Impacts of Various Levels of Mulching on The Yield of Maize, Water Use Efficiency, Soil Organic Carbon And Physical and Chemical Properties Under Different Methods of Sowing

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Abstract

The study was chalked out with the hypothesis that to quantify the impact of various levels of mulches on maize yield, soilphysico-chemical traitsand carbon content under various sowing methods. In this context, bed & flat sowing methods and two levels of mulches (0 & 8 Mgha^{-1}) were adopted by using split plot Randomized Complete Block Design (RCBD) in study site. Crop (Maize) was sown in raised beds which were made with the help of bed planter and flat plots using the choppa method. Irrigated when required. All the treatments were replicated thrice. The material of mulching was applied when germination completed. The results exhibited that the plant height, weight of 100 grains, yield of grain as well as biological yield were maximum under bed sowing method & mulching at 8 Mg ha^{-1}.The water use efficiency (WUE) was highest (i.e 2.24 kg m^{-3}) that was 100% high in treatments combination $BM_{w.st}$ as compared to FM_0. The improvement in the soil structure was shown by lower bulk density (BD) (6.9 %) and high rate of infiltration (11.6 %) was found under bed sowing method in contrast to flat sowing method. These finding are paradox for the scientific community to verify this fact on large scale in the field.

Keywords | Mulch, maize, soil properties, sowing methods, infiltration rate

Introduction

Globally, the maize (Zea mays L.) is a popular cereal crop globally after rice and wheat to feed the humanity. Worldwide average maize yield is almost double as compared to rice and four times more as compared to wheat. Prior to fodder, it was being used as a staple food in different nationsworldwide. But in Pakistan, maize being a 3rd cereal crop is cultivated on 1418 thousand hectares during 2020-21. The production was 7.883 million tonnes in 2020-21(Economic Survey of Pakistan, 2021 Pakistan Bureau of Statistics).

Maize is water exhaustive crop and exploration of new techniques is dire need to combat water scarcity for its sustainable production. The Furrow-bed irrigation method saved significant quantity of water (Choudhry et al., 1994) and documented further effectual use in contrast to the surface irrigation (Khan et al., 1998). Selvaraju and Iruthayaraj (1993) observed that the furrow irrigation resulted a greater leaf area, crop growth as well as grain yield than that of alternate or paired skip furrow irrigation. Kemper et al. (1975) noticed that irrigation through flood on the whole field resulted leaching of nitrates from the root zone with concomitant loss in fertilizer. However, the extra irrigation resulted more leaching losses of fertilizer and thus decreased the plant height, dry matter as well as grain yield (Shah et al., 2013). Under the regime of water scarcity and decreasing trend of crop production, it is important to explore better planting methods having high water use efficiencies in order to provide optimum water for crop. Earlier studies regarding non-permanent beds and furrow irrigation in Pakistan reported 20% and 48% increase in yields of wheat and cotton, respectively (Houet al., 2010; Akhtar et al., 2018).

Mulching is a beneficial management strategy for dealing with water scarcity. It improves agricultural productivity by regulating the farm environment through influencing soil temperature, leaching, and other factors SOC content, evapotranspiration as well as fertilizer loss from runoff (Roldan et al., 2003). In addition, by increasing the physical properties of the soil, you can boost your yield (De Silva et al., 2003;Shah et al., 2013). Under winter wheat, evaporation is reduced by 50%, and during a wheat harvest, we conserved roughly 80 mm of water (Wang et al., 2001).

In case of flood and basin irrigation system the application losses in fields were about 25-40% (World Bank, 1997). The reasons of the low efficiencies of application in Indus Basin

Irrigation System (IBIS) are the result of over irrigation, old methods of irrigation as well as timings, poor irrigation scheduling and unlevelled fields (Gill, 1994). Water use efficiency can also be improved by monitoring application losses The availability of water in Pakistan is decreasing with alarming rate because of increasing population pressure which places our country in 'high stress' category in relation to inadequate water resources. Per capita water availability in 1951 in Pakistan was about 5300 cubic meters, which has now reduced to about 1090 cubic meters which touched the level of 1000 cubic meters because increasing pressure of population and lengthy drought periods. According to an estimate, additionally about 48 billion cubic meter water would inevitable in order to meet the agricultural demand of the country (Government of Pakistan, 2020). Right now, water shortage created a shift from traditional methods of crop production to modern methods in order to save water.

Either this parameter increased the best by adopting modern irrigation scheduling or by programmed schedules, by providing optimum quantity of water, has become a serious issue for many years (Zibri, 2015). Mulching is considered as the best technology for improving quality and fertility of soil. Mulching reduces the evaporation losses by restoring water and maintaining water and temperature (Athy*et al.,* 2006). Mulching has direct impact on organic matter content of soil (Qamar, 2015). Under scenario of water scarcity, mulch application exhibited main benefit of conservation of soil moisture. Application of mulching has boosted crop yield due to water restoration, play role in temperature moderation, decreased soil and water erosion, decreased salt movement from lower to upper layers, and minimized weed infestation (Bu *et al.,* 2002). McMillen (2013) observed encouraging effect of mulching on soil organic matter. Organic amendments contributed a crucial role in enhancingthe fertility of soil for better production of crop (Khan *et al.,* 2007) and such growing awareness about sequestration of carbon in the soil during current years has developed serious economic as well as environment motivations. The sequestration of carbon in arable lands and in plant material in order to reduce the impact of emission of CO_2 can be accomplished through the production of additional biomass in a specific time period, or by the addition of external C source in the soil, like, organic amendments (i.e., manures and mulches). Mulch application exhibited an increase in carbon sequestration, aggregates stability, declined compaction and surface crusting and enhanced water restoration as well as infiltration of soil (Mueller *et al.,* 2012).In the light of above discussion, this study has been planned with the objective to assess the sowing methods mulch effect on the water use efficiency, physical characteristics of soil, SOC and maize yield.

MATERIALS AND METHODS

Study site and collection of soils samples

After site selection, field experiments were carried out to evaluate the impacts of different categories of mulch on the yield of maize, use efficiency ofwater, SOC and physical characteristics of soilin different methods of sowing by using split plot design(RCBD). Before sowing of crop, we collected the composite soil samples randomly from the field under study. The soil samples were dried in shade, grinded, mixed properly and sieved through a 2 mm sieve and examined for different soil parameters. Soil physical properties i.e. analysis of particle size as well as BD of soil and chemical properties were too assessed prior to start the experiment and are given in Table-1.

