Pak. J. Bot., 52(2): 639-644, 2020. DOI: http://dx.doi.org/10.30848/PJB2020-2(27)

ROLE OF DAIRY MANURE IN IMPROVING WHEAT YIELD UNDER DEFICIT IRRIGATION

SARVET JEHAN[1], MUHAMMAD IQBAL[1], ZAHIR AHMED ZAHIR[1] AND MUHAMMAD FAROOQ[2]

[1]*Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad*
[2]*Department of Agronomy, University of Agriculture Faisalabad*
[*]*Corresponding author's e-mail: sarvetirani@yahoo.com*

Abstract

Water scarcity has become a challenge for food security at national and global level. This problem has been aggravated by population explosion and inefficient irrigation practices. Keeping this in view, a lysimetric experiment was carried out to evaluate the impact of dairy manure under various moisture levels on growth and produce of wheat and soil properties. Three levels of irrigation were maintained based on soil field capacity (FC) at 60%, 80% and 100% FC in main plots, while four levels of dairy manure at 10, 15, 20 and 25 Mg ha^{-1} were used in subplots. It was found that dairy manure improved the hydraulic conductivity under each moisture regimes and it was dependent on quantity applied. Soil bulk density and soil strength decreased with increase in level of dairy manure. The deficit moisture level in soil suppressed the growth and reduced the wheat yield, however, application of dairy manure mitigated the moisture deficiency and improved growth and yield parameters. Similarly soil moisture content affected the photosynthetic rate of the plants, but amending soil with dairy manure alleviated this stress. Application of dairy manure significantly enhanced soil organic carbon at all levels of irrigation. The results suggest that dairy manure can alleviate growth and yield reduction of wheat caused by water deficiency through improvement in soil properties and by enhancing soil organic carbon contents.

Key words: Deficit irrigation, Field capacity, Soil health, Dairy manure.

Introduction

The most commonly grown crop all around the world is wheat (Anon., 2014a). Out of total cultivated land around the world, approximately one sixth is comprised of wheat crop (Mustafa *et al.*, 2004). Wheat is the most staple food crop in Pakistan and has 10.0 % contribution in agriculture and its share in GDP of Pakistan is 2.1% (Anon., 2014b).

Water availability is very critical for the growth and development of wheat crop. Presently, Pakistan is facing water scarcity that demands to look into other alternatives so that food security can be ensured. In South Asia, Pakistan is the only country that utilizes 98% of its freshwater resources for agriculture purpose (Shehzad *et al.*, 2007). Irrigation has a strong effect on wheat yield (Payero *et al.*, 2006). Poor management of water resources regarding irrigation scheduling, results in low water use efficiency that negatively affects the wheat yield in Pakistan (Laghari *et al.*, 2008). Addition of manure has shown positive effect on wheat crop yield and yield related factors (Ali *et al*., 2015).

Availability of water and nitrogen are the most crucial crop growth factors in yield enhancement of wheat (Mueller *et al*., 2012). The increase in demand for food by the growing population requires an increase in use efficiency of water and nitrogen for crops. Proper management of water and nitrogen has been identified as basic step for obtaining higher yield (Sinclair & Rufty, 2012). Sustainable production of agriculture demands management strategies towards enhancing water and nitrogen use efficiency.

Efficient nitrogen utilization in irrigated cropping system depends on the effective management of water resources (Vazquez *et al*., 2006). Proper management of nitrogen and water resources can improve the sustainability of agriculture and are expected to meet food demands for growing population (FAO, 2003). Deficit irrigation does not relate to the total absence of water, but, it is the application of water at certain critical growth stages (Kang *et al*., 2002). The deficit irrigation practice has acquired importancedue to thecontinuous decrease in the availability of freshwater used for agriculture production (Cai & Rosegrant, 2003). Deficit irrigation increases water use efficiency (WUE) of wheat (Xue *et al*., 2006) and it may decrease wheat yield by reducing photosynthesis rate under stress which can be compensated by the organic manuring (Wang, 2008).

Combined application of organic matter and water is not only economically feasible but also supplies essential nutrients that reduce the environmental hazards (Khaliq *et al*., 2004). The synthetic fertilizers in comparison to manure application improves soil structure, soil aeration, soil moisture contents and nutrients holding capacity by adding organic matter to soil (Deksissa *et al*., 2008).

With the imminent threat of scarcity of water in Pakistan, there is a need to move towards deficit irrigation agriculture. Deficit irrigationscoupled with manure applicationcan meet water requirements of crop and produce a yield that can fulfil ever-increasing food demand. It willameliorate thestructure of soil, ability to hold water and further addition of organic matter in the soil will enhance the recycling of nutrients. This high fertility of the soil will results into high water use efficiency (WUE).

