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# Maize Response to Soil Conditioning and Irrigation Regimes

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**Key words:** Blister, Dough, Humic acid, Soil conditioning, Tassel visible

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## Abstract

The study was undertaken to evaluate the response of soil conditioning and irrigation regimes on maize. Soil conditioners improve the physical conditions of soil and provide conducive environment for crops growth and development. Four irrigation regimes (3, 4, 5 and 6 irrigations) per main plot at known critical growth stages (emergence, 4 leaves, 8 leaves and tassel visible, blister and dough), three organic soil conditioners (farmyard manure (FYM), crop residue and humic acid (2 and 4 kg $ha^{-1}$), alone and in combinations with gypsum as inorganic soil conditioner (SC) to subplots were applied one week before sowing at Agronomy Research Farm, The University of Agriculture Peshawar. Design used was RCB with split plot arrangement having 3-replications. Results revealed that higher crop growth rate (10.1 $gm^{-2}day^{-1}$) between tassel visible and blister stages was recorded in four times, while higher crop growth rate (9.6 $gm^{-2}day^{-1}$) between blister and dough stages, delayed maturity (90 days) and higher grain yield (4010 $kgha^{-1}$) were observed in five times irrigated plots as compared to other irrigation regimes. Soil moisture contents significantly increased (20.0 %) while significant reduction in soil bulk density (1.39 g $cm^{-3}$) was recorded with increase in irrigation numbers. Among soil conditioning FYM incorporation produced significantly higher crop growth rate (11.4 $gm^{-2}day^{-1}$) between tassel visible and blister stages, between blister and dough stages (10.6 $gm^{-2}day^{-1}$) and delayed maturity (102 days). Lowest bulk density (1.35 g $cm^{-3}$) and highest soil moisture contents (20.5 %) were observed in FYM and CR treated plots respectively. Gypsum application resulted in higher CGR, delayed maturity; higher grain yield moisture contents and lowest bulk density as compared to control. So application of farmyard manure (10 tons $ha^{-1}$) and gypsum (1 tons $ha^{-1}$) with five irrigations at the known critical stages were recommended for enhancing maize yield and improving soil fertility in Peshawar.

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## Introduction

Maize (*Zea mays* L.) is an important cereal crop of the world and has great economic value in poultry and livestock production (Harris *et al.*, 2007). It is the 3rd most promising cereal crop of Pakistan after wheat and rice and second in khyber Pakhtunkhwa after wheat. It was grown on an area of 1.19 m ha with a total production of 4.99 m tons with a national average yield of 3590 kg $ha^{-1}$ in Pakistan. In KP, it was grown on about 0.44 m ha with a total production of 0.96 m tons and an average yield of1838 kg $ha^{-1}$ (MNFSR 2016).

Maize cultivation is virtually confined to irrigated areas. The farmers apply 6-8 irrigations at their own discretion irrespective of the demand of the crop. There are reports which show that application of water at the critical stage is greater than the indiscriminate water application. Hammad *et al.* (2013) reported that maximum leaf area, numbers of grains per ear, grain yield were achieved when 8 irrigations were applied at critical growth stages but omission of single irrigation at tasseling and grain filled duration reduced yield by 30 % and 20 % respectively.

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 soil conditioners" are added to the soil. Crop residues (CR) are important renewable, cheap and organic sources which are readily available to farmers. Rehman (1996) and Sial *et al*, 2007 reported that CR and FYM improve physical properties of soil, improve soil humus content, soil water holding capacity, cation exchange capacity, conservation of moisture and also the portion of water available for plant growth.

Humic acid (HA) has been reported as a potential soil conditioning showing constant impact on crop growth and development, water and nutrient uptake and soil water and nutrient status (Pinton *et al.*, 2007). Khattak and Muhammad (2008) have reported that HA application in along with other nutrients has additive effect in increasing nutrients and water availability and yield of various crops and also promote micro organisms activities in soil (Bhardwaj and Gaur, 1970). Gypsum application improved soil physical condition, increased calcium uptake, water availability and reducing soil compaction and crusting that all favor the growth of plants. Gypsum provides calcium which is needed to flocculate clay in acid and alkaline soils and improve root growth, air and water movement in the soil (Sumner *et al.*, 1986; Sheinberg *et al.*, 1989).

Keeping in view the importance of these factors the present experiment was designed using maize as test crop to determine the most promising irrigation regimes and soil conditioning for improving soil physical conditions that favor maize growth.

## Materials and methods

*Experimental Details*

Field experiment on "Maize response to soil conditioning and irrigation regimes" was conducted at Agronomy Research Farm, The University of Agriculture, Peshawar during summer 2011 and was repeated on the same field in summer 2012. Irrigations regimes as factor were allotted to main plots while soil conditioners were allotted to the subplot as another factor. The experiment was laid out in randomized complete block design with split plot arrangements having three replications, with a subplot size of 6 m x 4 m. One week before the sowing of maize crop soil conditioners were applied. Soil conditioners applied were organic soil conditioners (crop residue, farm yard manure and humic acid) while the inorganic source of soil conditioner was gypsum (G). Two levels of humic acid (HA) at the rate of 2 kg and 4 kg $ha^{-1}$ were also used as soil conditioners (SC). In case of comparison between organic and inorganic sources SC refer to organic source and of course gypsum (G) as inorganic source. Maize cultivar "Azam" was planted at the seed rate of 30 kg $ha^{-1}$with row to row distance of 75 cm and plant to plant distance of 25 cm. There were 8 rows per plot. The maize crop was planted on $24^{th}$ and $27^{th}$ June in 2013 and 2014, respectively.

Phosphorus as $P_2O_5$ was applied at the rate of 60 kg $ha^{-1}$, while nitrogen as a urea was applied at the rate of 120 kg $ha^{-1}$to the field. 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 temperature was 40°C while minimum temperature was 23°C during the first and second year of experiment (2011 and 2012). Rainfall data shown in Fig. 2 reveals 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.

