Research Article

# Impact of Soil Conditioning and Irrigation Regimes on the Performance of Maize Crop

**Muhammad Ijaz Khan*** **and Amanullah Jan**

*Department of Agronomy, Faculty of Crop Production Sciences, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan.*

**Abstract** | In order to improve the physical conditions of soil and provide favorable environment for the growth and development of crops, soil conditioners are used. This study was carried out to evaluate the impact of soil conditioning and irrigation regimes on the performance of maize crop during 2011 and 2012. Four irrigation regimes ranging from 3-6 irrigation in relation to the critical stages of maize crop were applied. Irrigation consisted of 93 mm water. Three organic soil conditioners viz., farmyard manure (10000 kg $ha^{-1}$), wheat straw as crop residue (10000 kg $ha^{-1}$) and two levels of humic acid (2 and 4 kg $ha^{-1}$), alone and in combinations with gypsum (1000 kg $ha^{-1}$) as inorganic soil conditioner were applied a week before sowing of maize. Design used was randomized complete block with split plot arrangement replicated thrice. Experimental site was Agronomy Research Farm, The University of Agriculture Peshawar. Irrigations regimes were subjected to main plots while soil conditioners to subplots. Results of the two years study indicated that most of the yield and soil parameters were affected by irrigation regimes significantly. Higher crop growth rate, leaf area plant, plant height, biological yield (above ground parts of the plant), grain and straw N contents were found in five times irrigated plots as compared with lower irrigation regime. Results showed that growth characteristics and quality of maize were significantly affected by soil conditioners (SC). Farmyard manure incorporation produced significantly higher crop growth rate, leaf area $plant^{-1,}$ taller plant, higher biological yield, grain and straw N contents of maize crop as compared to other soil conditioners and control treatments. Data on the effect of gypsum application as sole or in combination with the other SC revealed that addition of gypsum had significantly increased all parameters as compared with no gypsum application. It is concluded that farmyard manure (10000 kg $ha^{-1}$) and gypsum (1000 kg $ha^{-1}$) with five irrigations at the known critical stages (at emergence, 4 leaves, 8 leaves and tassel visible and blister) performed better as compared with other treatments applied for obtaining good return from maize crop in Khyber Pakhtunkhwa, Province, Pakistan.

**Received** | February 13, 2017; **Accepted** | January 29, 2018; **Published** | February 26, 2018
***Correspondence** | Muhammad Ijaz Khan, Department of Agronomy, Faculty of Crop Production Sciences, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan; **Email:** ijaz_agrian@yahoo.com
**Citation** | Khan, M.I. and A. Jan. 2018. Impact of soil conditioning and irrigation regimes on the performance of maize crop. *Sarhad Journal of Agriculture,* 34(1): 173-187.
**DOI** | http://dx.doi.org/10.17582/journal.sja/2018/34.1.173.187
**Keywords** | Soil conditioning, Humic acid, Regimes, Tassel visible, Blister, Dough

## Introduction

Maize (*Zea mays* L.) is the third most important cereal crop in the world after wheat and rice both in area sown and production obtained (Kara and Biber, 2008; Morris, 1998). In Pakistan, maize was sown on 1.13 million hectares area with 4.695 million tons production having normal yield of 3590 kg $ha^{-1}$ (Anjum et al., 2014). In Khyber Pakhtunkhwa maize was planted on 0.475 million hectares area with production of 0.887 million tons on average basis (Shafi et al., 2007). The average yield of maize (1868 kg $ha^{-1}$)

in Khyber Pakhtunkhwa province of the country was almost half of the national average yield (MNFSR, 2015-16) and our average yield is extremely low as compared with other leading growing countries of maize in the world where the average grain yield exceeds 5000 kg ha$^{-1}$. Inefficient use of the available water and lack of proper soil management practices are amongst the important factors limiting maize production at the regional and national level in Pakistan.

In the study area (Khyber Pakhtunkhwa, Pakistan) maize is mainly grown as summer season crop. Surface irrigation is predominate water application method in the country. Water application to a crop is based on the numbers of irrigation given per growing season. Efficiency of water applied and yield of crop depends on water application at critical growth stage of crop. Filintas (2003) reported that for achieving maximum production, maize requires large quantities of seasonal water and depends upon the climatic condition and length of growing period. For achieving maximum yield of 4000 kg/ha in Pakistan seasonal irrigation of 400-600 mm have been recommended for maize (Pervez et al., 2004).

The physical condition of the soil is another important factor that affects crop production. Poor soil physical condition limit the movement of soil moisture, plant water uptake, soil aeration and performance of roots. To overcome these hindrances the improvement in the soil physical conditions, soil amending materials called "soil conditioners" are added to the soil. Wheat straws as crop residues (CR) are important renewable, cheap and organic sources which are readily available to farmers. Rehman (1996) reported that CR and FYM built up soil humus status, improved water holding capacity of soil and increasedcation exchange capacity and conserved soil moisture. Sial et al. (2007) mentioned that the application of manure as farm yard manure (FYM) improved physical properties of soil, increased soil water holding capacity and also the fraction of water needed by the plants for their growth and development.

Gypsum application improved soil physical condition, increased calcium uptake, water availability and reduced subsoil aluminum toxicity that all favored the growth of plants (Norton and Rhoton, 2007). Soil conditioning is required to improve soil structure required for growth of underground part of the plant, movement of air and water through the soil and gypsum flocculate clay in acid and alkaline soils as it provides calcium (Sumner et al., 1986; Sheinberg et al., 1989). Humic acid exerts a stimulatory, conditioning and growth promoting effect on soil when applied in combination with chemical fertilizers due to its chelating properties to hold nutrients ions and released them as and when required by the plants (Linchen, 1978). Khattak and Muhammad (2008) reported that HA application in conjunction with NPK or micronutrients (Cu and Zn) had additive effect in increasing nutrients and water availability and yield of various crops. HA act as a catalyst in boost up the movement of soil microorganisms (Bhardwaj and Gaur, 1970).

Keeping in view the importance of these factors the present experiment was designed using maize as test crop under the climatic condition of Peshawar valley with the objective to determine the most promising irrigation regime and best soil conditioner for higher production of maize crop.