Earlier experiments were carried out with multiple levels of manure with irrigation at 100% field capacity, however, deficit irrigation with different levels of manures has not been studied in previous decades. For this purpose deficit irrigation at two levels with multiple levels of manure was applied on the wheat crop to find out the impact on soil physical properties and the interplay of yield with irrigation and manure application. This research was based on hypothesis that addition of dairy manure with deficit irrigation would compensate yield gap under full irrigation and deficit irrigation. Research was aimed to achieve targeted wheat crop yield with improvement in soil health under deficit irrigation practice using dairy manure.

Materials and Methods

Experimental site and treatments: The lysimeter trial was carried out at research area, Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad (Latitude 31° to 26' N and Longitude 73 ° to 67' E) during 2014-15. Research was conducted to study the dynamics of soil physical properties after the dairy manure application and performance of wheat under different levels of soil moisture content. According to its climate, the region lies in subtropical, semi-arid type. Soil (0-30 cm) was analyzed for various physico-chemical properties before sowing (Table 2). The samples of soil were dried in air and then were passed through a 2 mm sieve. Soil pH and EC were determined through saturated soil paste following Richards Method (1954). Total N was determined through Bremner and Mulvanry Method (1982). Olsen method was used to measure soil extractable phosphorus (Olsen & Sommers, 1982) and Richard's method was used to measure available K by using flame photometer (Richards, 1954).

Soil physical parameters were determined in field that included bulk density (BD) of soil by the soil core methodology (Blake & Hartge, 1986), the strength of soil was measured through cone penetrometer, the texture of soil was analyzed by Bouyoucos hydrometer method (Moodie *et al*., 1959) and the Guelph permeameter was utilized for calculating the saturated hydraulic conductivity (Rickley Hydrological Company, Columbus, OH, USA). Plot size of 56 m^2 (7 m × 8 m) was used as experimental unit. Split-plot design was used keeping irrigation levels in main plots while dairy manure levels in sub plots. The recommended rate of phosphorus, nitrogen and potassium were applied as urea, single superphosphate and sulphate of potash, respectively. Four levels of dairy manure (10, 15, 20 and 25 Mg ha^{-1}) were applied. Dairy manure was mixed into the soil before sowing of wheat at the time of seedbed preparation. The composition of dairy manure is shown in Table 1. Irrigation was applied according to the moisture treatments; $I_{0.6}$= 60% FC, $I_{0.8}$=80% FC and $I_{1.0}$= 100% FC throughout the growth period from sowing to harvesting. For this purpose calculated amount of irrigation water was applied through cutthroat flumes. The field were irrigated to the required depth and the time required for irrigation was calculated as follows:

Qt = Ad, Q = discharge (m^3 min^{-1}), t = time (min), A = area of plot (m^2), d = depth of irrigation (m).

At maturity stage the crop was harvested and data for the plant growth, yield and soil properties was taken.

Measurement of growth, yield and photosynthetic rate: Wheat was harvested at maturity from each experimental unit separately. Agronomic parameters including plant height, spike length, and grain yield were determined. At maturity, from 1 m^2 area of each plot, ten plants were selected at random from the plot, the height of ten plants were measured from the soil surface to the tip of the ear head with the help of a measuring scale and then average was calculated. Spike length of same ten plants was taken and mean was calculated.The crop area of 1 m^2 was harvested and was manually threshed. The yield was calculated by weighing on the electronic balance in kilograms and then later grain yield was converted in tons per hectares. The photosynthetic rate was taken with a portable infra-red gas analyzer (IRGA) (model LCi-SD; ADC Bioscientific Ltd., England) from ten plants per experimental unit during vegetative growth stage. The photosynthetic rate was taken at 1200-1400 µ*M* m^{-2} s^{-1} photon flux density (Ben Asher *et al.*, 2006).

Table 1. Manure composition.

Parameter	% ± S.E
Moisture content	60.4 ± 2.8
N	0.94 ± 0.03
P_2O	0.51 ± 0.02
K	1.19 ± 0.03
Organic carbon	40.7 ± 1.31

Table 2. Physicochemical characteristics of experimental site.

Soil characteristic	Value	Method
Soil texture	Sandy clay loam	Bouyoucos (1962)
Electrical conductivity	1.41dSm^{-1}	Richard (1954)
pH	7.48	McLean (1982)
Bulk density	1.40 Mgm^{-3}	Blake & Hartge (1986)
Soil organic carbon	0.46%	Ryan *et al*., (2001)
NO_3^- nitrogen	4.5mg kg^{-1}	Sims & Jackson (1971)
Available P	7.88mg kg^{-1}	Soltanpour & Workman (1979)
Available K	114.6mg kg^{-1}	Simard (1993)
Saturation percentage	32.25 %	Richard, 1954

Soil properties: The samples from soilwere collected from the field after the crop harvest and analyzed for bulk density, hydraulic conductivity, soil strength.Soil core method outlined by Blake & Hartage (1986) was used to calculate bulk density of soil, cone penetrometer was used for the measuring soil strength, The bouyoucos hydrometer method outlined by Moodie *et al*., (1959) was used for evaluating soil texture and Guelph permeameter developed by Rickly hydrological company (Columbus, OH, USA) was used for measuring saturated hydraulic conductivity.