*Procedure for recording the parameters*

Crop growth rate ($m^{-2}$ g $day^{-1}$) was determined by taking destructive sampling between (vegetative and tassel visible) and (tassel visible and blister) stages The harvested biomass was oven dried at 80 °C for 24 hours for having a constant dry weight then mean CGR was calculated by the formula proposed by Hunt (1978). Days to physiological maturity was counted from the date of sowing till physiological maturity of crop in each subplot. Appearance of black layer at seed base and milk line in each subplot was used as criteria for physiological maturity (Lauer, 1994). Grain yield (kg $ha^{-1}$) was recorded by harvesting five central rows in each subplot, threshed, cleaned and weighed. The data recorded for grain yield in each subplot was converted into kg $ha^{-1}$.

The soil samples were taken from each subplot before sowing and after the harvest of the crop. The soil obtained from core samplers was placed in moisture cane and weight, and then dried at 105°C to a constant weight and weighed again. Weight of the cane was subtracted from the total fresh and dried weight to give mass of soil to calculate soil moisture by formula given by Ross (1989). Bulk density was determined by core method and was calculated by using formula proposed by Power (1991).

Data were analyzed statistically using variance techniques following to the randomized complete block design (RCBD) by using computer software statistics 8.1 (Steel & Torrie, 1984). Treatments means were compared using LSD at 5% significance level.

## Results and discussion

*Crop growth rate between tassel visible and blister stages*

Mean value of the data (Table 3) revealed that G, W and SC had significantly affected crop growth rate between tassel visible and blister stages. Significantly higher crop growth rate was recorded during 2012 as compared with 2011.

**Table 1.** Physico-chemical characteristics of experimental soil before the initiation of the trial (0-15 cm).

| Soil Properties | Units | Values |
|---|---|---|
| Textural Class | --- | 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 |

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.

In case of irrigation regimes higher crop growth rate (10.1 $gm^{-2}$ $day^{-1}$) between T and B stages was recorded in plots where four irrigations at (emergence + 4 leaves + 8 leaves + Tassel visible stage) were applied while plots received less than four irrigation (Omitting one irrigation) resulted in lower crop growth rate (8.1 $gm^{-2}$ $day^{-1}$).

This might be due to higher moisture and nutrients availability. Our results are in line with Saif *et al.*, (2003) who reported that highest CGR was recorded at four or five irrigations application while no further increase in CGR was observed with further increase in irrigation up to 6 regimes.

The findings of Hassan, (2003) and Kazmi *et al.* (2003) also indicated that CGR in maize increased with increased in irrigation numbers up to the maximum of five.

Mean value of the data showed that G application resulted in significantly higher crop growth rate (10.1 $gm^{-2}$ $day^{-1}$) as compared with no G applied plots (8.1 $gm^{-2}$ $day^{-1}$).

**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) | T6 = | Crop Residue + Gypsum |
| T2 = | Gypsum | T7 = | Humic acid 2 + No Gypsum |
| T3 = | FYM + No Gypsum | T8 = | Humic acid 2 + Gypsum |
| T4 = | FYM + Gypsum | T9 = | Humic acid 4 + No Gypsum |
| T5 = | Crop Residue + No Gypsum | T10 = | Humic acid 4 + Gypsum |

Data on the following parameters of soil and crop were recorded during this study.

Crop growth rate (between vegetative and tassel visible stages), Crop growth rate (between tassel visible and blister stages). Physiological maturity, Grain yields ($kgha^{-1}$), Bulk density and Soil moisture.

The reason might be that gypsum application prevent dispersion of soil particles, reduce surface crust formation, increase water infiltration rates, water movement into and through the soil profile and increased air and water entry into the soil as reported by (Brauer *et al.*, 2006). Goatley and Schmidt, 1990 reported that gypsum stimulate the CGR. In case of SC, CGR (11.4 $gm^{-2}$ $day^{-1}$) was significant higher in plots where FYM was applied at the rate 10 tons $ha^{-1}$ while minimum (6.7 $gm^{-2}day^{-1}$) in control plots.

Our results are an affiliation with Pinton *et al.*, 2007 who reported that FYM is a potential soil conditioning showing significant impact on CGR and development, water and nutrient uptake and soil water and nutrient status.

The interaction between G x SC was also significant for crop growth rate recorded (Fig.3) between blister and tassel visible stages which indicating that G x SC application had more crop growth rate compared to without G.

Steeper CGR was recorded in FYM x G than other SC. These results are in line with that of Berecz *et al.* 2005 who reported that crop growth rate was significantly higher in the treatments having FYM and gypsum application.

**Table 3.** Crop growth rate between T-B stages, Crop growth rate between B-D stages, grain filled duration and physiological maturity of maize as affected by soil conditioning and irrigation regimes during 2011 and 2012.

| Treatments | | CGR ($gm^{-2}day^{-1}$) between T-B | CGR ($gm^{-2}day^{-1}$) between B-D | Physiological maturity |
|---|---|---|---|---|
| Irrigations | | | | |
| 3 | | 8.1 b | 7.8 c | 94 c |
| 4 | | 10.1 a | 8.7 b | 100 b |
| 5 | | - | 9.6 a | 101 b |
| 6 | | - | 8.2 b | 104 a |
| LSD | | * | 0.05 | 1.0 |
| Gypsum | (t $ha^{-1}$) | | | |
| Without Gypsum | 0 | 8.1 b | 6.0 b | 96 b |
| With Gypsum | 1000 | 10.1 a | 9.3 a | 100 a |
| Significance | | * | * | * |
| Soil conditioning | (kg $ha^{-1}$) | | | |
| Control | 0 | 6.7 d | 5.8 d | 91 d |
| Farmyard manure | 10000 | 11.4 a | 10.6 a | 98 b |
| Crop Residue | 10000 | 9.3 c | 9.4 b | 94 c |
| Humic acid1 | 2 | 8.5 c | 8.0 c | 97 b |
| Humic acid 2 | 4 | 9.7 b | 9.4 b | 102 a |
| LSD | | 0.31 | 0.37 | 1.0 |
| Year | | | | |
| 2011 | | 8.0 b | 6.9 b | 95 b |
| 2012 | | 9.8 a | 9.3 a | 99 a |
| Significance | | ** | * | * |
| Planned mean comparison | | | | * |
| Control | | 6.7 b | 5.8 b | 91 b |
| Rest | | 9.7 a | 9.3 a | 98 a |
| Interactions | | | | |
| G x SC | | * | * | * |
| W x SC | | ns | ns | ns |
| W x G | | ns | ns | ns |

Means in the same category followed by different letters are significantly different from each other at 5% level of probability.