## Materials and Methods

### *Experimental details*

Field experiments on "impact of soil conditioning and irrigation regimes on the performance of maize crop" were conducted for two consecutive growing season of maize crop (2011-2012) at Agronomy Research Farm, The University of Agriculture, Peshawar Khyber Pakhtunkhwa. Randomized complete block design with split plot arrangements was used to carry out the experiment having three replications, with a subplot size of 24 m$^2$ (6 m width x 4 m length). Main plot and subplot factors were irrigation regimes and soil conditioners, respectively. Soil conditioners were applied one week before sowing of maize crop. Soil conditioners applied were organic soil conditioners (wheat straw as crop residue, farm yard manure and humic acid) while the inorganic source of soil conditioner was gypsum (G). Two levels of humic acid (2 kg and 4 kg ha$^{-1}$) were also used as soil conditioners (SC). Maize cultivar "Azam" was planted at seed rate of 30 kg ha$^{-1}$with 75 cm row- rowand25 cm plant - plant distance. There were 8 rows per plot. The crop was sown on 27$^{th}$ June both in 2011 and 2012.The analyses showed that FYM and CR contained 0.70 and0.35 % Nrespectively.DAP was applied as a source of phosphorus at the rate of 60 kg ha$^{-1}$, while urea as a source of nitrogen was applied at the rate of 120 kg ha$^{-1}$to the field. The soil of the research site was silty clay loam, pediment alluvium, Ustochrept. Detail and combination of the treatments are as follow:

Figure 1 showed that during maize growing season (June- September) of both years the temperature was almost stable. Maximum and minimum temperatures were 40˚C and 23˚C during the first and second year of experiment (2011 and 2012), respectively. Rainfall data shown in Figure 2 reveal that the total rainfall during growing of maize in year 2011 was 204.4 mm while during 2012 the total rainfall was 190.5 mm.

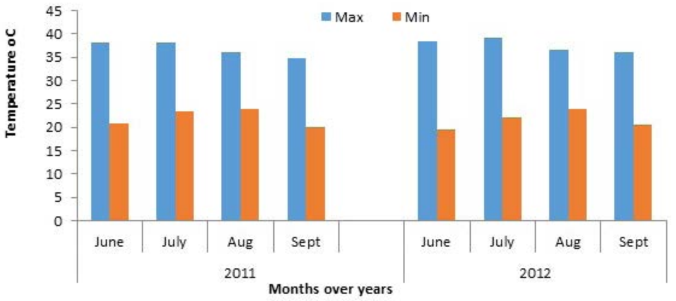


**Figure 1:** *Mean monthly temperature data.*

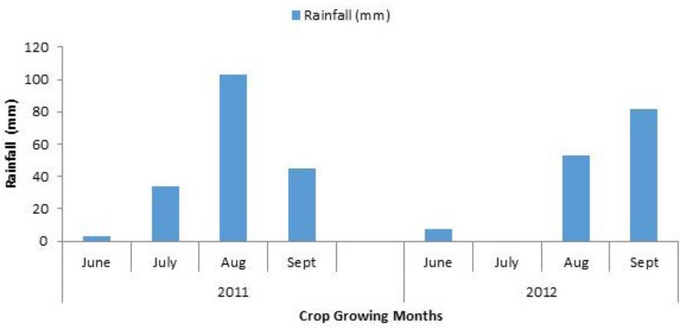


**Figure 2:** *Mean monthly rainfall data for the maize growing period for Year, 2011 and 2012.*

**Table 1:** *Physico-chemical characteristics of research site before the initiation of the trial (0-15 cm).*

| Soil Properties | Units | Values |
|---|---|---|
| Class of Texture | --- | Silty clay loam |
| pH (1:2.5) | --- | 7.74 |
| $EC_e$ (1: 2.5) | $dSm^{-1}$ | 0.37 |
| Clay | % | 40.1 |
| Silt | % | 50.9 |
| Sand | % | 8.7 |
| Bulk density | $g\ cm^{-3}$ | 1.46 |
| Total organic carbon | % | 0.59 |
| Total Nitrogen | $g\ kg^{-1}$ | 0.42 |

In this study our main objective was not to reduce or increase the quantity of each irrigation event, but applied the same amount at each occasion. Irrigations were omitted at different growing stages of maize crop. Constant amount of water (93 mm per irrigation) as surface irrigation was given at the most critical growth stages of maize plant as those defined by Ritichi et al. (1992) and given in Table 2.

**Factor A.** Main plot: Irrigation

**Table 2:** *Irrigation schedule for maize crop grown during 2011 and 2012.*

| Irrigation applied at growth stage | | Numbers of Irrigations applied | | | |
|---|---|---|---|---|---|
| | | W6 | W5 | W4 | W3 |
| Emergence (VE) | | √ | √ | √ | √ |
| 4 Leaves (V20) | | √ | √ | √ | √ |
| 8 Leaves (V40) | | √ | √ | √ | √ |
| Tassel visible (VT) | | √ | √ | √ | X |
| Blister stage (R2) | | √ | √ | X | X |
| Dough stage (R4) | | √ | X | X | X |
| Total Amount of Water Applied (mm) | | 558 | 465 | 372 | 279 |
| **Rainfall (mm)** | Year 1 | 204.5 | | | |
| | Year 2 | 190.5 | | | |
| Time taken per irrigation of main plot | | 28 minutes | | | |

*Ritichi et al, (1992);* **√:** *Irrigation applied;* **x:** *Irrigation omitted at growth stage.*

**Factor B:** Sub Plot: Soil Conditioning.

| **Soil Conditioning (SC)** | **($kg\ ha^{-1}$)** |
|---|---|
| Farmyard manure (FYM) | 10000 |
| Crop Residue (CR) | 10000 |
| Humic Acid (HA1) | 2 |
| Humic Acid (HA2) | 4 |
| Control (00) | 0 |

**Factor C:** Sub Plot: Gypsum

| | |
|---|---|
| Gypsum (G) Added(+) | 1000 |
| Gypsum (G) Not Added(-) | 00 |

*Treatment Combinations (B x C)*

T1 =Control (00)T2 =Gypsum
T3 =FYM + No Gypsum T4 =FYM + Gypsum
T5 =Crop Residue + No Gypsum T6 =Crop Residue + Gypsum
T7 =Humic acid 2 + No Gypsum T8 =Humic acid 2 + Gypsum
T9 = Humic acid 4 + No Gypsum T10 =Humic acid 4 + Gypsum