Experimental layout and Design

The methods of sowing (i.e. bed sowing and flat sowing) were placed in the main plot, whereas

Table 1. Physico-chemical features of soil experimental site

Characteristics	Units	Value
Sand	%	40
Silt	%	37.9
Clay	%	22.0
Textural class	--	Loam
Saturation percentage	%	42
Bulk density (BD)	Mg m^{-3}	1.38
Soil organic carbon (SOC)	%	0.41
EC_e	dS m^{-1}	1.44
pH	--	7.4
Total N	g kg^{-1}	0.46
Available P	mg kg^{-1}	9.9
AvailableK	mg kg^{-1}	115.7

the mulching levels were placed in the sub-plots (55 m2). The details of six treatments combinationsused. (i) BM0 = Bed sowing and straw of wheat @ 0 Mg ha-1, (ii) BMwst = Bed sowing and straw of wheat @ 8 Mg ha-1, (iii) FM0 = Flat sowing and Wheat straw @ 0 Mg ha-1 and (iv) FMwst = Flat sowing and wheat straw @ 8Mg ha-1. Randomized Complete Block Design inthe Split plot prearrangement with three replications was employed. The methods of sowing were placed in the main plots whereas levels of mulches in the sub plot.

Crop Husbandry

A rotavator was used to prepare a well-pulverized field, and beds were fashioned with the help of a bed-planting-machine after fertilizer was applied. The crop was planted using the choppa method in August in a prepared seedbed with a row to row distance of 45 cm and a plant to plant distance of 20 cm, using maize hybrid "Pioneer-3062" seed. Two seeds were deposited into each hole. The crop received a basalrate of application of 250 kg of N, 120 kg ofP2O5, and 125 kg of K2O ha-1. Using triple super phosphate (TSP), muriate of potash (MOP)and urea, a complete dose of phosphorus(P), potassium (K)& 1/3rd of nitrogen (N) was used at the time of sowing. At knee height, the remaining 1/3rd of the N was administered while remaining 1/3rdN at teselling stage. To mature the crop, eight irrigations were used in total. The first irrigation was applied 15 days after sowing, and further irrigations were given as needed. A cut throat flume was used to apply irrigation water to each treatment.

Characteristics of crop growth and soil properties

Plant height (cm), weight of 100-grain (g), grain yield (Mg ha-1), biological yield (Mg ha-1) and HI (percent) was measured for maize crop growth. Mineral nutrition in the form of N, P, and K (g kg-1) was also measured in the shoots. The efficiency of irrigation was also calculated. Soil BD (Mg m-3), bulk porosity (m3 m-3) from 0-10 cm depth of soil, and the SOC from 0-20 cm soil depth at crop harvest after harvesting. The quantities of N, P, and K in the soil (g kg-1) also determined.

Analytical techniques

Soil examinations

The Bouyoucous hydrometer method was used to quantify particle soil analysis, and the International Textural Triangle was used to identify soil textural class (Moodieet al., 1959). The pH of the soil paste (pHs) was obtained using a model HM-12 pH meter and the U.S. Salinity Lab. Staff (1954), (Method 2, p. 84 method). The Conductivity Meter Model-4070 was employed to determine the electrical conductivity (dS m-1) (Method 21a, 21c, p. 102). Method 2, p. 107, was used to calculate the percentage of soil saturation. The method given by Ryan et al.(2001) was employed to determine the amount of organic carbon in the soil. The BD of the soil was calculated using Blake and Hartge's (1986) methodology. The following formula was used to calculate the soil porosity (f) using itsBD (b) as well as particle density (p). 1- (b / p) = f. Aninfiltrometer with double ring was employedto determine the rate of infiltration. Using a driving plate and an impact absorbing hammer, the inner and the outer rings were driven 5 cm in the dirt. Water was poured into the inner & outer circles. The water flowed vertically through the inner ring into the soil till it reached a steady rate (Klute, 1986). Jackson (1962) techniques were applied to find the total N contents of soil. At 880nm wavelength, the available P in soil was determined using Spectrophotometer (Method 16, p. 134). Corning Flame Photometer-410 was used to assess soil extractable K.

Plant samples collection and analysis

Harvests were made on an area of 1 m^2 each plot as they reached maturity. In the field, the fresh weight was calculated, and an aliquot was obtained at random for dry matter as well asN analyses. The samples of shoot stored at temperature (65°C) for about 48 hours before being weighed dry. The shoot samples were pulverized and the amounts of N, P, and K in the maize shoots determined using Moore and Chapman's (1986)method of digestion. The N content was evaluated using the Kjeldhal technique after digestion. After calibrating with P standards, the P level was evaluated using an ANA-730 Spectrophotometer at 470 nm wavelength(Method 61, p. 134). The K level was measured using a Flame Photometer. A standard curve was produced using standards of K (2 to 20 ppm) made using AR KCl. Plant K values were calculated using a standard curve.

Analytical statistics

The data obtained from the study was statistically analyzed through split plot design (RCBD) (Steel et al., 1997). The LSD (Least Significant Difference) method was applied to make comparisons between treatment means (Gomez and Gomez, 1999).

Results

Agronomic characteristics

Plant height (cm), weight of100-grain (g), yield of the grain (Mg ha-1), biological yield (Mg ha-1), index of harvest (percent), and water usage efficiency (kg m-3) were all affected by mulch and sowing methods (Fig. 1).

Height of the plant

Plant height (206.9 cm) was higher in plots where bed sowing was used, whereas plant height was lower in plots where flat sowing was used (187.9 cm). As a result, when comparing BS to FS, the average increase in plant height was 10.3 percent. When straw mulch was applied at 8 Mg ha-1, the maximum mean value of plant height was measured at 201.9 cm, whereas the minimum was 192.3 cm in the control. In terms of the interaction effect, In terms of the interactive effect of mulch and sowing methods, the treatment combination BMw.st. had the highest mean plant height of 211.5 cm, followed by 203.1 cm in the case of BM0. In the treatment combination FM0, the minimum plant height (185.2 cm) was recorded (Fig. 1). The use of wheat straw in the bed increased plant height by 5.1 percent over the control. In the case of flat seeding, the wheat straw treatment showed a 4.48 percent increase in plant height over the control.

Weight of 100-grains(g)

The data demonstrated that plots where bed sowing was used produced higher 100-grain weight (36.8 g), but plots where flat sowing was used produced lower 100-grain weight (31.1 g). The mulched area had a higher 100-grain weight (36.0 g) than the control area, which had a lower 33.0 g. As shown in Fig. 1, BMw.st. had the highest 100-grain weight of 39.1 g, resulting in a 29.2 percent increase in 100-grain weight over FM0. When the therapies were compared, it was discovered that BMw.st has a substantial influence on 100-grain weight when compared to the other treatments.