The organic carbon contents in the soil were estimated by the methodology outlined by Ryan *et al.,* (2001). 500 mL beaker was used in which 1 gram of air dry soil was taken and 10 mL of 1M solution of potassium dichromate was added. Then 20 mL of concentrated sulfuric acid was added and the beaker was gently shaken afterwards the beaker was put down for 30 minutes for settling down of the suspensions. The 200 mL of deionized water was added to the beaker and to that 10 ml of concentrated orthophosphoric acid was mixed and allowed to cool. Cooled solution in the beaker was mixed with 10-15 drops of Dephenylamine indicator. The whole mixture was titrated against 0.5 M ferrous sulfate solution, until the color changed from violet blue to green. The contents were titrated against 0.5 M ferrous ammonium sulfate solution, until the color changed from violet blue to green.1st two blank readings were taken of the solution prepared from the above stated protocol and then soil samples were added and readings were recorded.

Percentage of oxidazable organic carbon = ((V$_{blank}$-V$_{sample}$) x 0.3 x M) / (Weight of soil (g))

Total organic carbon percentage (weight/weight) = 1.33 x % Oxidizable organic carbon

M= Ferrous sulfate solution molarity

V$_{blank}$ = Volume of ferrous ammonium sulphate solution used for blank (mL)

V$_{sample}$ = Volume of ferrous ammonium sulphate solution with soil sample

Statistical analysis: The collected data was analyzed for ANOVA using randomized complete block design with split plot arrangements. Further significance of interaction was analyzed using honestly significant difference test (HSD) (Montogomery, 2013) at 5% probability level.

Results

Soil physical parameters: Analysis of variance indicated that there was significant effect of irrigation and dairy manure on soil physical parameters like bulk density of soil, soil strength and soil hydraulic conductivity. Combined application of manure and irrigation was highly significant at $I_{0.8}$ and $I_{1.0,}$ while, least significant at $I_{0.6}$. Bulk density shows the ability of soil to function for plant support, movement of water and solutes through soil. Full irrigation ($I_{1.0}$) indicated a significant decrease in soil bulk density (1.29 Mg ha^{-1}) with application of manure at 25 Mg ha^{-1}. Among deficit irrigation levels, $I_{0.8}$ showed a decrease in bulk density (1.30 Mg ha^{-1}) with application of dairy manure at 25 Mg ha^{-1}. Bulk density was reduced from 1.48 to 1.39, 1.43 to 1.30 and 1.36 to 1.30 at field capacity of 60%, 80% and 100 %, respectively with the application of dairy manure at 25 Mg ha^{-1} (Table 3).

Application of dairy manure significantly enhanced soil hydraulic conductivity by 49.39%, 25.6% and 15.65% under $I_{0.6}$, $I_{0.8}$ and $I_{1.0}$, respectively. Maximum hydraulic conductivity (56.67 mm hr^{-1}) was shown under full irrigation with application of dairy manure at the rate of 25 Mg ha^{-1} and minimum (28 mm hr^{-1}) by deficit irrigation level $I_{0.6}$ with dairy manure application at the rate of 10 Mg ha^{-1} (Table 4). Addition of manure enhanced rate of hydraulic conductivity highly significantly under full irrigation condition than deficit irrigation, however, under deficit irrigation level $I_{0.8}$, high rate of manure application (25 Mg ha^{-1}) showed hydraulic conductivity rate (54 mm hr^{-1}) that was 10.2% higher than that obtained under full irrigation ($I_{1.0}$) with DM @ 10 Mg ha^{-1} (49 mm hr^{-1}).

Under various interactions of deficit irrigation and dairy manure, $I_{0.8}DM_{25}$ resulted in minimum soil strength values that was 3.04% less than under full irrigation with manure application at the rate of 10 Mg ha^{-1} and 9.48% less than under deficit irrigation level $I_{0.6}$ with manure application at the rate of 10 Mg ha^{-1} (Table 5). Deficit irrigation level $I_{0.8}$ resulted in minimum soil strength values of 548 k pa at manure level of 25 Mg ha^{-1}. Application of dairy manure indicated positive impact on soil strength values even under deficit irrigation level $I_{0.6}$. Application of high rate of dairy manure under $I_{0.6}$ decreased soil strength values from 600 to 576.7 k pa.

Positive effect of dairy manure on soil infiltration rate was observed even under deficit irrigation conditions. Mean maximum percentage infiltration rate shown by treatment combination $I_{1.0}DM_{25}$ was 121.02% higher than that of minimum percentage rate (22.17 mm hr^{-1}) observed by treatment combination $I_{0.6}DM_{10}$. Application of DM_{25} resulted in 68.4%, 65.05% and 18.6% increase in infiltration rate than DM_{10} under $I_{0.6}$, $I_{0.8}$ and $I_{1.0}$, respectively (Table 6).