**Table 3:** *Average Crop growth rate ($gm^{-2}day^{-1}$) of maize as affected by soil conditioning and irrigation regimes during year 2011 and 2012.*

| **Treatments** | | **Years (Y)** | | **Two years average** |
|---|---|---|---|---|
| | | **2011** | **2012** | |
| **No. of Irrigations** | | | | |
| 3 | | 5.8 c | 6.2 c | 6.0 c |
| 4 | | 7.2 b | 8.0 b | 7.6 b |
| 5 | | 8.8 a | 10.4 a | 9.6 a |
| 6 | | 8.5 a | 10.0 a | 9.3 a |
| LSD (0.05) | | 0.40 | 1.0 | 0.60 |
| Gypsum | ($t\ ha^{-1}$) | | | |
| Without gypsum (-) | 0 | 6.3 b | 7.7 b | 7.0 b |
| With gypsum (+) | 1 | 8.0 a | 9.2 a | 8.6 a |
| **Significance** | | * | * | * |
| **Soil conditioning (SC)** | **($kg\ ha^{-1}$)** | | | |
| T1= Control | 0 | 5.0 d | 6.2 d | 5.6 d |
| T2= Farmyard manure (FYM) | 10000 | 9.2 a | 11.0 a | 10.1 a |
| T3= Crop Residue (CR) | 10000 | 8.4 b | 9.3 b | 8.8 b |
| T4= Humic acid (HA1) | 2 | 6.2 c | 7.8 c | 7.0 c |
| T5= Humic acid (HA2) | 4 | 9.1 b | 10.3 b | 9.7 b |
| LSD (0.05) | | 0.35 | 0.44 | 0.37 |
| Year Mean | | 6.0 b | 8..6 a | |
| **Planned Mean Comparison** | | | | |
| **Treatment** | | **Mean** | **Contrast** | **Significance** |
| Control (T1) | | 5.6 | T1 vs T2+T3+T4+T5 | ** |
| Rest (T2+T3+T4+T5) | | 8.9 | | |
| FYM (T2) | | 10.1 | T2 vs T3 | ** |
| CR (T3) | | 8.8 | | |
| FYM (T2) | | 10.1 | T2 vs T4 + T5 | ** |
| HA (T4 + T5) | | 8.4 | | |
| CR (T3) | | 8.8 | T3 vs T4 + T5 | ns |
| HA (T4 + T5) | | 8.4 | | |
| **Interactions** | | | | |
| W x G ns | Y x W | ns | Y x W x SC | ns |
| W x SC ns | Y x G | ns | Y x G x SC | ns |
| G x SC * | W x G x SC | ns | Y x W x G x SC | ns |
| Y x SC ns | Y x W x G | ns | | |

*Means in the same category with the same letters are not significantly different from each other at 5% level of probability.* ***:** *Significant at 5% level of probability;* ****:** *Significant at 1% level of probability;* **ns:** *Non significant.*

*Procedures*

The growth rate ($g\ m^{-2}\ day^{-1}$) of the crop was determined by taking destructive sampling at 20 days interval. The harvested biomass was dried in oven at 80 $^0$C for 24 hours for having a constant dry weight. Then mean CGR was calculated by the formula proposed by Hunt (1978).

$$CGR = \frac{W2 - W1\ 1}{T2 - T1\ GA}$$

Leaf area $plant^{-1}$ ($cm^2$) was determined by measuring the length and width of all leaves of five selected plants randomly in three central rows from each subplot and calculated according to the following formula proposed by Saxena (1965).

*Leaf area $plant^{-1}$ = No. of leaves $plant^{-1}$ x avg. leaf length x avg. leaf width x Correction Factor (0.75)*

Data on plant height (cm) was recorded from base of plant to tassel base in each sub plot of five plant selected randomly at maturity and averages was calculated. Biological yield (above ground parts of the plant) was calculated in each subplot by harvesting five central rows, dried and then weighed with electric balance. The data obtained for biological yield in every subplot was changed into kg $ha^{-1}$. Grain and straw nitrogen analysis was made for maize grain. At the harvest of maize in both years the samples (grain and straw) were collected from each treatment, dried and ground in a Willey's Mill and samples were analyzed for N contents through the Kjildhal method outlined by Breemner and Mulvaney (1982).

### Statistical analysis

The collected data were statistically analyzed using the procedure out lined by Steel and Torrie (1984).

## Results and Discussion

### *Crop growth rate*

Data concerning average crop growth rate are shown in Table 3. Perusal of the mean data indicated that gypsum, irrigation regime and soil conditionings had improved average crop growth rate significantly. The interaction between G x SC and year effect was also significant for crop growth rate. During second year (2012) average crop growth rate was significantly higher (8.6 $gm^{-2}day^{-1}$) as compared with first year (6.0 $gm^{-2}$ $day^{-1}$) of the experiment. Crop growth rate was also significantly affected by irrigation regimes. Crop growth rate was higher (9.6 $gm^{-2}$ $day^{-1}$) in plots where five irrigations were applied at (emergence + 4 leaves + 8 leaves + Tassel visible + blister stage) while significantly lower average crop growth rate (6.0 $gm^{-2}$ $day^{-1}$) were observed in plots receiving three irrigations and was at par with irrigation increased up to six irrigation. The findings of Hassan (2003) and Kazmi et al. (2003) also indicated that CGR in maize increased with increase in irrigation numbers up to the maximum of five irrigation. Data further showed that crop growth rate was significantly faster (8.6 $gm^{-2}$ $day^{-1}$) in plots where gypsum was applied while lower CGR (7.0 $gm^{-2}$ $day^{-1}$) was observed in no G applied plots. Gypsum accelerated growth rate of maize as a result of improving conservation and movement of water in the soil (Norton and Rhoton, 2007). Significant higher CGR 10.1 $gm^{-2}$ $day^{-1}$ was received in plots where FYM was applied compared to control plots having lowerCGR (5.6 $gm^{-2}$ $day^{-1}$). Our results are in accordance with Micske et al. (1990) who observed that farmyard manure had brought significant and positive changes in the growth rate, leaf area, and leaf area index, yield and harvest index of maize. Significant differences were recorded among various SC applied. Planned mean comparison revealed that average CGR was higher in SC treated plots compared with control.

The interaction between G x SC was also significant for average crop growth rate (Figure 3). The interaction indicating that crop growth rate increased with G application compared with no G. Higher crop growth rate was observed in case of combined application of SC x G, however faster CGR was received from those plots where FYM was incorporated in combination with G.

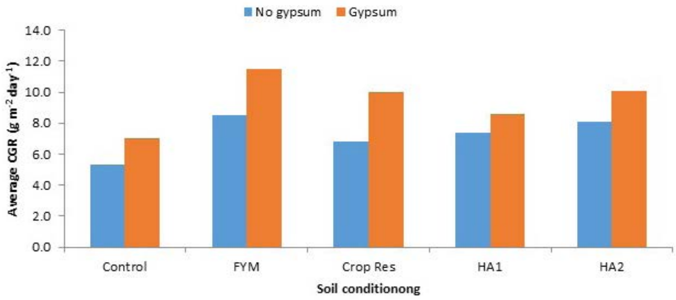


**Figure 3:** *Interrelationship between G x SC for average CGR (g $m^{-2}$ $day^{-1}$) of maize.*

### *Leaf area plant$^{-1}$*

Table 4 revealed that leaf area $plant^{-1}$($cm^2$) was significantly affected by gypsum, irrigation numbers and soil conditioning. The interaction between W x SC and G x SC and year effect was also significant for leaf area $plant^{-1}$. Considerably higher leaf area $plant^{-1}$ (4302 $cm^2$) was recorded during 2012 as compared with 2011 (4067 $cm^2$). Data showed that higher leaf area $plant^{-1}$ (4388 $cm^2$) was obtained in plots where five irrigations were applied at (emergence + 4 leaves + 8 leaves + Tassel visible + blister stage) which was statistically similar to leaf area $plant^{-1}$ recorded at six irrigation number compared to leaf area $plant^{-1}$ (3874 $cm^2$) of the plots irrigated thrice. Irrigation increased leaf parameters (leaf area and leaf area index) of the maize crop (Moiez et al., 2003) and water shortage during any stage of growth and development of the crop reduced leaf area $plant^{-1}$ and leaf area index (Pandey et al., 2000; Traore et al., 2000) of maize crop. Higher leaf area $plant^{-1}$ (4231 $cm^2$) was recorded in those subplots where gypsum was used compared to plots having no G application. Our results are also in line with Downey (1991) and Fontanetto et al. (2000)