Grain Yield (Mg ha-1)

According to the results, methods of sowing and mulch application, besides their interactive effect, had a substantial impact on the yield of grain, resulting in an enhancement in grain output. With an average yield of 10.5 Mg ha-1, bed sowing(BS) method had a significant increase (30.7 percent) than flat sowing (FS), which had an average yield of 8.15 Mg ha-1. The highest yield of grains in the case of BS was owing to a greater number of grains and a higher grain weight per 100 grains. In terms of mulch application, the highest yield (10.3 Mg ha-1) was achieved with wheat straw (7.9 Mg ha-1) and 8.28 Mg ha-1 with control. Wheat straw application resulted in a 27.4% increase in grain output over control. The effect of mulched bed sowing was obvious (11.7 Mg ha-1) was discovered, which was 70.7 percent higher in contrast to flat seeding with no any mulching treatment (FM0). Among all the treatment combinations, FM0 produced the lowest yield of 6.88 Mg ha-1.

Biological output (Mg ha^{-1})

The data revealed that sowing methods have considerable differences in their effects, with BS having a greater biological output (26.8 Mg ha-1) than FS (24.0 Mg ha-1) and a 10.6% enhancement over the flat method sowing approach. The levels of Mulching considerably boosted the biological yield, with a highestyield of 26.1 Mg ha-1 in the treatment in which wheat straw was treated at an 8 Mg ha-1 rate and the lowest yield of 24.9 Mg ha-1 in the control (no mulch used). When the mulch and sowing procedures were combined, application rate BMw.st produced the highest biological yield of 27.0 Mg ha-1, which was non-significant on statistical basis when compared to BM0, FMw.st, and FMo.

Maize harvest index as a function of mulch and sowing methods

The HI indicates a crop's ability to divide dry matter into economic (grain) production.Mulching levels had a statistically significant influence on HI, while sowing methods had no statistical relevance, however BS enhanced HI by 19.5% over FS. The Mw.st therapy resulted in 22.8 percent higher HI than the M0 treatment. The maximum HI (43.0%) and minimum HI (29.2%) were found in bed sowing with mulch (7.9 Mg ha-1) and sowing through flat bed without mulch.

Water Use Efficiency (kg m-3)

The water use efficiency of maize on the basis of grain yield ranged between 2.25 and 1.21 kg m-3 for two different planting patterns with two degrees of mulch, according to the data. WUE was found to be significantly affected by sowing methods, mulch levels, and their interactions. Mulching materials had a considerable impact on maize's water consumption efficiency. FMwst had 39.95 percent greater WUE than the control group (no mulch). Water use efficiency increased in raised beds, owing to the use of more water by the flat approach and the enhanced microclimate in raised bed planting, which reduced disease and lodging. In terms of interaction, the highest WUE was 2.55 kg m-3 with the BMw.st combination, whereas the lowest value was 0.89 kg m-3 with FM0.In BMo and FMw.st, the WUE values for the other treatments were 1.88 and 1.35 kg m-3, respectively.