Table 3. Interactive effect of different levels of irrigation and dairy manure on soil bulk density (Mg m^{-3}) under lysimeter.

DM	Irrigation			Mean
	$I_{0.6}$	$I_{0.8}$	$I_{1.0}$	
DM_{10}	1.48±0.09a	1.43±0.06c	1.36±0.06f	1.42±0.77A
DM_{15}	1.44±0.09b	1.38±0.08e	1.33±0.05h	1.38±0.66B
DM_{20}	1.43±0.08c	1.35±0.05g	1.31±0.06i	1.36±0.57C
DM_{25}	1.39±0.07d	1.30±0.07ij	1.30±0.08j	1.33±0.65D
Mean	1.44±0.70A	1.36±0.54B	1.33±0.17C	

DM: Dairy manure; $I_{0.6}$: 60% Field capacity; $I_{0.8}$: 80% FC; $I_{1.0}$: 100% Field capacity. Means sharing similar letter in a row or in a column are statistically non-significant (p>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean

Table 4. Interactive effect of different levels of irrigation and dairy manure on soil infiltration rate (mm hr^{-1}) under lysimeter.

DM	Irrigation			Mean
	$I_{0.6}$	$I_{0.8}$	$I_{1.0}$	
DM_{10}	22.17±0.60g	27.67±0.88f	41.33±0.88c	30.39±1.88D
DM_{15}	23.83±0.44g	30.67±0.67e	45.33±0.88b	33.28±1.90C
DM_{20}	32.33±0.88e	37.33±0.88d	47.67±0.88ab	39.11±1.30B
DM_{25}	37.33±0.88d	45.67±0.67b	49.00±0.58a	44.00±1.77A
Mean	28.92±1.90C	35.33±1.11B	45.83±0.94A	

DM: Dairy manure; $I_{0.6}$: 60% Field capacity; $I_{0.8}$: 80% FC; $I_{1.0}$: 100% Field capacity. Means sharing similar letter in a row or in a column are statistically non-significant (p>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean

Table 5. Interactive effect of different levels of irrigation and dairy manure on soil hydraulic conductivity (mm hr^{-1}) under lysimeter.

DM	Irrigation			Mean
	$I_{0.6}$	$I_{0.8}$	$I_{1.0}$	
DM_{10}	28.00±0.58j	43.00±0.58g	49.00±0.58e	40.00±2.10D
DM_{15}	35.67±0.33i	46.00±0.58f	52.33±0.47c	44.67±1.44C
DM_{20}	38.17±0.44h	50.67±0.33d	54.67±0.43b	47.83±1.49B
DM_{25}	41.83±0.17g	54.00±0.58b	56.67±0.63a	50.83±1.29A
Mean	35.92±1.54C	48.42±1.29B	53.17±1.18A	

DM: Dairy manure; $I_{0.6}$: 60% Field capacity; $I_{0.8}$: 80% FC; $I_{1.0}$: 100% Field capacity. Means sharing similar letter in a row or in a column are statistically non-significant (p>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean

Table 6. Interactive effect of different levels of irrigation and dairy manure on soil strength under lysimeter.

DM	Irrigation			Mean
	$I_{0.6}$	$I_{0.8}$	$I_{1.0}$	
DM_{10}	600.00 ±2.08a	577.67±1.20d	564.67±1.45e	580.78±3.22A
DM_{15}	589.33 ±1.20b	565.67±1.76e	549.00±1.15g	568.00±3.89B
DM_{20}	582.67 ±1.20c	557.00±1.15f	537.33±1.20h	559.00±4.59C
DM_{25}	576.67 ±1.20d	548.00±0.58g	527.33±1.45i	550.67±3.17D
Mean	587.17±2.69A	562.08±3.34B	544.58±4.23C	

DM: Dairy manure, $I_{0.6}$: 60% Field capacity; $I_{0.8}$: 80% FC, $I_{1.0}$: 100% Field capacity. Means sharing similar letter in a row or in a column are statistically non-significant (p>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean

Table 7. Interactive effect of irrigation and dairy manure on grain yield (kg ha^{-1}) of wheat crop under lysimeter trial.

DM	Irrigation			Mean
	$I_{0.6}$	$I_{0.8}$	$I_{1.0}$	
DM_{10}	2.37 ± 0.91i	2.82 ± 0.21g	3.55 ± 0.3d	2.91 ± 0.47D
DM_{15}	2.58 ± 0.81h	3.12 ± 0.42e	3.80 ± 0.53c	3.17 ± 0.58C
DM_{20}	2.78 ± 0.5g	3.54 ± 0.52d	3.99 ± 0.7b	3.44 ± 0.68B
DM_{25}	2.94 ± 0.3f	3.93 ± 0.7b	4.24 ± 0.83a	3.70 ± 0.90A
Mean	2.67 ± 0.06C	3.35 ± 0.13B	3.90 ± 0.08A	

DM: Dairy manure; $I_{0.6}$: 60% Field capacity; $I_{0.8}$: 80% FC; $I_{1.0}$: 100% Field capacity. Small letters represent comparison among interaction means and capital letters are used for overall mean. Means sharing similar letter in a row or in a column are statistically non-significant (p>0.05)

Table 8. Interactive effect of irrigation and dairy manure on plant height (cm) under lysimeter trial.