**Table 4:** *Leaf area plant$^{-1}$ (cm$^2$) of maize as affected by soil conditioning and irrigation regimes during 2011 and 2012.*

| Treatments | | Years (Y) | | Two years average |
|---|---|---|---|---|
| | | 2011 | 2012 | |
| **No. of Irrigations** | | | | |
| 3 | | 3797 c | 3951 c | 3874 c |
| 4 | | 4040 b | 4156 b | 4098 b |
| 5 | | 4334 a | 4442 a | 4388 a |
| 6 | | 4288 a | 4311 a | 4299 a |
| LSD (0.05) | | 183 | 190 | 201 |
| Gypsum | (t ha$^{-1}$) | | | |
| Without gypsum (-) | 0 | 3958 b | 4059 b | 4008 b |
| With gypsum (+) | 1 | 4156 a | 4307 a | 4231 a |
| **Significance** | | * | * | * |
| **Soil conditioning (SC)** | **(kg ha$^{-1}$)** | | | |
| T1= Control | 0 | 3722 c | 3795d | 3758 d |
| T2= Farmyard manure (FYM) | 10000 | 4405 a | 4530a | 4467 a |
| T3= Crop Residue (CR) | 10000 | 3979 b | 4183 c | 4081 c |
| T4= Humic acid (HA1) | 2 | 3998 b | 4082 c | 4040 c |
| T5= Humic acid (HA2) | 4 | 4180 b | 4326 b | 4253 b |
| LSD (0.05) | | 155 | 120 | 170 |
| Year Means | | 4067 b | 4302 a | |
| **Planned Mean Comparison** | | | | |
| **Treatment** | | **Mean** | **Contrast** | **Significance** |
| Control (T1) | | 3758 | T1 vs T2+T3+T4+T5 | ** |
| Rest (T2+T3+T4+T5) | | 4210 | | |
| FYM (T2) | | 4467 | T2 vs T3 | ** |
| CR (T3) | | 4081 | | |
| FYM (T2) | | 4467 | T2 vs T4 + T5 | * |
| HA (T4 + T5) | | 4146 | | |
| CR (T3) | | 4081 | T3 vs T4 + T5 | ns |
| HA (T4 + T5) | | 4146 | | |
| **Interactions** | | | | |
| W x G ns | Y x W | ns | Y x W x SC | ns |
| W x SC * | Y x G | ns | Y x G x SC | ns |
| G x SC * | W x G x SC | ns | Y x W x G x SC | ns |
| Y x SC ns | Y x W x G | ns | | |

*Means in the same category with the same letters are not significantly different from each other at 5% level of probability.* *****: *Significant at 5% level of probability;* ******: *Significant at 1% level of probability;* **ns:** *Non significant.*

who reported that gypsum delayed growth stages (leaf area and leaf area index) of maize. Similarly leaf area plant$^{-1}$ was significantly higher (4467 cm$^2$) in plots treated with FYM as compared with control plots where lower leaf area plant$^{-1}$ of 3758 cm$^2$ was observed. Significant increase in root shoot dry weights, leaf area, ear per plant and yield of maize with incorporation of FYM at 10 tons ha$^{-1}$ as soil conditioning has been reported by Adeyemo and Agele (2010). Planned mean Comparison indicated that leaf area plant$^{-1}$ was higher in plots treated with soil conditioners (4210 cm$^2$) when compared to control plots (3758 cm$^2$).

The interaction between W x SC for leaf area plant$^{-1}$ of maize was significant (Figure 4). The figure indicated that with increase in irrigation numbers up to certain limit SC had produced greater leaf area plant$^{-1}$ but further increase in irrigation number leaf area plant$^{-1}$ brought no significant changes in leaf area plant$^{-1}$.Among SC applied plots, FYM treated plots responded well with increase in irrigation as compared with others. It is indicated that when there is limited irrigation FYM can help to maintain leaf growth. No significant difference was observed in leaf area plant$^{-1}$ in plots where other soil conditionings were used. The interaction between G x SC for leaf area plant$^{-1}$ of maize (Figure 5) revealed that leaf area plant$^{-1}$ enhanced with application of SC in gypsum applied plots as compared with no G application. Farmyard manure having G application had produced significantly broader leaves as compared with other soil conditionings used. FYM application resulted in higher leaf area when used in combination with G as compared with sole application.

