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Response of Maize (Zea mays L.) to soil conditioning and moisture regimes in arid environment of Dera Ismail Khan

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Abstract
Soil conditioners were used to enhance the physical conditions of soil and provide a favorable environment for the growth and development of maize crop. This study was carried out to evaluate the impact of soil conditioning and moisture regimes on the performance of maize crop during 2016 and 2017. Four moisture regimes ranging from 3-6 irrigation in relation to the critical stages of maize crop were applied. Irrigation consisted of 93 mm of water. Tree 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. The design used was a randomized complete block with split plot arrangement replicated thrice. The experimental site was Agricultural Research Institute, Horticulture, Dera Ismail Khan. Moisture 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 fve 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 Dera Ismail khan, Pakistan.
***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 of production having a normal yield of 3590 kg ha-1(Anjum et al., 2014). In Dera Ismail Khan, Khyber Pakhtunkhwa maize was planted on 0.475 million hectares area with the production of 0.887 million tons on an average basis (Shaf et al., 2007). Te 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 (Dera Ismail Khan, 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. The efficiency of water applied and the yield of the crop depends on water application at a critical growth stage of the 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 the 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) Te physical condition of the soil is another important factor that

affects crop production. Poor soil physical condition limits 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 the soil and increased cation exchange capacity and conserved soil moisture. Sial et al. (2007) mentioned that the application of manure as farmyard 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 the 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 an additive effect in increasing nutrients and water availability and yield of various crops. HA act as a catalyst to 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 Dera Ismail Khan 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 seasons of maize crop (2016-2017) at Agricultural Research Institute, Horticulture, Dera Ismail Khan 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 m2 (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, farmyard 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 a seed rate of 30 kg ha-1with 75 cm row- rowand25 cm plant - plant distance. There were 8 rows per plot. The crop was sown on 27th June both in 2016 and 2017. Te analyses showed that FYM and CR contained 0.70 and0.35 % N respectively. 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. Weather data are given in Table 1 and Physico-chemical characteristics of the soils are given in Table 2.

Table 1: Monthly seasonal precipitation, temperature and relative humidity (%) at Cotton Research Station, Dera Ismail Khan during 2016and 2017 growing seasons

Month	2016								2017							
	Temp (°C)			Relative humidity (%)					Temp (°C)			Relative humidity (%)				
				800hrs		1400 hrs		Rainfall (mm)				800hrs		1400 hrs		Rainfall (mm)
	Max	Min	Mean	Max	Min	Max	Min		Max	Min	Mean	Max	Min	Max	Min	
March	35	11	23	94	54	79	25	50	34	5	20	94	54	79	25	22
April	41	13	27	92	52	77	23	38	38	6	22	75	36	56	29	-
May	42	19	31	75	39	63	20	12	45	7	26	57	30	36	23	17
June	44	21	33	81	46	58	27	16.5	45	12	29	65	34	50	26	6.0
July	42	24	33	81	48	68	36	34	45	18	32	73	30	42	23	111
August	40	23	32					35	41	20	31	73	42	49	26	43
September	39	20	30	82	65	71	28	-	40	18	29	73	42	41	22	40.0
October	34	19	27					4	36	18	27	72	52	52	25	-
November	30	6	18	90	59	91	65	-	31	10	21	81	69	78	53	-
Total rainfall								189.5								239.0

Source: *Arid Zone Research Council (AZRC), D.I.Khan, Pakistan.*

Table 2. Physico-chemical characteristics of the soils used for the experiments at Cotton Research Station, D.I.Khan

Characteristics		Values	
		2016	2017
Texture Class		Silty Clay	Silty Clay
Electrical conductivity (EC)	dSm^{-1}	2.66	2.75
Soil pH (1:1)		7.60	7.80
Organic Matter	%	0.68	0.89
NO_3-N	mg kg^{-1}	5.52	5.56
Available K (mg kg^{-1})	mg kg^{-1} soil	180	150
AB-DTPA extractable P	mg kg^{-1} soil	13.8	11.6
Total N	g kg^{-1} soil	0.99	0.66

Source: Soil Chemistry Laboratory, Agriculture Research Institute, Dera Ismail Khan, Pakistan

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 deferent growing stages of maize crop. A 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 3.

Factor A. Main plot: Irrigation

Table 3: Irrigation schedule for maize crop grown during 2016 and 2017.

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 is taken per irrigation of main plot	28 minutes			

Ritichi et al, (1992); √: Irrigation applied; x: Irrigation omitted at the 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

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 an oven at 80 ^{0}C for 24 hours for having a constant dry weight.

Ten mean CGR was calculated by the formula proposed by Hunt (1978).

CGR= W2-W1 1/ T2- T1GA

Leaf area plant^{-1} (cm2) 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 the base of plant to tassel base in each subplot of five plants selected randomly at maturity and averages were 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. Te data obtained for biological yield in every subplot was changed into kg ha^{-1}. Grain and straw nitrogen analysis were 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

Te collected data were statistically analyzed using the procedure outlined by Steel and Torrie (1984). **Results and Discussion**

Crop growth rate

Data concerning the average crop growth rate are shown in Table 4. A perusal of the mean data indicated that gypsum, irrigation regime and soil conditioning had improved average crop growth rate signifcantly. Te interaction between G x SC and year effect was also significant for crop growth rate. During the second year (2017) average crop growth rate was signifcantly higher (8.6 gm-2day-1) as compared with the first year (6.0 gm^{-2} day^{-1}) of the experiment. The 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 signifcantly 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. Te findings of Hassan (2003) and Kazmi et al. (2003) also indicated that CGR in maize increased with an increase in irrigation numbers up to the maximum of five irrigation. Data further showed that crop growth rate was signifcantly 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 the 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 lower CGR (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. The planned mean comparison revealed that average CGR was higher in SC treated plots compared with control. 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.