DM	Irrigation			Mean
	$I_{0.6}$	$I_{0.8}$	$I_{1.0}$	
DM_{10}	58.00 ± 1.15i	70.13 ± 1.10g	78.16 ± 1.19ef	68.76 ± 2.96C
DM_{15}	63.50 ± 1.79h	76.00 ± 1.28f	87.00 ± 1.15c	75.50 ± 3.42B
DM_{20}	65.60 ± 1.70h	78.80 ± 1.42e	103.00 ± 2.1a	82.47 ± 5.49A
DM_{25}	69.27 ± 1.97g	82.83 ± 1.44d	95.33 ± 1.88b	82.48 ± 3.78A
Mean	64.09 ± 1.27C	76.94 ± 1.41B	90.87 ± 2.83A	

DM: Dairy manure; $I_{0.6}$: 60% Field capacity; $I_{0.8}$: 80% FC; $I_{1.0}$: 100% Field capacity. Small letters represent comparison among interaction means and capital letters are used for overall mean. Means sharing similar letter in a row or in a column are statistically non-significant (p>0.05)

Table 9. Interactive effect of different levels of irrigation and dairy manure on photosynthetic rate (µmol m^{-2}s^{-1}) under lysimeter trial.

DM	Irrigation			Mean
	I_1	I_2	I_3	
DM_1	8.48 ± 0.02j	9.94 ± 0.03g	11.14 ± 0.02e	9.85 ± 0.38D
DM_2	8.99 ± 0.03i	10.54 ± 0.02f	14.01 ± 0.03a	11.18 ± 0.74C
DM_3	9.46 ± 0.02h	11.08 ± 0.03e	13.49 ± 0.02b	11.34 ± 0.59B
DM_4	9.98 ± 0.03g	11.94 ± 0.02d	13.17 ± 0.01c	11.69 ± 0.47A
Mean	9.23 ± 0.17C	10.88 ± 0.22B	12.95 ± 0.33A	

DM: Dairy manure; $I_{0.6}$: 60% Field capacity; $I_{0.8}$: 80% FC; $I_{1.0}$: 100% Field capacity. Small letters represent comparison among interaction means and capital letters are used for overall mean. Means sharing similar letter in a row or in a column are statistically non-significant (p>0.05)

Table 10. Interactive effect of different levels of irrigation and dairy manure on spike length (cm) under lysimeter trial.

DM (Mg ha^{-1})	Irrigation			Mean
	$I_{0.6}$	$I_{0.8}$	$I_{1.0}$	
DM_{10}	7.51 ± 0.07l	8.13 ± 0.09h	8.95 ± 0.08f	8.20 ± 0.51D
DM_{15}	7.72 ± 0.08k	8.31 ± 0.09g	9.28 ± 1.02d	8.44 ± 0.83C
DM_{20}	7.91 ± 0.06j	9.00 ± 0.09e	9.86 ± 1.03b	8.92 ± 0.98B
DM_{25}	8.06 ± 0.09i	9.53 ± 1.01c	10.01 ± 1.04a	9.20 ± 1.19A
Mean	7.80 ± 0.37C	8.74 ± 0.97B	9.52 ± 1.03A	

DM: Dairy manure; $I_{0.6}$: 60% Field capacity; $I_{0.8}$: 80% FC; $I_{1.0}$: 100% Field capacity. Small letters represent comparison among interaction means and capital letters are used for overall mean. Means sharing similar letter in a row or in a column are statistically non-significant (p>0.05)

Yield-related parameters: Combined application of manure and irrigation showed significant results for yield-related parameters i.e, Plant height, grain yield, spike length photosynthetic rate, biomass yield and harvest index. Grain yield is the most important parameter regarding wheat yield production. Interactive impact of irrigation and manure has shown a significant effect on wheat crop yield.

Mean maximum grain yield was by treatment combination $I_{1.0}$ DM_{25} and minimum by $I_{0.6}$ DM_{10}. Application of DM @ 25 Mg ha^{-1} resulted in 22.78, 39.36 and 19.77% increase in yield than application of DM @ 10 Mg ha^{-1} under 60, 80 and 100% FC, respectively (Table 7).