* = Significant at 5% level of probability

ns = Non significant

T = Tassel visible stage

B = Blister stage

D = Dough stage

*Crop growth rate between blister and dough stage*

Data concerning crop growth rate are shown in Table 3. Perusal of the mean data revealed that G, W and SC had significantly affected crop growth rate between blister and dough stage. During second year CGR was significantly higher (9.3 $gm^{-2}day^{-1}$) as compared with first year (6.9 $gm^{-2}$ $day^{-1}$) of the experiment. Crop growth rate was 9.4 $gm^{-2}$ $day^{-1}$ between D and B stage was higher in five times irrigated plots at (emergence + 4 leaves + 8 leaves + Tassel visible + blister stage) while lower CGR (7.8 $gm^{-2}$ $day^{-1}$) in three times irrigated plots. Our results are in accordance with Zaka *et al.* 2005 reported that CGR, seed weight, seed quality were improved and the yield was increased by 40% with irrigation given at vegetative and tasseling stages**.**

Data further showed that that the G applied plots had significantly faster crop growth rate (9.3 $gm^{-2}$ $day^{-1}$) while lower CGR (8.0 $gm^{-2}$ $day^{-1}$) was recorded for control plots. Our results are supported by Eyheraguibel *et al.* (2007) who concluded that G increased CGR, root elongation shoot and leaf biomass and yield of maize crops. Farmyard manure resulted in significantly higher CGR 10.6 $gm^{-2}$ $day^{-1}$ while minimum CGR (5.8 $gm^{-2}$ $day^{-1}$) were observed in control plots. Micske *et al.* (1990) observed that FYM application resulted significant and positive changes in the growth rate, leaf area, leaf area index, yield and harvest index of maize. Planned mean comparison showed that crop growth rate was higher in treated plots compared with control.

**Table 4.** Bulk density (at depth of 0-15 and 16-30 cm) and soil moisture (at depth of 0-15 and 16-30 cm) after harvest of maize as affected by soil conditioning and irrigation regimes during 2011 and 2012.

| Treatments | | Grain yield (kg $ha^{-1}$) | Bulk density (at depth of 0-15 cm) | Soil moisture after harvest (at depth of 0-15 cm) |
|---|---|---|---|---|
| Irrigations | | | | |
| 3 | | 3418 c | 1.45 a | 17.2 c |
| 4 | | 3630 b | 1.41 b | 18.1 b |
| 5 | | 4010 a | 1.42 b | 18.5 b |
| 6 | | 3750 ab | 1.39 c | 20.0 a |
| LSD | | 191 | 0.02 | 0.43 |
| Gypsum | (t $ha^{-1}$) | | | |
| Without Gypsum | 0 | 3526 b | 1.44 a | 17.6 b |
| With Gypsum | 1000 | 3859 a | 1.39 b | 19.3 a |
| Significance | | * | ** | * |
| Soil conditioning | (kg $ha^{-1}$) | | | |
| Control | 0 | 3238 d | 1.49 a | 17.0 c |
| Farmyard manure | 10000 | 4483 a | 1.35 d | 18.4 b |
| Crop Residue | 10000 | 3593 c | 1.40 c | 20.5 a |
| Humic acid1 | 2 | 3541 c | 1.43 b | 18.3 b |
| Humic acid 2 | 4 | 3806 b | 1.43 b | 18.5 b |
| LSD | | 133 | 0.03 | 0.30 |
| Year | | | | |
| 2011 | | 3624 b | 1.44 a | 18.0 b |
| 2012 | | 3781 a | 1.39 b | 20.2 a |
| Significance | | * | ** | * |
| Planned mean comparison | | | | |
| Control | | 3238 b | 1.49 a | 17.0 b |
| Rest | | 3806 a | 1.40 b | 18.8 a |
| G x SC | | * | * | * |
| W x SC | | * | ns | ns |
| W x G | | ns | ns | ns |

Means in the same category followed by different letters are significantly different from each other at 5% level of probability.

* = Significant at 5% level of probability

ns = Non significant

The interaction between G x SC for CGR (Fig.4) indicating that maximum CGR was observed in case of combined application of SC x G, however maximum CGR was recorded in those plots where FYM was applied in combination with G compared to other SC. Kiani *et al* (2005) was of the view that G and FYM increases CGR, delayed tasseling, silking and extended grains filling period.