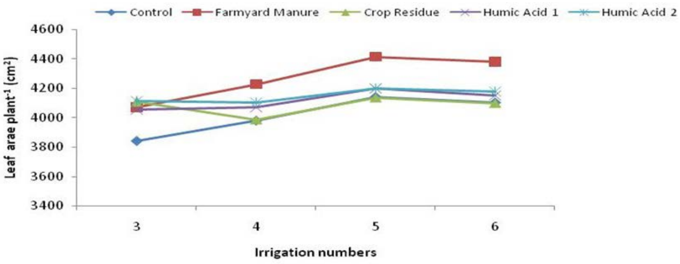


**Figure 4:** *Interrelationship between W x SC for leaf area plant$^{-1}$(cm$^2$) of maize.*

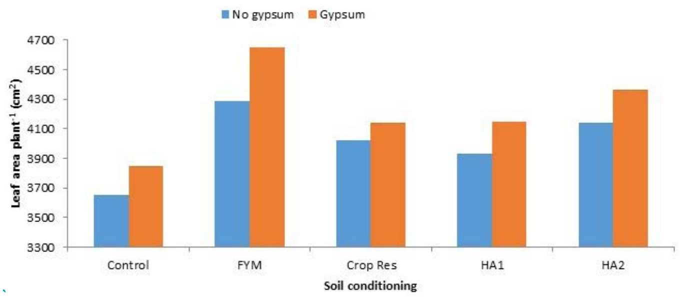


**Figure 5:** *Interaction between G x SC for leaf area plant$^{-1}$(cm$^2$) of maize.*

## *Plant height*

Data concerning plant height (cm) of maize as influenced by soil conditioning and irrigation regimes are reported in Table 5. Meditation of the data indicated that plant height was affected by all the factors under study significantly. All the interactions were significant except W x G for plant height. The year effect was non-significant for plant height for both years of experimentation. Based on the results of two years of experimentation taller plants of 206.8 cm were observed in plots where five irrigations were applied while dwarf plants (193.8 cm) were recorded in plots where three irrigations (Omitted three irrigations at (tassel visible, blister stage and dough stage) were applied and was at par with six irrigation. Our results confirmed the findings of Anjam et al. (2014) who suggested that plant height showed linear response to increase in irrigation frequency up to some levels. On the other hand there is also some evidence as reported by Soler et al. (2007) and Cakir (2004) that water deficiency at any growth stage reduce the plant height of maize. Based on the two years average taller plants of 203.0 cm were recorded in G treated plots compared to plot with no G (195.1 cm). For increasing crop productivity and soil fertility gypsum application is the best option to be used as it had significant effect on plant height and straw and grain N percentage in maize crop (Bello, 2012). Plant height had also significant response to SC. Higher plant height was obtained from plots treated with SC than plots without SC. The results of our experiment are supported by Jadoon et al. (2004) who reported that grain yield, biological yield, plant height and leaves plant$^{-1}$ were higher in maize with the application of FYM. Significantly taller plants were found in rest treated plots as compared to control plots. Similarly FYM treated plots resulted in taller plants as compared with HA.

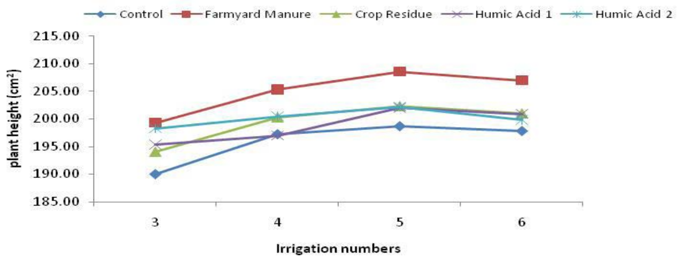


**Figure 6:** *Interrelationship between W x SC for plant height (cm) of maize.*

The interaction between W x SC for plant height was significant (Figure 6). The interaction reflects that plant tallness increased with increase in irrigation levels from W3 to W5 and SC application. Among SC application FYM produced taller plants even with lower irrigation regime than other SC. However taller plants were recorded when FYM was used in combination with five numbers of irrigation. Plant height increased with increase in irrigation number from three to five but further increase in irrigation numbers did not increase plant height significantly in all the SC applied plots. The interaction between G x SC also affected plant height (Figure 7) which showed that plant height was notably influenced by G in plots where SC was applied. Gypsum application in combination with FYM had resulted in taller plants compared sole application or in combination with other SC. The increase in plant height was more in case of G x SC as compared with control. Amongst SC treated plots the taller

**Table 5:** *Plant height (cm) of maize as affected by soil conditioning and irrigation regimes during 2011 and 2012.*

| **Treatments** | | **Years (Y)** | | **Two years average** |
|---|---|---|---|---|
| | | **2011** | **2012** | |
| **No. of Irrigations** | | | | |
| 3 | | 193.6 c | 193.9 c | 193.8 c |
| 4 | | 196.8 b | 199.9 b | 198.4 b |
| 5 | | 206.5 a | 207.1 a | 206.8 a |
| 6 | | 202.3 ab | 204.1 ab | 203.2 ab |
| LSD (0.05) | | 2.22 | 1.38 | 1.39 |
| Gypsum | (t ha$^{-1}$) | | | |
| Without gypsum (-) | 0 | 193.9 b | 196.3 b | 195.1 b |
| With gypsum (+) | 1 | 202.7 a | 203.2 a | 203.0 a |
| **Significance** | | * | * | * |
| **Soil conditioning (SC)** | **(kg ha$^{-1}$)** | | | |
| T1= Control | 0 | 189.0 d | 191.1 d | 190.1 d |
| T2= Farmyard manure (FYM) | 10000 | 208.3 a | 207.7 a | 208.0 a |
| T3= Crop Residue (CR) | 10000 | 195.7 c | 198.7 c | 197.2 c |
| T4= Humic acid (HA1) | 2 | 198.3 b | 198.5 c | 198.4 c |
| T5= Humic acid (HA2) | 4 | 200.3 b | 202.8 b | 201.5 b |
| LSD (0.05) | | 1.4 | 1.58 | 1.47 |
| Year Means | | 198.3 | 199.7 | |
| **Planned mean comparison** | | | | |
| **Treatment** | | **Mean** | **Contrast** | **Significance** |
| Control (T1) | | 190.1 | T1 vs T2+T3+T4+-T5 | ** |
| Rest (T2+T3+T4+T5) | | 201.2 | | |
| FYM (T2) | | 208.0 | T2 vs T3 | * |
| CR (T3) | | 197.2 | | |
| FYM (T2) | | 208.0 | T2 vs T4 + T5 | ** |
| HA (T4 + T5) | | 199.9 | | |
| CR (T3) | | 197.2 | T3 vs T4 + T5 | ns |
| HA (T4 + T5) | | 199.9 | | |
| **Interactions** | | | | |
| W x G ns | Y x W | ns | Y x W x SC | ns |
| W x SC * | Y x G | ns | Y x G x SC | ns |
| G x SC ** | W x G x SC | ns | Y x W x G x SC | ns |
| Y x SC ns | Y x W x G | ns | | |

*Means in the same category with the same letters are not significantly different from each other at 5% level of probability.* *****: *Significant at 5% level of probability;* ******: *Significant at 1% level of probability ns = Non significant.*

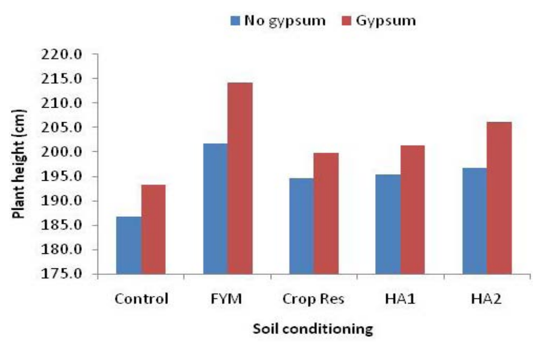


**Figure 7:** *Interrelationship between G x SC for plant height (cm) of maize.*

plants were observed in FYM treated plots with both G applied or not. Plant height responded positively to the application of G along with FYM as compared with other treatments.

