without any serious harm, provided minimum extra surface water as leaching fraction periodically, to avoid multi-cropping seasonal salinity build-up effect. However this is proposed that the study may be verified in the field environment with proper soil-water management. Due to scarcity of water in semi-arid areas, it could be applied socio-economically with supplement but limited surface irrigation during sensitive crop stages. The proposed system will be helpful in reducing waterlogging, drainage disposal, balance with shortage water, increase soil and agro-productivity, and will enhance biosaline agriculture system in semi-arid areas.

4. References

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