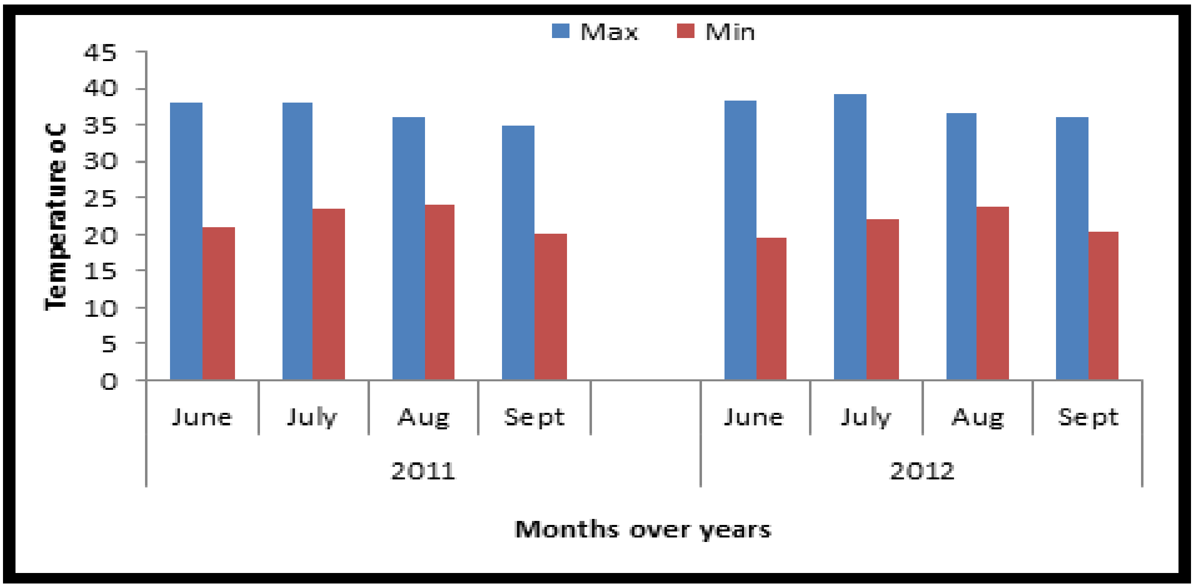


**Fig. 1.** Mean monthly temperature data.

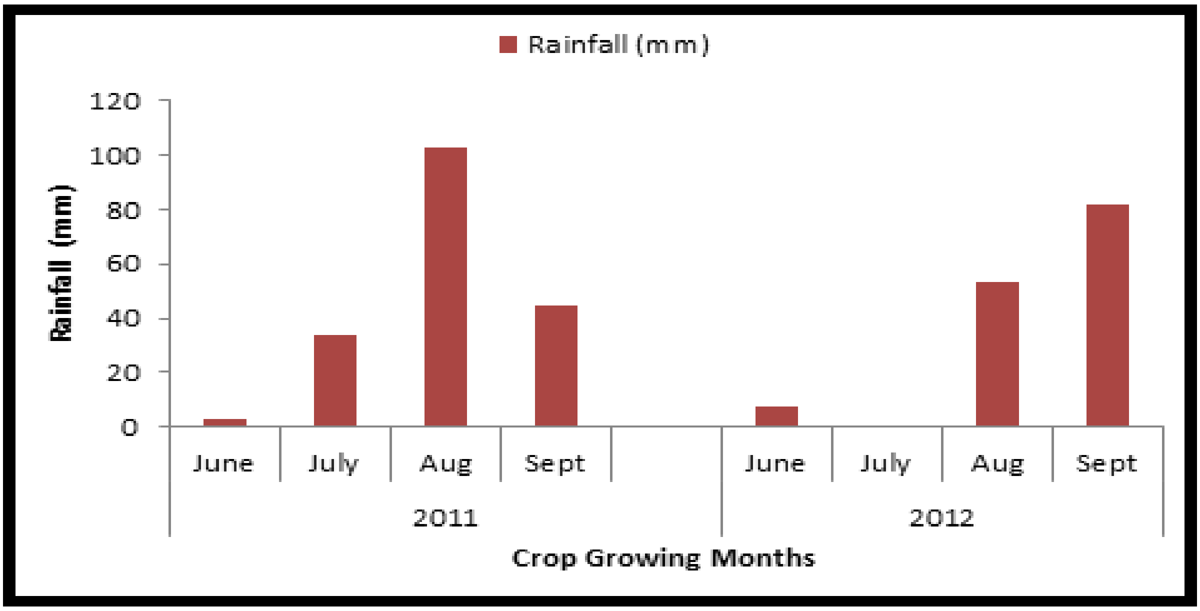


**Fig. 2.** Mean monthly rainfall data for the maize growing period for Year, 2011 and 2012.

*Days to maturity*

Mean value of the data (Table 3) revealed that G, W and SC had significantly affected by physiological maturity. Interaction between G x SC and year effect was also significant for days to physiological maturity. Delayed physiological maturity (99 days) was observed in 2012 as compared to 2011 (95 days).

Maximum days to physiological maturity (104 days) were observed in plots where six irrigations applied at all known critical crop growth stages as compared to three irrigations regimes (three irrigations omitted at tasseling, blister and dough stages). Delay in physiological maturity might be due to improvement in soil moisture status and soil fertility.

The results of Shirazi *et al.* (2014) and Doorenbos and Kassam, (1979) further confirmed our findings that with increase in irrigation extended GFD, delayed maturity and boost up yield as compared to minimum and control. Gypsum application delayed physiological maturity (99 days) compared with no G (95 days). Gypsum avoids surface crust formation, promote seedling emergence, increase water conservation, infiltration and movement through the soil profile (Norton and Rhoton, 2007) and as a results increase the growth period of maize. Our findings are also confirmed by Fontanetto *et al.* (2000) who were of the view that gypsum application delay maturity, tasseling, silking and increased emergence and grain yield.