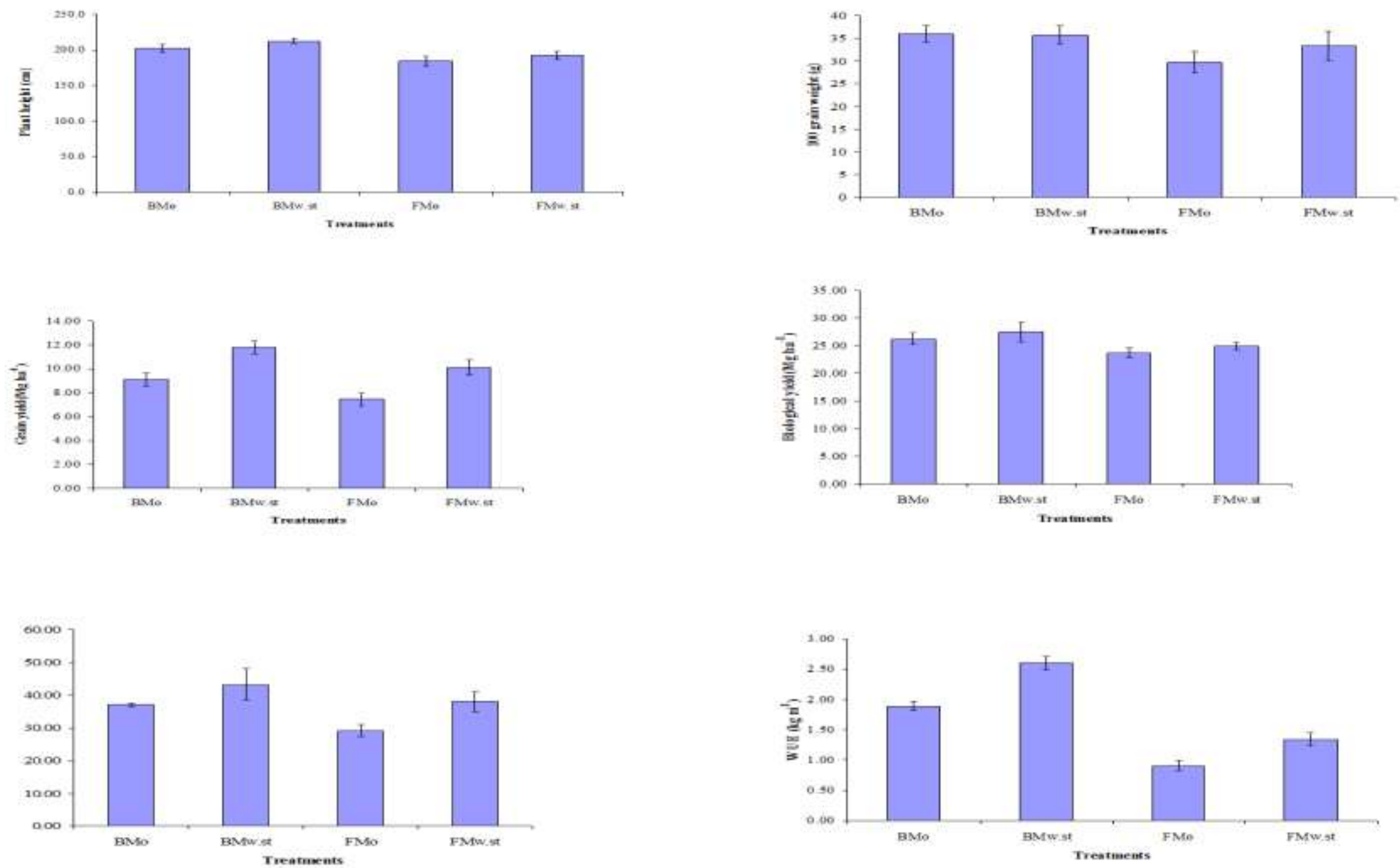

Figure 1: Impact of mulch and sowing methods on the height of plant (cm), weight of 100-grains (g), grain yield (Mg ha^{-1}), biological yield (Mg ha^{-1}), HI (%) and efficiency of water use (kg m^{-3}). Whereas BM_0 = Bed sowing and wheat straw @ 0.0 Mg ha^{-1}, BM_{wst} = Bed sowing and wheat straw application @ 8 Mg ha^{-1}, FM_0 = Flat sowing and wheat straw @ 0.0 Mg ha^{-1}, FM_{wst} = Flat sowing and wheat straw @ 8Mg ha^{-1}.

Maize crop nutrient status

Figure 2 exhibited the impacts of mulch and seeding methods on the shoot N,P and K concentration (g kg^{-1}).

Nitrogen content of shoot (g kg^{-1})

The statistical behavior of several treatments on the N concentration by the maize crop is depicted in Figure 2. When compared to flat sowing, the concentration of N in the maize shoots at the time of harvest was high in the bed sowing approach (18.7 g kg-1) (14.97 g kg-1). As a result, maize plants grown in beds had a 24.91 percent higher shoot N concentration than those grown in flat basins. When using wheat straw (7.98 Mg ha-1) as a mulch, the shoot N content was 18.4 g kg-1 and 15.1 g kg-1, respectively. When wheat straw was used instead of control, there was a 20.5 percent rise in shoot N concentration. In terms of the interaction effect, the treatment combination BMw.st yielded the highest value of shoot N concentration (20.2 g kg-1), while FM0 yielded the lowest (13.1 g kg-1). When BMwst was used instead of BM0, there was a obvious increase in shoot N of 17.7%.

Phosphorus concentration in the shoot (g kg-1)

On shoot P concentrations, both sowing methods and mulching amounts had significant effects. Maize shoot P content was 17.1 percent higher in bed sowing methods than in conventional sowing methods. In terms of mulching, the highest shoot P concentration (3.59 g kg-1) was found in the wheat straw (8 Mg ha-1) and 3.20 g kg-1 which was observed in control. When wheat straw used instead of control, there was a 10.8% rise in shoot P content. In terms of the interaction effect, BMw.st had the highest mean value of shoot P (3.72 g kg-1), which was followed by 3.65 g kg-1 for BM0 (Fig 2).

Potassium concentration in the shoot (g kg-1)

Figure 2 shows how the methods of sowing and mulch had a considerable impact on shoot K concentration and their interaction. The highest K concentration (16.7 g kg-1) was found in a crop seeded by bed planting, whereas a K concentration of 16.1 g kg-1 that was found in a crop sown by flat sowing. As a result, maize crops grown by bed planting had 5.5 percent higher shoot K concentrations as compared to those grown by flat sowing. The interactive effect of methods of sowing as well as mulching levels on shoot concentration of

K revealed that mulching under bed sowing has a substantial impact on shoot K concentration. As a result, the combination of treatment of BMw.st increased shoot K levels by 2.8 and 6.1 percent, respectively, compared to BM0 and FMwst.