Mean maximum plant height (103 cm) was observed in treatment combination $I_{1.0}DM_{20.}$ Under full irrigation, application of DM @ 25 Mg ha^{-1} resulted in reduced plant height than that observed at DM_{20}.Minimum plant height (58 cm) was observed with treatment combination $I_{0.6}DM_{10}$ (Table 8). Under deficit irrigation levels, mean maximum plant height (82.8 cm) was shown in $I_{0.8}$ with application of DM @ 25 Mg ha^{-1} and mean minimum plant height (58 cm) in $I_{0.6}$ with application of DM @ 10 Mg ha^{-1}.

The photosynthetic rate showed significant differences among interactions of different levels of irrigation and manure (Table 9). Maximum photosynthesis rate (13.2) was shown under full irrigation with application of dairy manure at the rate of 25 Mg ha^{-1} and that was 55% higher than by deficit irrigation level $I_{0.6}$ with dairy manure application @ 10 Mg ha^{-1}. Addition of manure significantly enhanced photosynthetic rate under full irrigation condition than deficit irrigation, however, under deficit irrigation level $I_{0.8}$, high rate of manure application (25 Mg ha^{-1}) showed photosynthetic rate (11.9) that was higher than that obtained under full irrigation (11.1) with low level of manure (10 t ha^{-1}).

Mean maximum spike length (10.01 cm) was shown under full irrigation with application of dairy manure at the rate of 20 Mg ha^{-1} and minimum (7.51 cm) at deficit irrigation level $I_{0.6}$ with dairy manure application @ 10 Mg ha^{-1} (Table 10). Addition of manure enhanced spike length more significantly under full irrigation condition than deficit irrigation, however, under deficit irrigation level $I_{0.8}$, high rate of manure application (25 Mg ha^{-1}) showed mean maximum spike length (9.53) that was higher than that obtained under full irrigation (8.95) with low level of manure (10 Mg ha^{-1}).

Soil organic carbon contents: Dairy manure application significantly enhanced soil organic carbon (SOC) contents. The results indicated that high carbon contents were found under high rate of application of dairy manure as application of DM @ 25 Mg ha^{-1} resulted in an increase in SOC contents from 0.7 to 1, 0.69 to 1 and 0.67 to 1.03 under $I_{0.6}$, $I_{0.8}$ and $I_{1.0}$, respectively. Among different treatment combinations, mean maximum SOC was shown in treatment combination $I_{1.0}DM_{25}$ was 1.03% followed by $I_{0.8}DM_{25}$ (1%) and $I_{0.6}DM_{25}$ (1%). Mean minimum SOC contents were found in treatment combination $I_{1.0}DM_{10}$ as 0.67%.

Discussion

Interactive effect of manure and irrigation showed asignificant effect on soil physical parameters i.e, soil bulk density, strength and hydraulic conductivity. Addition of manure manure helped to build up nutritional status of the soil and also improved soil quality (Khaliq *et al*., 2006; Idrees, 2003). Soil bulk density and strength significantly decreased with high application of manure even under deficit irrigation ($I_{0.8}$), this is because manure adds organic carbon to the soil which is a key indicator of soil health, and it improves soil structure and enhances soil porosity and decreases soil bulk density. Similar results were found by Masood *et al*., (2012) who carried out pot experiment to check the effect of manure on characteristics of soil and production of maize crop. He concluded that high rate of manure resulted in decrease of bulk density. Reddy *et al*., (2000) also found similar results with application of organic manure.

Soil hydraulic conductivity is an important soil physical parameter regarding deficit irrigation practice as it shows the ability of soil to transmit water. Addition of manure has shown a significant increase in hydraulic conductivity not only under full irrigation but also under deficit irrigation ($I_{0.8}$). Addition of manure to soil enhances soil porosity which results in improved soil structure and hydraulic conductivity. Many field studies have shown increase in hydraulic conductivity by application of manure (Khan *et al.*, 2007) that might be related to the increased soil macro aggregation by the addition of organic matter to soil (Shirani *et al*., 2002; Min *et al*., 2003). Manure acts as a rich source of soil organic carbon and it has shown significant increase in SOC contents in our study and effect of deficit irrigation was non-significant on SOC contents. Similar to our findings, Lou *et al*., (2011) also found a positive correlation between manure and total organic carbon in long term field experiment.

Incorporation of dairy manure also showed a significant effect on yield-related parameters. Results showed that addition of manure was very effective under deficit irrigation ($I_{0.8}$), which suggest that high rate of application of manure under deficit irrigation ($I_{0.8}$) results in yield which is higher than under full irrigation without manure application. Manure acts as slow and steady release of nutrients to soil and enhances nutrients build up in soil. As manure acts as rich source of organic matter which improves soil aeration, soil structure, soil nutrient and water holding capacity which in return enhance soil fertility. Combined application of organic and inorganic fertilizers maintain soil organic matter in soil and results in increase in crop yield (Sena *et al*., 2002: Manna *et al*., 2005). Positive effect of manure incorporation on the growth of wheat crop has been observed in several studies (Kumbhar *et al*., 2007; Singh & Agarwal, 2001; Uygur & Şen, 2018). Zhang *et al*., (2016) also showed that upon application of manure 30% increase in wheat crop yield was witnessed than the alone application of chemical fertilizer.