### *Biological yield*

Data regarding biological yield (kg ha$^{-1}$) of maize are given in Table 6. Mean value of the data revealed that G, W and SC had a significant effect on biological yield of maize crop. The year effect and the interaction

**Table 6:** *Biological yield (kg ha$^{-1}$) of maize as affected by soil conditioning and irrigation regimes during 2011 and 2012.*

| Treatments | | Years (Y) | | Two years average |
|---|---|---|---|---|
| | | 2011 | 2012 | |
| **No. of Irrigations** | | | | |
| 3 | | 9040 c | 9720 c | 9380 c |
| 4 | | 9699 b | 9940 b | 9820 b |
| 5 | | 10411 a | 10996 a | 10704 a |
| 6 | | 9932 b | 10356 b | 10144 ab |
| LSD (0.05) | | 463 | 542 | 359 |
| Gypsum | (t ha$^{-1}$) | | | |
| Without gypsum (-) | 0 | 9348 b | 9959 b | 9653 b |
| With gypsum (+) | 1 | 10194 a | 10625 a | 10409 a |
| **Significance** | | * | * | * |
| **Soil conditioning (SC)** | **(kg ha$^{-1}$)** | | | |
| T1= Control | 0 | 9259 c | 9602 c | 9430 d |
| T2= Farmyard manure (FYM) | 10000 | 10653 a | 11293 a | 10973 a |
| T3= Crop Residue (CR) | 10000 | 9488 b | 9957 b | 9722 c |
| T4= Humic acid (HA1) | 2 | 9794 b | 10250 b | 10022 b |
| T5= Humic acid (HA1) | 4 | 9860 b | 10359 b | 10109 b |
| LSD (0.05) | | 472 | 433 | 370 |
| Year Means | | 9902 b | 10464 a | |
| **Planned Mean Comparison** | | | | |
| **Treatment** | | **Mean** | **Contrast** | **Significance** |
| Control (T1) | | 9430 | T1 vs T2+T3+T4+T5 | ** |
| Rest (T2+T3+T4+T5) | | 10206 | | |
| FYM (T2) | | 10973 | T2 vs T3 | * |
| CR (T3) | | 9722 | | |
| FYM (T2) | | 10973 | T2 vs T4 + T5 | * |
| HA (T4 + T5) | | 10066 | | |
| CR (T3) | | 9722 | T3 vs T4 + T5 | ns |
| HA (T4 + T5) | | 10066 | | |
| **Interactions** | | | | |
| W x G * | Y x W | ns | Y x W x SC | ns |
| W x SC ns | Y x G | ns | Y x G x SC | ns |
| G x SC ** | W x G x SC | ns | Y x W x G x SC | ns |
| Y x SC ns | Y x W x G | ns | | |

*Means in the same category with the same letters are not significantly different from each other at 5% level of probability;* ***:** *Significant at 5% level of probability;* ****:** *Significant at 1% level of probability* **ns:** *Non significant.*

between W x G and G x SC was also significant for biological yield. During second year of the experimentation higher biological yield (10464kg ha$^{-1}$) was produced as compared to first year (9902kg ha$^{-1}$). Higher biological yield of (10704kg ha$^{-1}$) was observed in five times irrigated plots (stress imposed at dough stage) compared to plots (9380kg ha$^{-1}$) receiving three irrigations (stress imposed at tassel visible, blister and dough stages). Both Irrigation and quality of water affect the height of plant, rate of germination, grains ear$^{-1}$, production and the efficiency of water utilized by the plants (Irfan et al., 2014). In case of G, higher biological yield (10409kg ha$^{-1}$) was founded in G treated plots while lower biological yield of 9653kg ha$^{-1}$ was found in those plots where no G was applied. Gypsum application proved to be the best treatment giving higher biological yield and delayed maturity of maize (Zaka et al., 2005; Khurana and Sharma, 1995). Effect of SC was significant for biological yield. Higher biological yield (10973kg ha$^{-1}$) was observed in FYM applied

**Table 7:** *Grain N (g $kg^{-1}$) of maize as affected by soil conditioning and irrigation regimes during 2011 and 2012.*

| Treatments | | Years (Y) | | Two years average |
|---|---|---|---|---|
| | | 2011 | 2012 | |
| No. of Irrigations | | | | |
| 3 | | 18.7 c | 18.8 d | 18.7 c |
| 4 | | 19.7 b | 19.4 c | 19.6 b |
| 5 | | 20.8 b | 20.9 b | 20.8 b |
| 6 | | 21.6 a | 21.7 a | 21.6 a |
| LSD (0.05) | | 0.10 | 0.12 | 0.12 |
| Gypsum | (t $ha^{-1}$) | | | |
| Without gypsum (-) | 0 | 19.5 b | 19.3 b | 19.4 b |
| With gypsum (+) | 1 | 21.9 a | 21.0 a | 21.0 a |
| Significance | | * | * | * |
| Soil conditioning (SC) | (kg $ha^{-1}$) | | | |
| T1= Control | 0 | 18.2 c | 17.9 d | 18.1 c |
| T2= Farmyard manure (FYM) | 10000 | 21.4 a | 23.1 a | 22.2 a |
| T3= Crop Residue (CR) | 10000 | 20.3 b | 19.7 c | 20.0 b |
| T4= Humic acid (HA1) | 2 | 20.6 b | 19.9 b | 20.2 b |
| T5= Humic acid (HA1) | 4 | 20.5 b | 20.3 b | 20.4 b |
| LSD (0.05) | | 0.11 | 0.13 | 0.10 |
| Year Means | | 20.2 | 20.2 | |
| **Planned Mean Comparison** | | | | |
| **Treatment** | | **Mean** | **Contrast** | **Significance** |
| Control (T1) | | 18.1 | T1 vs T2+T3+T4+T5 | ** |
| Rest (T2+T3+T4+T5) | | 20.7 | | |
| FYM (T2) | | 22.2 | T2 vs T3 | * |
| CR (T3) | | 20.0 | | |
| FYM (T2) | | 22.2 | T2 vs T4 + T5 | ** |
| HA (T4 + T5) | | 20.3 | | |
| CR (T3) | | 20.0 | T3 vs T4 + T5 | ns |
| HA (T4 + T5) | | 20.3 | | |
| **Interactions** | | | | |
| W x G ns | Y x W | ns | Y x W x SC | ns |
| W x SC ns | Y x G | ns | Y x G x SC | ns |
| G x SC * | W x G x SC | ns | Y x W x G x SC | ns |
| Y x SC ns | Y x W x G | ns | | |

*Means in the same category with the same letters are not significantly different from each other at 5% level of probability;* ***:** *Significant at 5% level of probability;* ****:** *Significant at 1% level of probability; ns: Non significant.*

plots; whereas lower biological yield (9430 kg $ha^{-1}$) was recorded in plots without FYM and other SC application. The results of our experiment are in association with Ihsan and Hasan (2013) who investigated that FYM significantly increased.

biological yield, plant height, grain yield, (Adeyemo and Agele, 2010; Singh and Agarwal, 2001; Chalk et al., 2003; Wang et al., 2004). Planned mean comparison showed that biological yield was higher (10206kg $ha^{-1}$) in treated plots as compared to rest treated and control plots (9430 kg $ha^{-1}$).