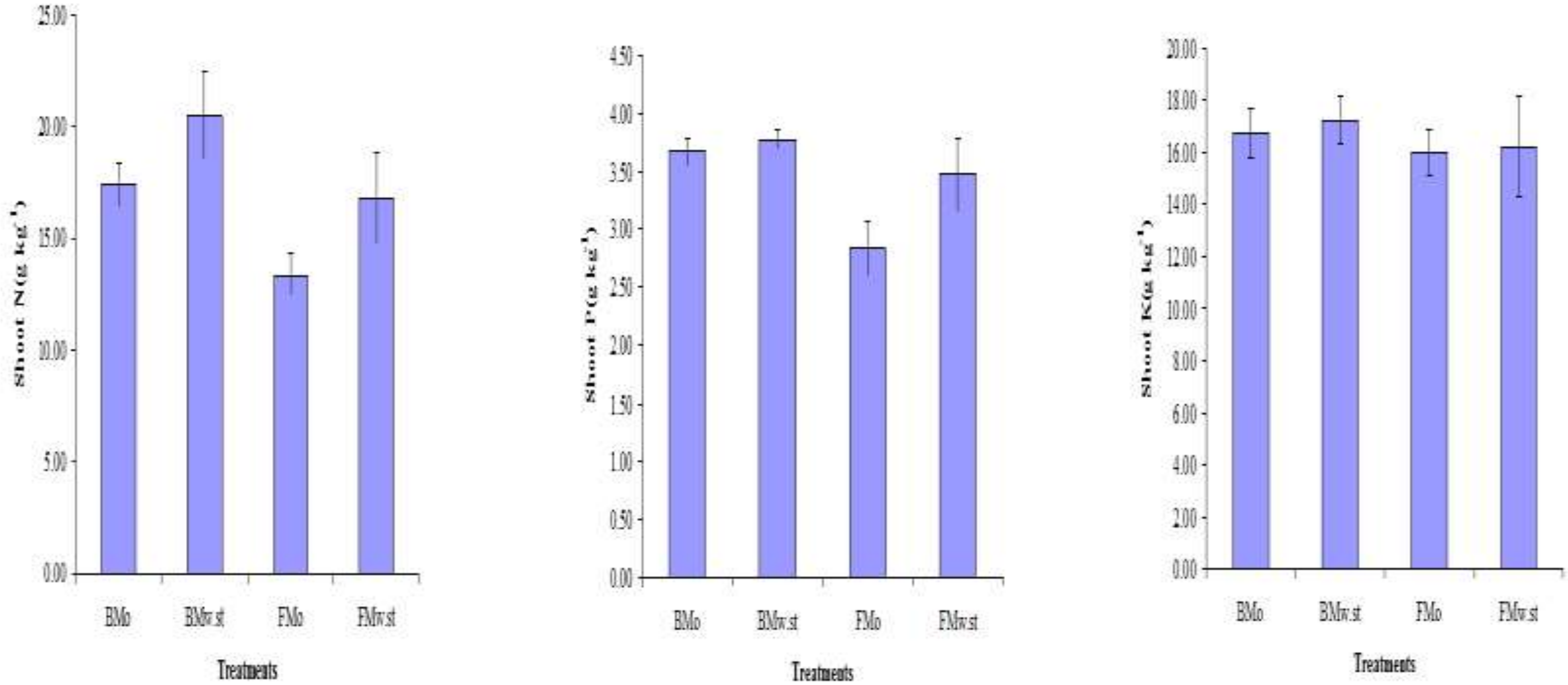

Figure-2: Mulching and sowing methods effect on shoot N (g kg^{-1}), P (g kg^{-1}) and K concentrations (g kg^{-1}). Whereas BM_0 = Bed sowing and wheat straw @ 0.0 Mg ha^{-1}, BM_{wst} = Bed sowing and wheat straw @ 8 Mg ha^{-1}, FM_0 = Flat sowing and wheat straw application (0 Mg ha^{-1}), FM_{wst} = Flat sowing and wheat straw application @ 8Mg ha^{-1}.

Chemical characteristics of soil

Figure-3 shows the impact of mulching and planting methods on soil N (g kg^{-1}), P (mg kg^{-1}), K (mg kg^{-1}) and organic carbon (percent) levels.

Nitrogen concentration (g kg-1)

The findings of statistical results interpretation of N concentration in soil (Appendix 10) revealed that sowing methods had a substantial impact on N concentration at 0-20 cm depth. Bed seeding yielded 34.0 percent more soil N than flat sowing. Mulch application significantly increased soil N by 20.3 percent in BMwst compared to BM0. Treatment BMwst had the highest N content (0.48 g kg-1), whereas treatment FM0 had the lowest (0.30 g kg-1) among the treatment combinations (Fig. 3).

Concentration of phosphorus (mg kg^{-1})

Appendix 11 contains data about the content of p in the soil (mg kg-1) as a function of sowing procedures (methods) and mulching levels, demonstrating that not only did sowing methods have a substantial impact on concentration of soil p up to the depth of 0-20 cm, however levels of mulching had a significant impact as well. In comparison to flat sowing, soil under bed sowing contained 41.8 percent more P. Mulch on the bed and flat seeding, on the other hand, increased P levels in the soil by 50.4 and 7%, respectively, over their respective controls. Under two seeding procedures, all treatment combinations receiving varied mulching levels were different from one other on statistical basis (Fig. 3). The highest soil P content was found in BMw.st (12.1 mg kg-1), however the lowest was found in BMw.st (12.0 mg kg-1).

Concentration of potassium (mg kg^{-1})

Appendix 12 contains information on the effects of different methods of sowing as well as wheat straw (mulch) on the soil K content. Application of Mulch, methods of sowing plus their interactions all showed a statistically significant impact on the soil K levels, according to the data. In terms of sowing methods, plots where bed sowing was used generated more K (126.0 mg kg-1), while plots where flat sowing was used produced less (112 mg kg-1). As a result, the average increase in K level in BS was 12.7 percent higher than in FS. In the bed sowing in which the straw of wheat was spread at 8 Mg ha-1, the maximum mean value of soil K was measured at 120.0 mg kg-1, with a minimum of 117.3 mg kg-1 in the control case.

Organic carbon (%)

The data on SOV content(Fig. 3) shows that planting methods and mulching had a considerable impact on the soil organic pool. When compared to flat sowing, the bed planting style increased SOC by 30.3 percent. The plots where wheat straw mulch was used had the highest levels of SOC (0.48 percent). With contrast, in the treatment combination FM0, the minimum (0.33 percent) was recorded. When compared to the control, the application of wheat straw mulch had no effect. Wheat straw mulch, on the other hand, enhanced SOC by 5 % when compared to control. In terms of the interaction effect (Fig. 3), the treatment combination BMw.st yielded the highest SOC (0.48 percent). FM0, alternatively, had the lowermost value (0.35 percent). Under BMw.st., a significant rise of 8.7% in SOC was reported compared to BM0.