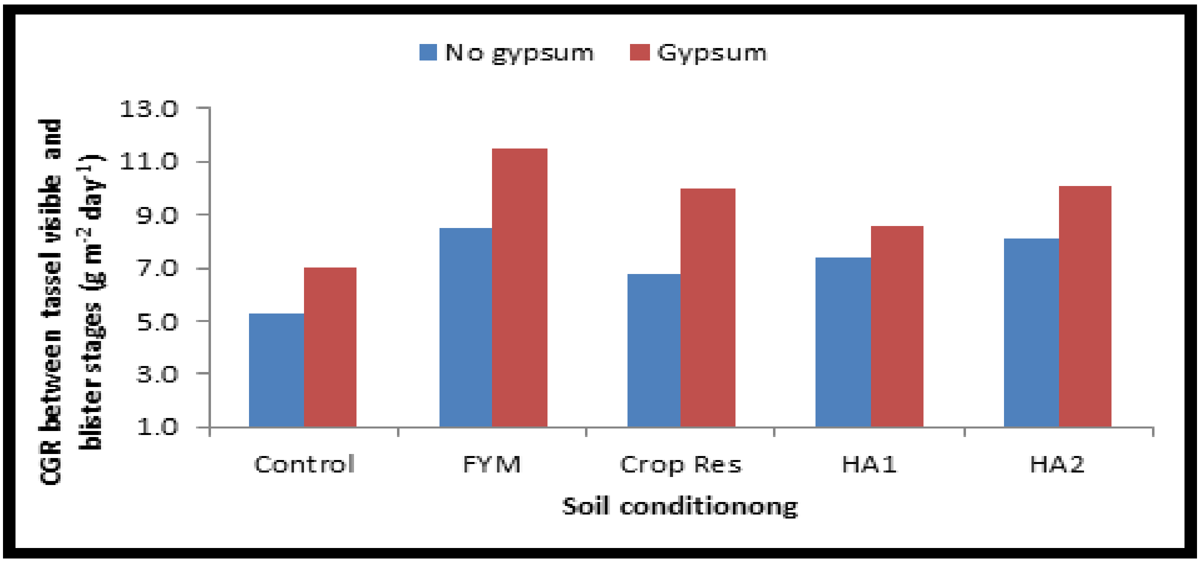


**Fig. 3.** Interaction between G x SC for CGR (g $m^{-2}$ $day^{-1}$) between tassel visible and blister stages of maize.

In case of SC physiological maturity (102 days) was delayed in plots where HA2 was applied compare with other SC and control plots. Sharif *et al.* (2002) are of the views that the delay in maturity, tasseling and silking of maize in their study is due to addition of HA which may be associated with the improved biochemical environment of the soil. The findings of Jillian, (1994); Li *et al., (*2003) and Khattak and Dost, (2008) confirmed our findings that HA restore microbial activities, increases growth period and availability of micronutrients and assimilation of N by plants.

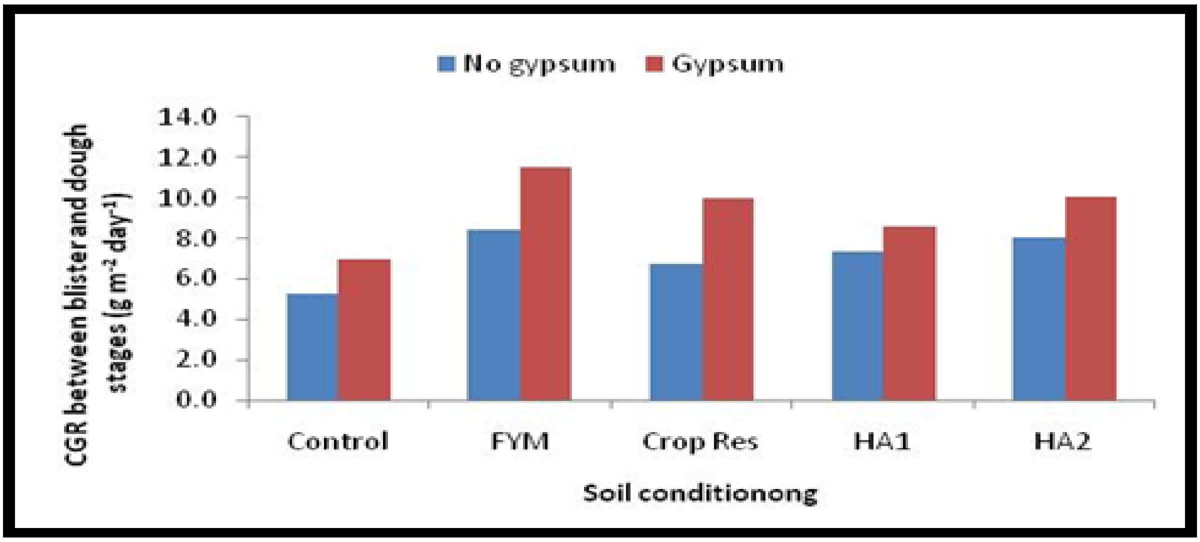


**Fig. 4.** Interaction between G x SC for CGR (g $m^{-2}$ $day^{-1}$) between blister and dough.

The interaction between G x SC Fig. 5 showed that physiological maturity was delayed in those plots where FYM was applied along with G application as compared with FYM applied plots without G application. Our results are in accordance with Farina and Cannon (1988) who concluded that gypsum and FYM application had resulted in higher leaf area, leaf area index and delayed maturity (Zaka *et al.*, 2005).