The interaction between G x W was significant for biological yield. The figure showed that when G was used as inorganic source of SC higher biological yield was observed at all levels of irrigation as compared to application of irrigations without G application so it showed that G performed well at the presence of sufficient amount of water at the initial stages of crop growth

(Figure 8). The data regarding interaction between G x SC (Figure 9) revealed that biological yield responded very well to application of G x SC as compared with no G. All the SC applied in the experiment produced higher biological yield in the presence of G as compared to no G application. It shows that G can increase biological yield even without SC but the increase with SC is many fold. Among SC, FYM respond positively to the application of G as higher biological yield was observed in those plots where FYM along with G was applied.

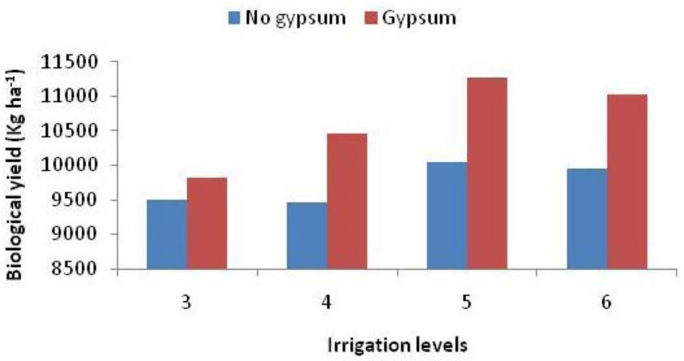


**Figure 8:** *Interrelationship between W x G for biological yield (kg ha$^{-1}$) of maize.*

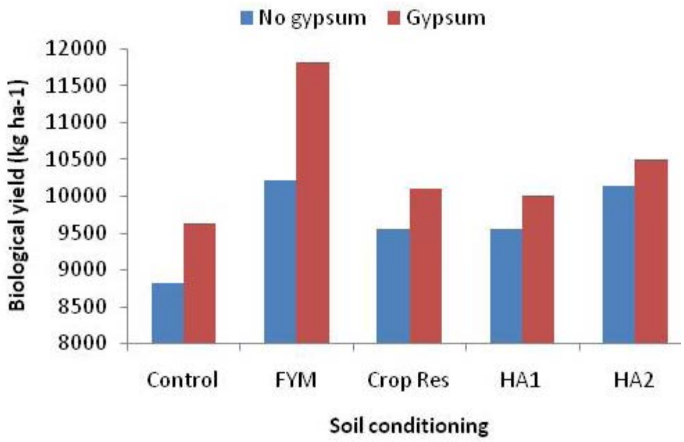


**Figure 9:** *Interrelationship between G x SC for biological yield (kg ha$^{-1}$) of maize.*

## *Grain nitrogen*

Data pertaining to nitrogen contents (%) in grains of maize are shown in Table 7. Mean value of the data revealed that G, W and SC had influenced grain nitrogen contents of maize. The year effect and all interactions were non significant with exception of G x SC for grains nitrogen contents of maize. In case of irrigation plots which received six irrigations at known critical growth stages had significantly increased nitrogen contents of maize grains (21.6 g kg$^{-1}$) as compared with other irrigations regimes applied in the experiment. Our results are supported by the finding of Ning et al. (2012) who stated that irrigation enhanced the rate of nitrogen uptake and rate of translocation to grain and straw of maize crop. Higher grain nitrogen contents (21.0 g kg$^{-1}$) were found in those plots where G was applied as inorganic soil conditioner compared with control plots where lower grains nitrogen contents (19.4 g kg$^{-1}$) were recorded. Berecz et al. (2005) observed that G application resulted in production of higher amount of dry matter and nitrogen concentration in both grains and straw of maize. Among SC, higher grains nitrogen contents (22.2 g kg$^{-1}$) were found in FYM applied plots while lowest grains nitrogen contents (18.1 g kg$^{-1}$) were found in plots where no SC was applied. Our results are in agreement with Bayu et al. (2006) who recognized that use of FYM enhanced nitrogen uptake by 21%–36%, grain and straw N and concentration of protein in grain of maize crop by 20 %–29%. Planned mean comparison revealed that grain N contents were higher in treated plots as compared with control plots.

Interaction between G x SC showed that initially all SC had lower maize grain nitrogen contents but significant increase in grain N contents was observed with G application. Higher grains nitrogen contents were observed when FYM and G were used as compared with no G application. No significant variations were found when G was used with other soil conditioners (Figure 10).

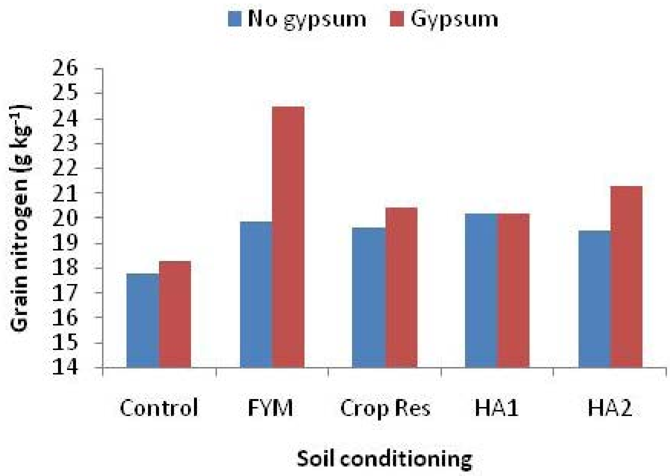


**Figure 10:** *Interrelationship between G x SC for grains N contents (g kg$^{-1}$) of maize.*

## *Straw nitrogen*

Perusal of the data (Table 8) showed that nitrogen contents (g kg$^{-1}$) in maize straw were significantly influenced by G, W and SC. The year effect was also significant for straw nitrogen contents. Interactions between G x SC was found significant for maize straw nitrogen contents. In second year of experiment higher straw N (9.1 g kg$^{-1}$) was recorded as compared with the first year (7.9 g kg$^{-1}$). Higher nitrogen contents in maize straw