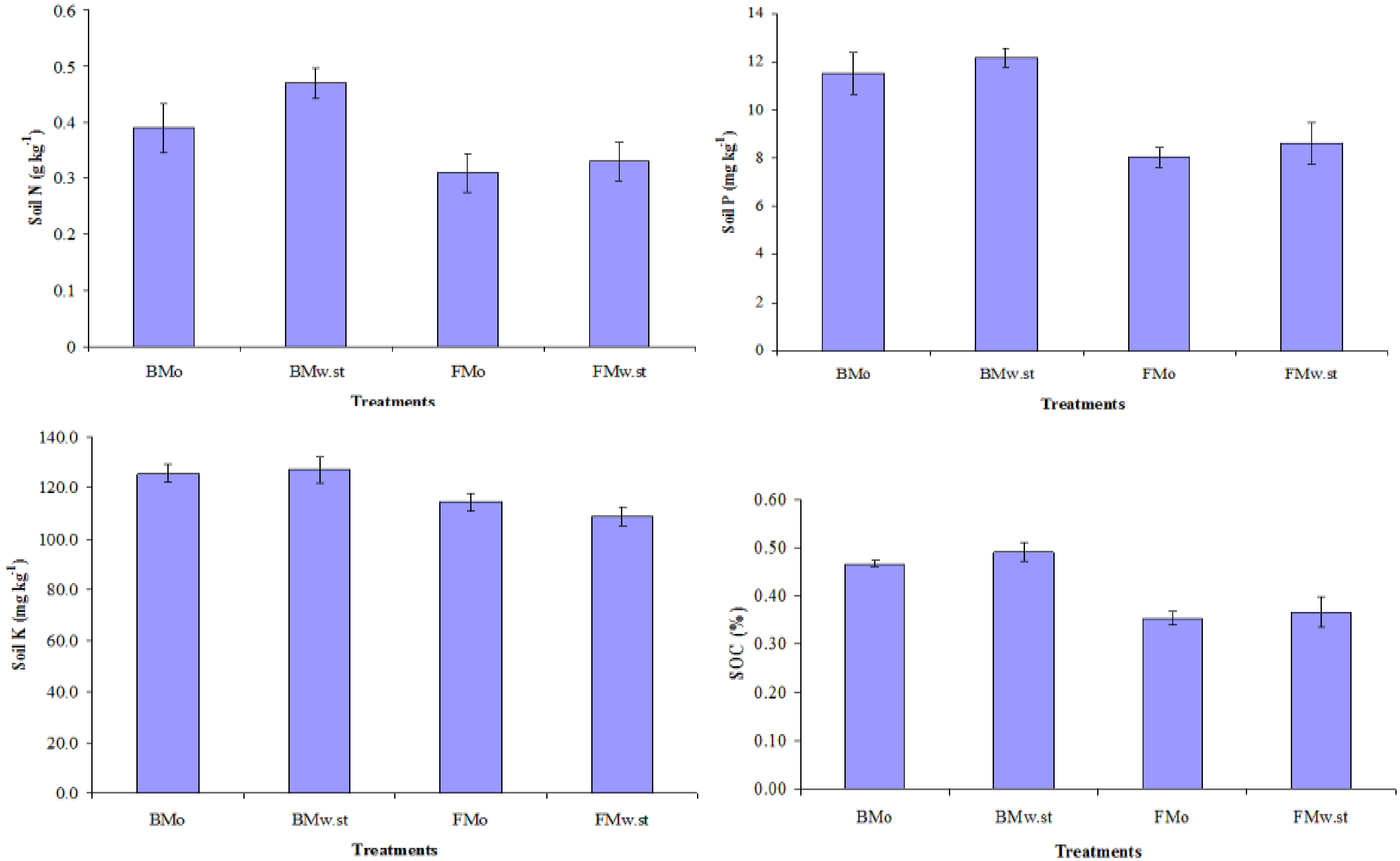

Figure 3: Influence of mulching& sowing methods on soil N (g kg^{-1}), P (mg kg^{-1}), K (mg kg^{-1}) and organic carbon (%) contents. Whereas BM_0 = Bed sowing and wheat straw application (0 Mg ha^{-1}), BM_{wst} = Bed sowing and wheat straw application @ 8 Mg ha^{-1}, FM_0 = Flat sowing and wheat straw @ 0 Mg ha^{-1}, FM_{wst} = Flat sowing and wheat straw @ 8Mg ha^{-1}.

Physical characteristics of soil

Figure-4 shows the effects of mulching and methods of sowing on BD of soil (Mg m^{-3}), infiltration rate (mm hr^{-1}), and soil porosity (m^3 m^{-3}).

Bulk Density (Mg m-3)

The top soil of the raised beds kept the structural stability and had a low BDthan the material in the level basin, as shown in Fig.4. The differences developed likely because the unsaturated situation of the raised beds caused lesser structural disturbance of the soil aggregates than the saturated situation of the basins. Bulk density in the bed sowing was 1.32 Mg m^{-3}, while the BD in the flat sowing technique was 1.41 Mg m^{-3}. Mulching had a considerable impact on BD of the soil, with M0 recording a greater BD of about 1.40 Mg m^{-3} and Mwst recording 1.36 Mg m^{-3} BD. The interactive impact was also significant in treatment combinations; FM0 treatment had a higher BD of 1.45 Mg m-3, while BMw.st. had the lowest BD value of 1.30 Mg m^{-3} at depth of 0-10 centimeter (Fig. 13). The BD in the bed sowing control plot (1.33 Mg m^{-3}) was not significant on statistical basis when compared to the mulch bed sowing plot (1.35 Mg m^{-3}) (1.30 Mg m^{-3}).

Rate of infiltration (mm hr^{-1})

Figure 4 shows the impacts of and mulching methods of sowing and on soil infiltration rate at the time of harvest of maize. Mulching levels had a substantial effect on infiltration rate, according to statistical analysis. When it came to mulching, the plots with mulch had a higher infiltration rate (48.5 mm hr-1) than the plots that were not mulched (43.0 mm hr-1). The manner of sowing has a considerable impact on the rate of infiltration. In comparison to flat basins, beds exhibited a 12.6 percent higher infiltration rate. In terms of interaction, the treatment combination BMw.st. had the highest infiltration rate (51.3 mm hr-1), followed by 45.3 mm hr-1 in BM0, and 40.5 mm hr-1 in the case of FM0 (Fig. 4).

Porosity (m3 m-3)

The data on soil porosity (m3 m-3) as a function of sowing methods and mulching levels is shown in Fig. 4, which shows that not only did sowing methods have a substantial impact on soil porosity at the 0-10 cm depth, but mulching levels had a significant impact as well. In comparison to the flat basin, the soil porosity of the beds sowing was 8.5% higher. Mulch in the bed and flat sowing, on the other hand, increased soil porosity by 2 and 4.3 percent, respectively, over their respective controls. Under two seeding procedures, all treatment combinations receiving varied mulching levels were statistically different from one other (Fig. 4). The highest soil porosity was found in BMw.st (0.50 m3 m-3), while the lowest was found in FM0 (0.44 m3 m-3).