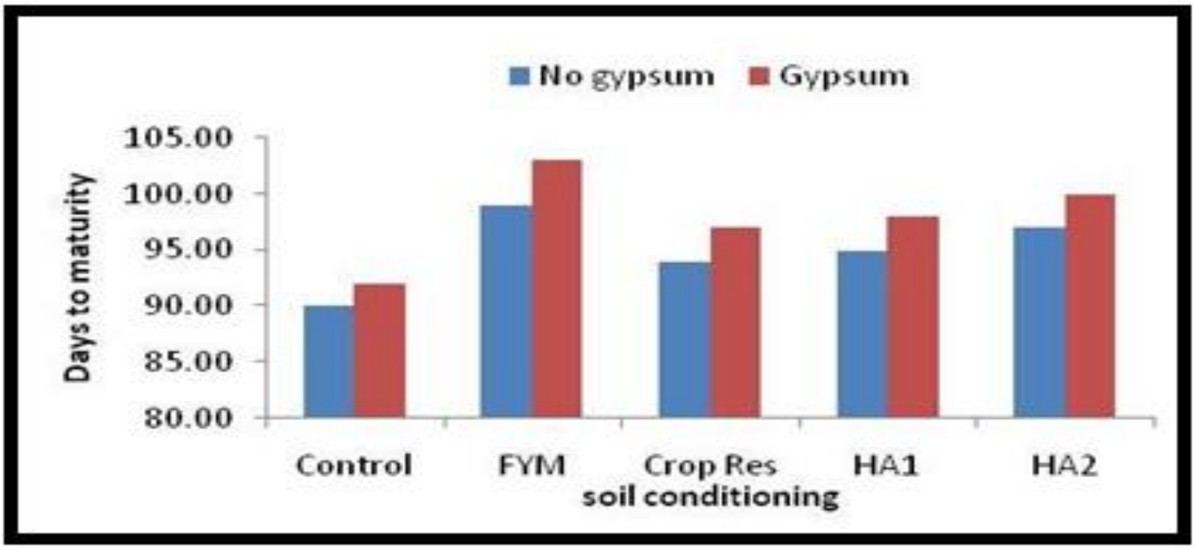


**Fig. 5.** Interaction between G x SC for day to maturity of maize.

*Grain yield*

Mean value of the data showed that grain yield was significantly affected by G, W and SC (Table 4). Reduction in grain yield (3624 kg ha$^{-1}$) was observed in 2011 as compared to 2012 (3781 kg ha$^{-1}$).

In case of irrigation regimes higher grain yield of 4010 kg ha$^{-1}$ was observed in plots where five irrigations (omitted one irrigation at dough stage) were applied while minimum grain yield (3481 kg ha$^{-1}$) in three times irrigated plots.

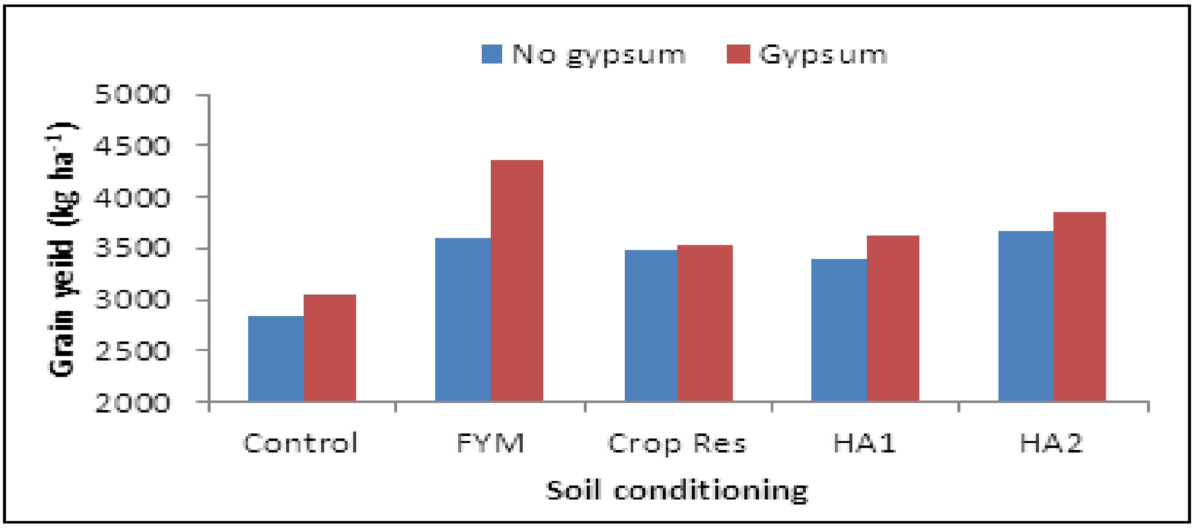


**Fig. 6.** Interaction between G x SC for grain yield (kg ha$^{-1}$) of maize.

Maize grain yield increased significantly by increasing irrigation water amount, and irrigation frequency (Yazar *et al.*, 1999; Kara and Biber, 2008; and Faci, 2009). Our results are in conformity with Seyyed (2012) and Anjam *et al.* (2013) who recorded highest yield under six irrigation compared to minimum irrigation levels. Abbas *et al.* (2005) who reported that yield parameters viz. ear plant$^{-1}$, rows ear$^{-1}$, grains ear$^{-1}$, mean grain weight, yield and harvest index were influenced significantly by eight irrigation regimes.

Gypsum treated plots resulted in higher grain yield (3859 kg ha$^{-1}$) while minimum (3526 kg ha$^{-1}$) in no G or control plots. Our findings are supported by Farina and Cannon, (1988) and Khurana and Sharma, (1995) who reported that gypsum application had resulted in higher grains ear$^{-1}$, kernel weight and grain yield of maize.

This might be due to the fact that gypsum application increased porosity, water and nutrients permeability, storage and uptake and yield components (Hussain *et al.*, 2001, Chen *et al.*, 2011) especially during water scarcity periods. In case of SC application higher grain yield (4283 kg ha$^{-1}$) was observed in FYM treated plots, where as minimum grain yield (3238 kg ha$^{-1}$) in control plots.