**Table 8:** *Straw N (g kg$^{-1}$) of maize as affected by soil conditioning and irrigation regimes during 2011and 2012.*

| **Treatments** | | **Years (Y)** | | **Two years average** |
|---|---|---|---|---|
| | | **2011** | **2012** | |
| No. of Irrigations | | | | |
| 3 | | 5.7 c | 7.6 d | 6.7 c |
| 4 | | 7.6 b | 8.9 c | 8.2 b |
| 5 | | 8.4 b | 9.2 b | 8.8 b |
| 6 | | 10.2 a | 10.9 a | 10.5 a |
| LSD (0.05) | | 0.10 | 0.9 | 0.9 |
| Gypsum | (t ha$^{-1}$) | | | |
| Without gypsum (-) | 0 | 7.2 b | 8.4 b | 7.8 b |
| With gypsum (+) | 1 | 8.8 a | 9.9 a | 9.3 a |
| Significance | | * | * | * |
| Soil conditioning (SC) | (kg ha$^{-1}$) | | | |
| T1= Control | 0 | 6.1 d | 6.5 c | 6.3 d |
| T2= Farmyard manure (FYM) | 10000 | 10.1 a | 11.4 a | 10.8 a |
| T3= Crop Residue (CR) | 10000 | 7.4 c | 8.9 b | 8.2 c |
| T4= Humic acid (HA1) | 2 | 7.4 c | 9.2 b | 8.3 c |
| T5= Humic acid (HA1) | 4 | 8..9 b | 9.6 b | 9.3 b |
| LSD (0.05) | | 0.19 | 0.13 | 0.10 |
| Year Means | | 7.9 b | 9.1 a | |

**Planned Mean Comparison**

| **Treatment** | **Mean** | **Contrast** | **Significance** |
|---|---|---|---|
| Control (T1) | 6.3 | T1 vs T2+T3+T4+T5 | ** |
| Rest (T2+T3+T4+T5) | 9.1 | | |
| FYM (T2) | 10.8 | T2 vs T3 | * |
| CR (T3) | 8.2 | | |
| FYM (T2) | 10.8 | T2 vs T4 + T5 | ** |
| HA (T4 + T5) | 8.8 | | |
| CR (T3) | 8.2 | T3 vs T4 + T5 | ns |
| HA (T4 + T5) | 8.8 | | |

**Interactions**

| | | | | | |
|---|---|---|---|---|---|
| W x G ns | Y x W | ns | Y x W x SC | ns | |
| W x SC ns | Y x G | ns | Y x G x SC | ns | |
| G x SC * | W x G x SC | ns | Y x W x G x SC | ns | |
| Y x SC ns | Y x W x G | ns | | | |

*Means in the same category with the same letters are not significantly different from each other at 5% level of probability;* ***:** *Significant at 5% level of probability;* ****:** *Significant at 1% level of probability;* **ns:** *Non significant.*

(10.5 g kg$^{-1}$) were observed in plots where six irrigations (no stress imposed) were applied at critical growth stages of crop, however lowest straw nitrogen contents (6.7 g kg$^{-1}$) were received in three times irrigated plots. Increases in irrigation frequency/numbers increased nitrogen, phosphorous and potassiumuptake by maize and ultimately increased straw and seed nitrogen contents of maize (Prasad and Prasad, 1988; Jose et al,. 2008). Higher straw nitrogen contents (9.3 g kg$^{-1}$) were recorded where G was applied as compared with no G treated plots where straw nitrogen contents were (7.8 g kg$^{-1}$). Among SC, higher straw nitrogen contents (10.8 g kg$^{-1}$) was reported in those plots where FYM was applied as soil conditioner while lowest straw nitrogen contents (6.3 g kg$^{-1}$) were found in control treatment. Gypsum application enhanced straw nitrogen contents of maize. Higher N contents were higher in both maize and wheat with the application of FYM as reported by Rasool et al. (2005) and Pathak et al. (2005). Planned mean comparison revealed that in treated plots straw nitrogen content was more (9.1 g kg$^{-1}$) as compared to the rest treated plots (6.3 g kg$^{-1}$).

The SC incorporation showed significant response to straw N. Interaction between G x SC (Figure 11) showed that lower straw nitrogen was recorded with all SC without G application but G application sufficiently increased straw N when used in combination with SC. Farmyard manure and G combination seems to be better for more straw N accumulation than other SC. It indicated that G can improve straw N even when there is no SC applied.

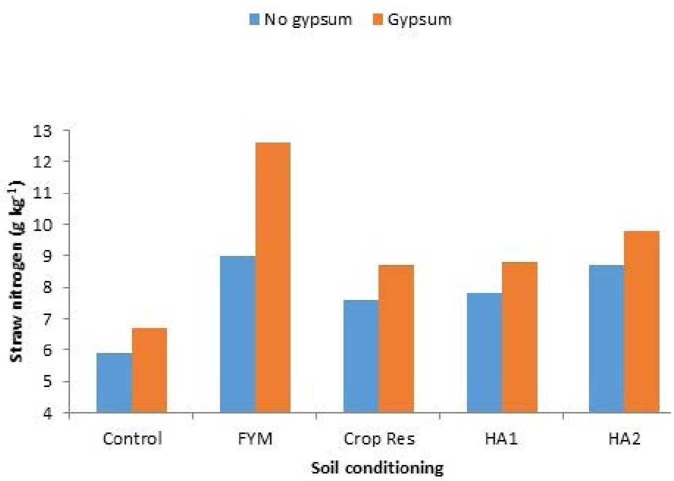


**Figure 11:** *Interaction between G x SC for nitrogen contents (g kg$^{-1}$) in maize.*

## Conclusions and Recommendations

On the assertion of observations made in this project, it is concluded that:

1. Six irrigations given at emergence, 4 leaves, 8 leaves, tassel visible,blister and dough stage had significantly increased growth of maize as compared to lower irrigation regimes.
2. Amongst organic soil conditioners, application of farmyard manure resulted in bumper and improved maize quality followed by HA2.
3. Gypsum application as inorganic soil conditioner resulted in higher crop growth and development and improved crop quality as compared to no gypsum.
4. Combination of gypsum + farm yard manure as soil conditioners having five irrigation regimes given at emergence, 4 leaves, 8 leaves and tassel visible and blister stages produced higher yield.
5. Crop performance and improvement in crop quality was better in second year of the experiment.

On the basis of experimental results and conclusion drawn, it is recommended that both farmyard manure (10 tons ha$^{-1}$) and gypsum (1 tons ha$^{-1}$) with five irrigation (at critical stages of emergence, 4 leaves, 8 leaves and tassel visible and blister stage) can perform better as compared with other soil conditioning and irrigation regimes for obtaining higher yield of maize crop in Khyber Pakhtunkhwa.

## Author's Contribution

**Muhammad Ijaz Khan:** Concieved the study, planned the experiments, cunducted the research and wrote the manuscript.
**Amanullah Jan:** Supervised the whole work and edited the manuscript.

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