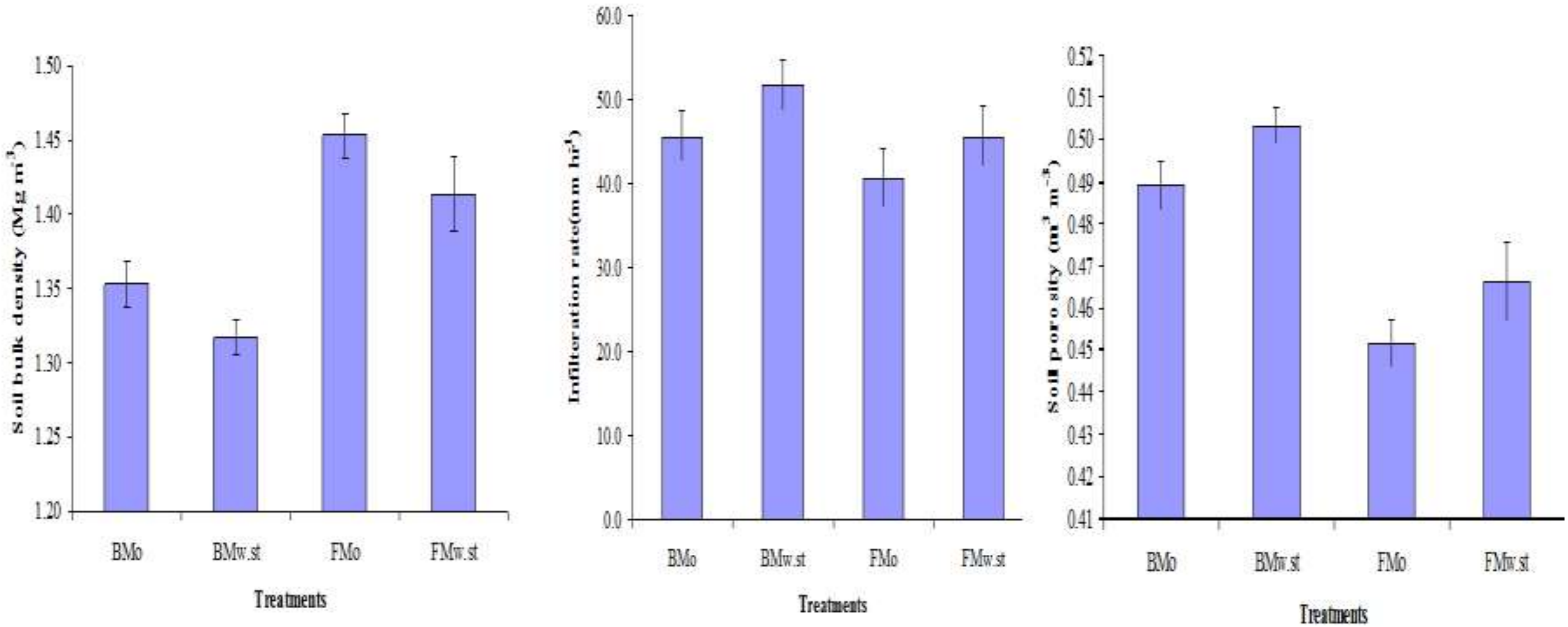

Figure 4: Effects of mulching and sowing methods on the bulk density of soil (Mg m^{-3}), rate of infiltration (mm hr^{-1}) and porosity of soil (m^3 m^{-3}). Whereas BM_0 = Bed sowing and wheat straw application (0 Mg ha^{-1}), BM_{wst} = Bed sowing and wheat straw application (8 Mg ha^{-1}), FM_0 = Flat sowing &wheat straw application (0 Mg ha^{-1}), FM_{wst} = Flat sowing &wheat straw application (8Mg ha^{-1}).

Discussion

Agronomic growth of maize crop

The use of mulch material in bed sowing produced superior results than flat sowing method, which is consistent with the findings of Abdullah *etal.* (2008), they found that the maximum plant height (209.2 cm) was observed in bed planting, whereas the minimum pla nt height (192.5 cm) was observed in flat sowing. Better nutrient availability, appropriate s oil conditions, and weed management in beds could all contribute to increased plant height. Shah *etal.* (2003) also discovered that ridge planting yielded the highest 1000-grain weight of maize (4.6 t ha-1) when compared to flat planting.Hassan *etal.* (2005) found similar outcomes in wheat-maize cropping patterns employing permanent raised beds versus flat basin at Mardan, Kh yber Pakhtunkhwa, Pakistan from 1999 to 2004.They discovered a 30 percent increase in maize output and a 13 percent increase in wheat yield for permanent raised beds. Mulch ap plication increased grain yield and WUEin wheat crops, according to Huang *etal.,* (2005). St raw mulch enhanced biomass and grain output by 37 percent and 52 percent, respectively, in 1997, and by 20 and 26 percent, respectively, in 1998, according to Huang *et al.,* (2005). Abdullah *et al.* (2008) found that planting practises had a substantial impact on biological yield.

They discovered that bed planting yielded a larger biological yield (10.5 t ha^{-1}) than flat sowing, which yielded a lower biological yield (6.9 t ha^{-1}). Shafiq*et al.* (2002) studied maize and wheat production using basin and furrow-bed irrigation systems, and their findings corroborated ours. They found that furrow-bed irrigation increased total fresh biomass, dry straw, and grain production by 24, 45, and 68 percent compared to basin irrigation.

The under manure mulch condition the better outcomes could be due to rapid mineralization in contrast to wheat straw mulch. Because of improved soil physical condition of newly raised beds, there could be an enhanced availability of nutrient and water which enhanced the efficiency of organic manure in contrast to other pattern of flat sowing. Graybill*et al.* (1991) too observed HI varies considerably among different methods of sowing. It has been well established that various sowing methods (Sharma and Saxena 2002) such as bed planting (Sayre 2002; Li *et al.* 2008; Mollah*et al.,* 2009; Quanqi*et al.* 2008), furrow beds (Shafiq*et al.* (2002) raised Bed planting (Qureshi and Barrett-Lennard, 1998; Tripathi*et al.* 2004; Hassan *et al.* 2005; Zhongming*et al.,* 2005; Ahmad and Mahmood 2005; Fahonget al., 2005; Hadda and Arora 2006; Akbar et al. 2007) and bed & flat planting methods (Bakhtet al. 2006; Hossain et al. 2006) have significantly improved maize productivity (Hsamar and Saxena 2002). However, our results are also in line with respect to their suggestions.

It was shown that while bed sowing enhanced WUEdue to water savings over furrow irrigated systems, when combined with organic manure mulching material, the other component, grain yield, also increased, creating a synergistic effect that greatly increased WUE.

In comparison to basins, Hassan et al. (2005) found that raised beds conserved irrigation water from16 to 50 percent, with about average of 36 percent.

Due to the fact that furrow irrigation requires less irrigation water than flood irrigation, WP increased by 14.9 percent as compared to the FP method.

It could be because of the little water consumption, higher grain production and WUE of the furrow-bed method.

It has been discovered that bed sowing is the optimum irrigation/planting method for giving water to sustainable agriculture. Thebed sowing method is the finest irrigation/planting method for providing sustainable agriculture with water limitations, based on low water consumption, high grain yield, and WUE of furrow-bed method. According to Sayre (2002), when compared to flat planting, bed planting saves 29 percent of water. Wheat straw mulch, according to Wang et al. (2001), reducedthe evaporation about 50% beneath winter wheat and saved roughly 80 mm of water during the entire growing season.

Mulching raised the WUE and yield of grain by reducing evaporation, increasing transpiration, and allowing water to percolate deeply, resulting in higher wheat yields and WUE (Zhang et al., 2007). Similar research has been done tosee how wheat straw affects WUE as well as wheat yield (Fan et al., 2005; Xuet al., 2007).