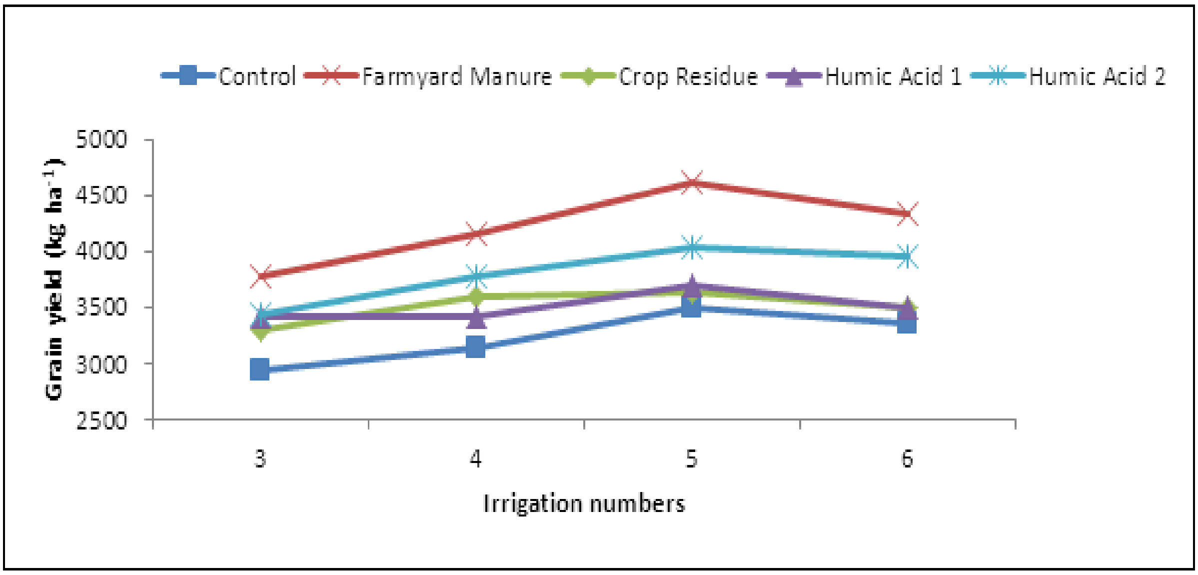


**Fig. 7.** Interaction W x SC for grain yield (kg ha$^{-1}$) of maize.

This increase could be due to the fact that that FYM conserve moisture, it provides sufficient nutrients in soil pool (Ortega *et al.*, 2000) and as result improved soil fertility and crop productivity (Singh *et al.*, 2007 and Yasin *et al.*, 2003). Micske *et al.*, 1990 reported that FYM significantly increase 1000 grain mass, grain ear$^{-1}$ and grain yield of maize crop. Our results are in accordance with the findings of Agba *et al.*, (2012); El Moez, (2003); Chalk *et al.*, (2003); Wang *et al.*, (2004) and Sharma and Saxena, (1985).

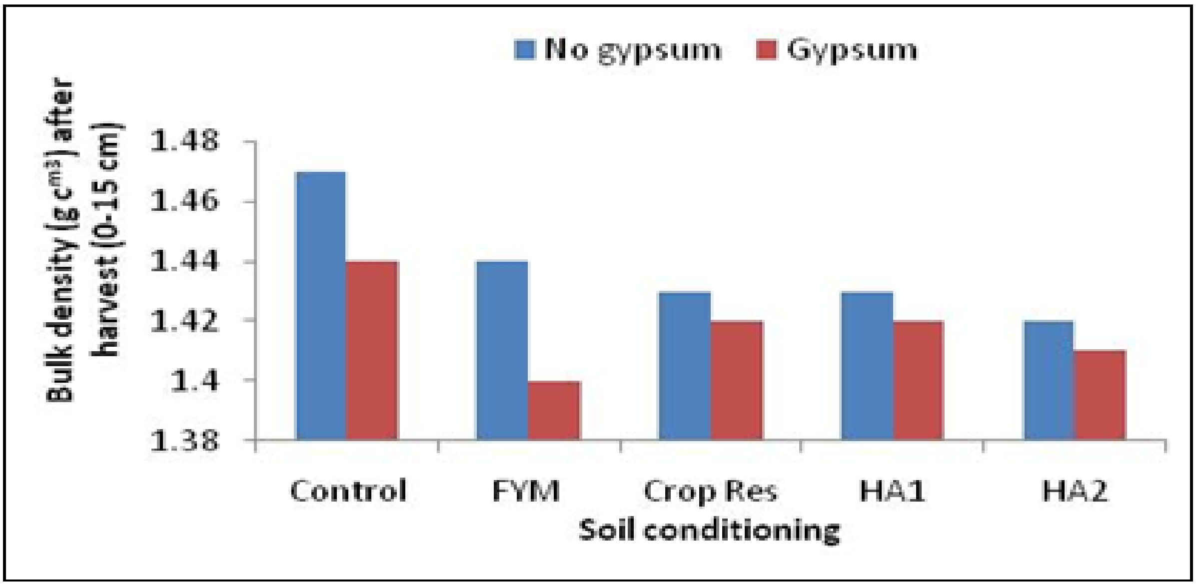


**Fig. 8.** Interaction between G x SC for bulk density (g cm$^{-3}$) after harvest (0- 15 cm).

The interaction between G x SC Fig. 6 showed that G application particularly with FYM increase grain yield of maize linearly. Our results are also in line with Shaimaa *et al.* (2012) who reported that G and FYM significantly increased grains yield, biological yield, 1000 grains weight. Bhatti *et al.* (2005) reported that gypsum and FYM gave higher grain weight and grain yield significantly over the control. The interaction between W x SC for grain yield (Fig. 7) showed that there was a positive association between FYM and irrigation numbers for grain yield. Our results are also in line with Jan *et al.*, (2014) who concluded from the experiment that plots treated with FYM having six irrigations improved maize yield.