Addition of manure under deficit irrigation level $I_{0.6}$ has shown significant effect on yield-related parameters. This may be because low moisture level causes high bulk density, less translocation of water and nutrients and in return poor soil health and decreased yield. In addition, soil water is also essential for the maintenance of catalytic activity of soil enzymes (Jiang & Zhang, 2002).

Conclusion

The investigation reported in this study indicates distinctive benefits of dairy manure along with deficit irrigation. Results showed that deficit irrigation ($I_{0.8}$) along with manure application not only resulted in achieving target yield but also improved soil health by lowering soil bulk density, improving soil hydraulic conductivity and by lowering soil strength. Improved soil properties resulted in better utilization of water and nutrients and thus improved crop yield. Soil organic carbon that is a key indicator of soil health improved by application of dairy manure. Under two levels of deficit irrigation, $I_{0.8}$ resulted in mean maximum wheat crop yield with application of DM_{25} while effect of dairy manure on soil physical properties was significant regardless of irrigation levels. We concluded that application of deficit irrigation (80% FC) could result in targeted wheat crop yield along with application of dairy manure (25 Mg ha^{-1}).

Acknowledgement

The author would like to appreciate Higher Education Commission Pakistan for providing funds to conduct this study in form of an indigenous scholarship.

References

Ahmed, S., A. Naveed, A. Shakoor, and M. Kaleem Ullah. 2007. Meeting future food demands of Pakistan under scarce water situation. Paper no. 667, Pakistan engineering congress. 70th annual session proceedings, Lahore.

Alexander, L.V., X. Zhang, T.C. Peterson, J. Caesar, B. Gleason, A.M.G. Klein Tank and A. Tagipour. 2006. Global observed changes in daily climate extremes of temperature and precipitation. *J. Geophysic. Res. Atm*., 5: 111-114.

Ali, K., M. Arif, S. Shah, Z. Hussain, A. Ali, S. Munir and H. Sher. 2015. Effect of organic and inorganic nutrients sources on Phenology and growth of wheat. *Pak. J. Bot*., 47: 2215-2222.

Anonymous. 2014a. Food and Agriculture Organization (FAO). Crop Prospects and Food Situation.

Anonymous. 2014b. GOP. Economic Survey of Pakistan 2013-14. Economic Advisor's Wing. Ministry of Finance, Government of Pakistan, Islamabad.

Ben-Asher, J., I. Tsuyuki, B.A. Bravdo and M. Sagih. 2006. Irrigation of grapevines with saline water, I. leaf area index, stomatal conductance, transpiration and photosynthesis. *Agri. Water Manag*., 83: 13-21.

Cai, X. and M.W. Rosegrant. 2003. 10th World Water Productivity: Current Situation and Future Options. *Water Prod. Agri*., 163.

Deksissa, T., I. Short and J. Allen. 2008. Effect of soil amendment with compost on growth and water use efficiency of Amaranth. In: Proc. of the UCOWR/NIWR Annual Conf. Int. Water Res. Challenges for the 21st Century and Water Resources Education, Durham, NC, USA.

Fang, Q., L. Ma, Q. Yu, L.R. Ahuja, R.W. Malone and G. Hoogenboom. 2010. Irrigation strategies to improve the water use efficiency of wheat–maize double cropping systems in North China Plain. *Agri. Water Manag*., 97:1165-1174.

Fao, F. 2003. Food and agriculture organisation of the United Nations.

Gentine, P., D. Entekhabi, A. Chehbouni, G. Boulet and B. Duchemin. 2007. Analysis of evaporative fraction diurnal behaviour. *Agri. & Forest Meteorol*., 143:13-29

Idris, M. 2003. Effect of integrated use of mineral, organic N and Azotobacter on the yield, yield components and N-nutrition of wheat (*Triticum aestivum*). *Pak. J. Biol. Sci*., 6:539-543.

Jiang, M. and J. Zhang. 2002. Water stress-induced abscisic acid accumulation triggers the increased generation of reactive oxygen species and up-regulates the activities of antioxidant enzymes in maize leaves. *J. Exp. Bot*., 53: 2401-2410.

Kang, S., L. Zhang, Y. Liang, X. Hu, H. Cai and B. Gu. 2002. Effects of limited irrigation on yield and water use efficiency of winter wheat in the Loess Plateau of China. *Agri. Water Manag.*, 55: 203-216.

Kang, S., L. Zhang, Y. Liang, X. Hu, H. Cai and B. Gu. 2002. Effects of limited irrigation on yield and water use efficiency of winter wheat in the Loess Plateau of China. *Agri. Water Manag*., 55: 203-216.

Khaliq, A., M.K. Abbasi and T. Hussain. 2006. Effects of integrated use of organic and inorganic nutrient sources with effective microorganisms (EM) on seed cotton yield in Pakistan. *Biores. Tech*., 97: 967-972.