Mulch application resulted an increase in maize crop growth (Rahman et al., 2005), yield and biomass percentage (Gajriet al., 1994; Tolket al., 1999; Iqbal et al., 2003; Khurshidet al., 2006), wheat growth (Yang et al., 2006) and wheat yield (Li et al., 1999). Moreover, wheat straw mulch also boosted emergence counting (24-42%), the tillers numbers (26-51%), the plant height (10-37.3 %) and resulted reduction in the biomass of weed (3-17%) (Ramakrishna et al., 2006; Zammuradet al. 2007) in wheat crop (Enejiet al., 2008) enhanced cowpea yield (El-Kader et al., 2010), maize yield (Murunguet al., 2011), grain and maize straw yield (Jan et al., 2001). Moreover, lowermost grains yield (2 ton ha-1) has been attained by conventional planting where the N was used through broadcast method with 50 kg N ha-1 (Hossain et al., 2001). In addition to this, application of mulch had significantly enhanced WUE (Shafiqueet al.,2003; Zhang et al. 2007; Jiyanget al., 2007; Behrouz and Kumar, 2008) in wheat as well as chick pea (Pramaniket al., 2009). It has also been evidenced in scientific literature that maize the area of leaf/plant and weight of 1000-grain was also the maximum (4.58 t ha-1) (Shah et al., 2003), optimum growth of maize (Ridge, broadcast and flat sowing), more N uptake (Khalequeet al., 2008), higher biological yield (Abdullah et al., 2008) and maximum grain yield (Freeman et al., 2007) were gained due to application of mulch. Their suggestions are also in symmetry to our data.

Nutrient uptake by maize crop

Maize crop had significantly uptake the N, P, K due to mineralization of mulches in soil. This might be credited to well-watered as well as healthy soil environment in case of raised beds, which in turn results enhanced N uptake by plant and increased yield. Enhancement in the fertilizer efficiency also been inveterate by Chaudhry et al. (1994). Limon et al. (2000) too experienced >10% Nutrients Use Efficiency (NUE) in case of bed sowing as compared to flat. Shoot P concentration increase in beds and levels of mulching is because of accelerated diffusion of P towards roots, which in turn resulted enhanced P uptake as well as yield of the crop. These findings endorsed to the resultant higher quantity of the available N and P because of this considerable increased use and the productivity. Additionally, significant increased in N, P and K levels and intake by maize grains plus maize yield (El-Sherbienyet al.,1999). Acharya and Sharma (1994) confirmed that mulch of wheat straw exhibited significant impact on P and potash concentration in the shoot over the control.

Soil Physico-Chemical Characteristics

Application of mulch had significantly improved the soil physic-chemical characteristics. In this context, mulch application increased soil N availability, according to Weerararna and

Asghar (1992). Yadavet al. (1994) similarly found that the wheat straw mulch increased soil P availability. Mulch additions increased SOC, aggregate stability, BD, crust, and NPK availability, as well as water restoration (Min et al., 2003). Our findings are also consistent with their recommendations. Under bed sowing, the BD value was lower, indicating that the organic manures was unable to reduce BD as much it might in the bed sowing, which kept structural stability because of reduced mechanical exposure. Correspondingly, Hassan et al. (2005) found that using the flat sowing technique increased BD by 2%. Compared to raise beds, there was a 6% rise in the upper soil layer and a 6% increase in the lower soil layer. Bed planting exhibited reduced crusting of the soil on the bed top, which meant lesser BD, according to Fahonget al. (2004). Because only 40% of the surface of the soil is exposed to water, there is less compaction and higher porosity as a result of bed planting. These findings could be explained by the soil being loose in beds, allowing additional pore space for the movement of water, but the material in the basins having a greater BD, allowing for less pore space for water movement. According to Hassan et al. (2005), sorptivity and cumulative intakes were higher on the tops of raised beds than in basins, and in basins than in the furrows between the beds. Raised beds had 2.8 times the cumulative infiltration of basins and 10 times the infiltration of furrows at the same time. Mulumba and Lal (2008) found that mulch rates of 4 Mg ha-1 increased porosity and 8 Mg ha-1 increased accessible water capacity and aggregate stability, corroborating our findings. Jordan et al. (2010) similarly observed that organic matter content rose in general as a result of mulch application, albeit no advantage was found beyond 10 Mg ha-1 year-1. Increased mulching rates enhanced BD, porosity, and aggregate stability, proving that these parameters interact. When comparing a permanent raised bed to a level basin, soil physical metrics like BD, soil porosity, infiltration as well as organic matter all improved (Hassan et al., 2005).

Mulching, a novel technique for enhancing the WUE. The mulching of straw has potential for enhancing the storage of water in soil (Tisdall and Adam, 1986; Shanging and Unger, 2001; Zhonget al.,2005; Dahiyaet al., 2007; Moreno and Moreno 2008; Sharma et al., 2009; Zhang et al., 2009), enhancing WUE (Stone and Nofziger, 1993; Tolket al., 1999; Ramalal and Nwokeocha 2000; Iqbal et al. 2003), modifying soil temperature (Gajriet al., 1994), improving soil physical and chemical properties (Opara-Nadi, 1993; Mandalet al., 2004) such as BD (Cook et al.,2006; Khurshidet al., 2006), soil quality such as N, P, K (Saidouet al., 2003), SOC (Canqui and Lal, 2007), soil physical attributes (Lukman and Lal, 2008; Mulumba and Lal, 2008) such as infiltration rate (Jordan et al., 2010), Soil porosity (Fahonget al., 2004), zero tillage (Derpsch, 2001), soil fertility (Dersch and Bohm, 2001) like soil N (Ahmad et al., 2002; Patel et al., 2006) and soil K (Govaertset al., 2007) in various types of soil. Their suggestions are also in commitment to our data.

Conclusion

The findings revealed that sowing methods and mulching levels had a substantial impact on the majority of maize growth and yield characteristics. Under a bed seeding pattern using wheat straw as mulching material, plant height, 100-grain weight, HI as well as grain yield of maize increased significantly. Mulching levels and planting patterns, on the other hand, had a substantial impact on WUE, HI, and maize shoot NPK concentrations, but had no effect on soil NPK concentrations. Sowing methods and mulching levels had a significant impact on SOCupto the depth of 20 cm; the treatment combination BMw.st, i.e. mulch @ 8 Mg ha-1 + Bed sowing, had the highest SOC, whereas FMo, i.e. mulch (control) + Flat sowing, had the lowest.

BD, soil porosity, and infiltration rate were all affected by sowing methods and mulching a mounts. When compared to flat sowing, bed sowing resulted in statistically significant decr eases in BD, higher porosity, and enhanced IR values. Finally, these experiments suggest that adoption of mulching on bed sowing would be viable option to get maximum maize yield and also to sustain the soil physic-chemical characteristics as compared to flat sowing strategies.

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