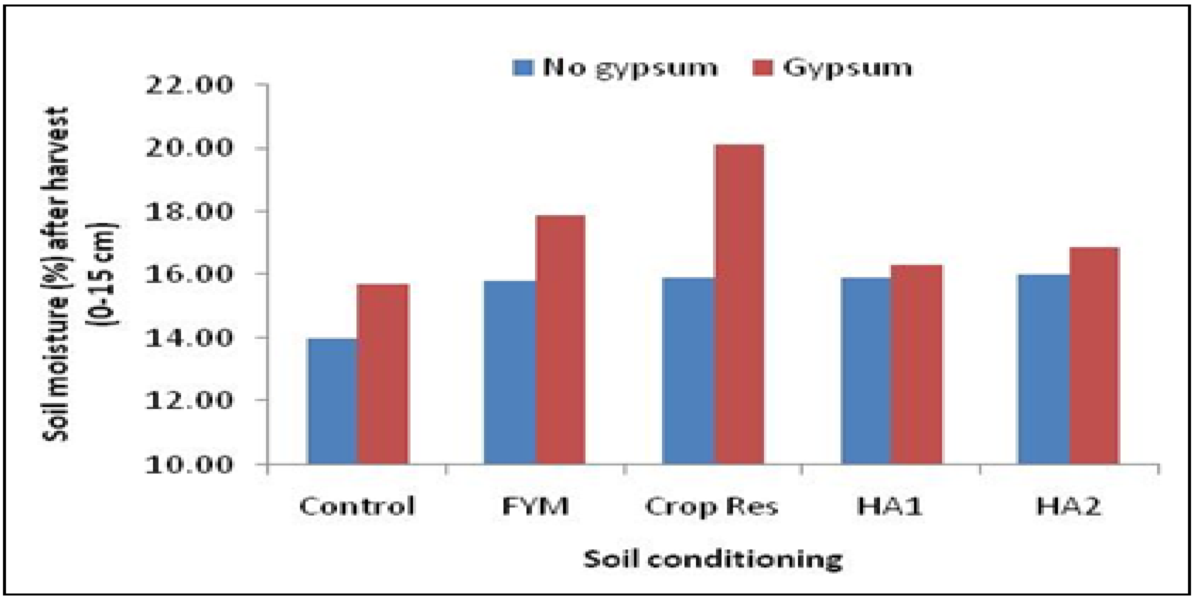


**Fig. 9.** Interaction between G x SC for soil moisture (%) after harvest (0- 15 cm).

*Bulk density after harvest (0-15 cm)*

Data concerning bulk density (g $cm^{-3}$) after harvest of crop is affected by soil conditioning and irrigation regimes are reported in Table 4. Irrigation numbers and SC had significantly influenced bulk density. The Interactions between G x SC and the year effect was also significant for bulk density. Bulk density was higher during first year as compared to second year. Mean data showed that bulk density decrease with increase in irrigation numbers from three to six. These results are an agreement with Hayat and ali (2004) who reported a reduction of 4 to 80% in bulk density with increase in irrigation number from four to six during the crop growing period. Our results are partially in accordance with Robert, (2006) who concluded that irrigation decrease bulk density, increases biomass yield, residue cover, and soil C and N levels. In case of G, higher bulk density (1.44 g $cm^{-3}$) were recorded in no G treated plots while lowest bulk density (1.39 g $cm^{-3}$) was found in G applied plots. Acharya *et al.*, 1988 reported that G application bring reduction in bulk density and increase in water infiltration, improvement in soil structures and water holding and retention capacity (Bhagat and Verma, 1991). Alam *et al*, 2003 and Soundarrajan *et al*, 2007 reported that G application significantly decreases the bulk density of post-harvest soil. Among SC, highest bulk density (1.49 g $cm^{-3}$) was observed in control plots while minimum bulk density (1.35 g $cm^{-3}$) was found in plots treated with FYM. Our reslats are in accordance with Khaleel *et al.,* 1988; Sarkar *et al.*, 2003; Agele *et al.,* 2005 and Liu *et al.,* 2013 who reported that FYM application decreases bulk density and in increase yield. Farmyard manure reduces bulk density and increase in water infiltration (Acharya *et al.*, 1988, Bhagat and Verma, 1991).

Interaction between G x SC (Fig. 8) showed that gypsum application in general had decrease bulk density as compared with no gypsum. Reduction in BD was steeper in plots where FYM was used in combination with G.

Our results are in line with Joachim *et al.* (2007) and Yaduvanshi and Swarup (2005) who investigated that combining FYM with gypsum significantly reduced bulk density and increase soil moisture contents after the harvest of the crop.

*Soil moisture contents (%) (0-15 cm) after harvest*

Data pertaining to soil moisture contents after harvest of crop are reported in Table 4. Mean value of the data showed that G, W and SC had significantly influenced soil moisture contents measured at the depth of 0-15 cm. Soil moisture contents (20.2 %) were higher in 2012 as compared to 2011 (18.0 %). Soil moisture contents (20.0 %) increases with increase in irrigation numbers. Chen *et al.*, 2011 reported that increasing irrigation frequency moisture retention in the soil increases. Gypsum incorporation resulted in maximum soil moisture contents (19.3 %) as compared to control (17.6 %). Our results are in agreement with those of Yadava and Chippa (2007) who reported that gypsum brings significant increase in available N, P, K, S, moisture content of soil as well as N contents in grain and straw after the harvest of the maize over control. These results are an agreement with Batti *et al.* (2005) who reported that gypsum treatment increased the available water/moisture in the soil and as a result increase the organic matter content of the soil. Among SC, maximum soil moisture contents (20.5 %) was observed in those plots where CR was applied while minimum soil moisture contents (17.0 %) was found in control plots. The findings of Khan *et al.*, 2010 confirmed our results that crop residue improve moisture contents in the soil, water holding capacity and also increases the available water for plant growth. Our results are in line with Acharya *et al.*,1988 and Baghat and Verma, 1991 who reported that crop residue (wheat straw) as SC increases soil moisture contents by increasing water infiltration rates and water retention capacity.

Interaction between G x SC was also significant and indicated (Fig. 9) soil moisture contents were higher with G as compared with no G application. Soil conditioning had increase soil moisture contents particularly with CR x G improved soil moisture retention as compared with other combination of SC x G. Our results are also in agreement with Elrahman *et al.* (2012) who reported that soil moisture contents, grain yield and 1000 grains weight were significantly increased with combined gypsum + FYM.

## Conclusion

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

Five irrigations given between emergence, 4 leaves, 8 leaves and tassel visible and blister stages significantly increased growth of maize as compared to lower as well was higher and later irrigation regimes. Amongst organic soil conditioners, application of farmyard manure resulted in bumper and improved maize quality followed by HA2. Gypsum application as Inorganic soil conditioners resulted in growth and development as compared to no gypsum and improved crop quality. 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. Crop performance and improvement in crop quality was better in second year of the experiment.

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