Khaliq, T., T. Mahmood, J. Kamal and A. Masood. 2004. The effectiveness of farmyard manure, poultry manure and nitrogen for corn (*Zea mays* L.) productivity. *Int. J. Agric. Biol*., 2: 260-263.

Khan, A.U.H., M. Iqbal and K.R. Islam. 2007. Dairy manure and tillage effects on soilfertility and corn yields. *Bioresour. Tech*., 98: 1972-1979.

Kumbhar, A.M., U.A. Buriro, F.C. Oad and Q.I. Chachar. 2007. Yield parameters and N-uptake of wheat under different fertility levels in legume rotation. *J. Agric. Tech*., 3: 323-333.

Lou, Y., M. Xu, W. Wang, X. Sun and K. Zhao. 2011. Return rate of straw residue affects soil organic C sequestration by chemical fertilization. *Soil & Till. Res*., 113: 70-73.

Manna, S. K., S. Sarkar, J. Barr, K. Wise, E.V. Barrera, O. Jejelowo and G.T. Ramesh. 2005. Single-walled carbon nanotube induces oxidative stress and activates nuclear transcription factor-κB in human keratinocytes. *Nano Lett.*, 5: 1676-1684.

Masood, S., T. Naz, M.T. Javed, I. Ahmed, H. Ullah and M. Iqbal. 2014. Effect of short-term supply of farmyard manure on maize growth and soil parameters in pot culture. *Arch. of Agron. & Soil Sci*., 60: 337-347.

Min, D.H., K.R. Islam, L.R. Vough and R.R. Weil. 2003. Dairy manure effects on soilquality properties and carbon sequestration in alfalfa orchard grass systems. *Comm. Soil Sci. Plant Anal*., 34: 781-799.

Mueller, N.D., J.S. Gerber, M. Johnston, D.K. Ray, N. Ramankutty and J.A. Foley. 2012. Closing yield gaps through nutrient and water management. *Nature*, 490: 254.

Parasuraman, K., A. Elshorbagy, and S.K. Carey. 2007. Modelling the dynamics of the evapotranspiration process using genetic programming. *Hydrol. Sci. J*., 52: 563-578.

Payero, O., R. Jose, Melvin, Steven, Irmak, Suat, Tarkalson and David. 2006. Yield response of corn to deficit irrigation in a semiarid climate. *Agri. Water Manag*., 84: 101-112.

Qiu, G.Y., L. Wang, X. He, X. Zhang, S. Chen, J. Chen and Y. Yang. 2008. Water use efficiency and evapotranspiration of winter wheat and its response to irrigation regime in the north China plain. *Agric. & Forest Meteorol*., 148: 1848-1859.

Ryan, P. R., E. Delhaize and D.L. Jones. 2001. Function and mechanism of organic anion exudation from plant roots. *Ann. Rev. Plant Biol.*, 52: 527-560.

Schmidhuber, J. 2004. The growing global obesity problem: some policy options to address it. FAO food and nutrition paper, Globalization of food systems in developing countries. *Imp. Food Sec. & Nutr.*, 33: 81-97.

Sena, M.M., R.T.S. Frighetto, P.J. Valarini, H. Tokeshi and R.J. Poppi. 2002. Discrimination of management effects on soil parameters by using principal component analysis: a multivariate analysis case study. *Soil Till. Res*., 67: 171-181.

Shirani, H., M.A. Hajabbasi, M. Afyuni and A. Hemmat. 2002. Effects of farmyard manure and tillage systems on soil physical properties and corn yield in central Iran. *Soil Till. Res*., 68: 101-108.

Sinclair, T.R. and T.W. Rufty. 2012. Nitrogen and water resources commonly limit crop yield increases, not necessarily plant genetics. *Global Food Secur.,* 1: 94-98.

Singh, R. and S.K. Agarwal. 2001. Growth and yield of wheat (*Triticum aestivum*) as influenced by levels of farmyard manure and nitrogen. *Ind. J. Agron*., 46: 462-467.

Uygur, V. and M. Şen. 2018. The effect of phosphorus application on nutrient uptake and translocation in wheat cultivars. *Int. J. Agric For Life Sci.*, 2: 171-179.

Wang, H., C. Liu and L. Zhang. 2002. Water-saving agriculture in China: an overview. *Adv. Agron*., 75: 135-171.

Xue, Q., Z. J.T. Zhu, B.A. Musick, B.A. Stewart and D.A. Dusek. 2006. Physiological mechanisms contributing to the increased water-use efficiency in winter wheat under deficit irrigation. *J. Plant Physiol.*, 163: 154-164.

Zhang, H. Q., X.Y. Yu, B.N. Zhai, Z.Y. Jin and Z.H. Wang. 2016. Effect of manure under different nitrogen application rates on winter wheat production and soil fertility in dryland. *Earth & Env. Sci*., 39: 12-48.

(Received for publication 26 September 2018)