Leaf area plant^{-1}

Table 5 revealed that leaf area plant^{-1}(cm^2) was significantly affected by gypsum, irrigation numbers, and soil conditioning. Te 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 cm2) was recorded during 2017 as compared with 2016 (4067 cm2). 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) 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 the 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. It indicated that with an 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 an 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 conditioning were used. The interaction between G x SC for leaf area plant^{-1} of maize revealed that leaf area plant^{-1} enhanced with the 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 conditioning used. FYM application resulted in higher leaf area when used in combination with G as compared with sole application

Table 4: Average Crop growth rate (gm-2day-1) of maize as affected by soil conditioning and irrigation regimes during the year 2016 and 2017

Treatments		Years (Y)		Two years average
		2016	2017	
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	Ns
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		

Table 5: Leaf area plant^{-1} (cm^2) of maize as affected by soil conditioning and irrigation regimes during 2016 and 2017

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 Mean		4067 b	4302 a	
Planned Mean Comparison				
Treatment		Mean	Contrast	Signifcance
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 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 signifcantly different from each other at 5% level of probability.
*: Signifcant at 5% level of probability; **: Signifcant at 1% level of probability;
ns: Nonsignificant.

Plant height

Data concerning plant height (cm) of maize as influenced by soil conditioning and irrigation regimes are reported in Table 6. 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 confrmed the findings of Anjam et al. (2014) who suggested that plant height showed a linear response to an 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 defciency 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 a significant response to SC. Higher plant height was obtained from plots treated with SC than plots without SC. Te 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.The interaction between W x SC for plant height was significant. The interaction reflects that plant tallness increased with an 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 fve numbers of irrigation. Plant height increased with an 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 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. Te 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

Biological yield

Data regarding biological yield (kg ha^{-1}) of maize are given in Table 7. Mean value of the data revealed that G, W, and SC had a signifcant effect on the biological yield of maize crop. Te year effect and the interaction between W x G and G x SC was also signifcant for biological yield. During the second year of the experimentation higher biological yield (10464kg ha^{-1}) was produced as compared to frst year (9902kg ha^{-1}). The 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 the plant, rate of germination, grains ear^{-1}, production and the defciency of water utilized by the plants (Irfan et al., 2014). In the case of G, higher biological yield (10409kg ha^{-1}) was founded in G treated plots while the 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 signifcant for biological yield. Higher biological yield (10973kg ha-1) was observed in FYM applied plots; whereas lower biological yield (9430 kg ha^{-1}) was recorded in plots without FYM and other SC application. Te 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). The 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 signifcant for biological yield. Te figure showed that when G was used as an inorganic source of SC higher biological yield was observed at all levels of irrigation as compared to the application of irrigations without G application so it showed that G performed well at the presence of the sufcient amount of water at the initial stages of crop growth (Figure 8). Te data regarding the interaction between G x SC revealed that biological yield responded very well to the application of G x SC as compared with no G. All the SC applied in the experiment produced a 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 folds. Among SC, FYM responds positively to the application of G as the higher biological yield was observed in those plots where FYM along with G was applied.

Table 6: Plant height (cm) of maize as affected by soil conditioning and irrigation regimes during 2016

and 2017

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 Mean		198.3	199.7	
Planned Mean Comparison				
Treatment		Mean	Contrast	Signifcance
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 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 signifcantly different from each other at 5% level of probability.
*: Signifcant at 5% level of probability; **: Signifcant at 1% level of probability;
ns: Nonsignificant.

Table 7: Biological yield (kg ha^{-1}) of maize as affected by soil conditioning and irrigation regimes during 2016 and 2017.

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 (HA2)	4	9860 b	10359 b	10109 b
LSD (0.05)		472	433	370
Year Mean		9902 b	10464 a	
Planned Mean Comparison				
Treatment		Mean	Contrast	Signifcance
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 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 signifcantly different from each other at 5% level of probability.
*: Signifcant at 5% level of probability; **: Signifcant at 1% level of probability;
ns: Nonsignifcant.

Grain nitrogen

Data pertaining to nitrogen contents (%) in grains of maize are shown in Table 8. 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 the 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 funding 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 the production of a 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 a grain of maize crop by 20 %–29%. The 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 a 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 signifcant variations were found when G was used with other soil conditioners.

Conclusions and Recommendations

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

1. Six irrigations are given at emergence, 4 leaves, 8 leaves, tassel visible, blister and dough stage had significantly increased the growth of maize as compared to lower irrigation regimes.
2. Amongst organic soil conditioners, application of farmyard manure resulted in the 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 + farmyard manure as soil conditioners having fve irrigation regimes given at emergence, 4 leaves, 8 leaves and tassel visible and blister stages produced a higher yield.
5. Crop performance and improvement in crop quality were better in the second year of the experiment.

On the basis of experimental results and the conclusion is drawn, it is recommended that both farmyard manure

(10 tons ha^{-1}) and gypsum (1 ton 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 a higher yield of maize crop in Dera Ismail Khan.

Table 8: Grain N (g kg^{-1}) of maize as affected by soil conditioning and irrigation regimes during 2016 and 2017.

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 (HA2)	4	20.5 b	20.3 b	20.4 b
LSD (0.05)		0.11	0.13	0.10
Year Mean		20.2	20.2	
Planned Mean Comparison				
Treatment		Mean	Contrast	Signifcance
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.
*: Signifcant at 5% level of probability; **: Signifcant at 1% level of probability;
ns: Non signifcant.

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