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Full Length Article

Yield and Quality Response of Maize Hybrids to Composted Poultry Manure at Three Irrigation Levels

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Abstract

Application of poultry manure in agricultural fields is potentially beneficial to agro-ecosystems, but challenging due to its excessive moisture, bad odor, transportation, inconsistent nutrient contents and phytotoxic substances, which may adversely affect the health of those who handle it. Composting as an agricultural best management practices (BMPs), could overcome the above issues. Field experiments were carried out in 2010 and 2011 under semi-aired conditions of Pakistan at the Agronomic Research Area of the University of Agriculture Faisalabad to study the effects of different rates of composted poultry manure (CPM) and levels of irrigation on maize yield and quality supported with an economic analysis. One drought tolerant and one sensitive maize hybrid (H_1 = Monsanto-919 and H_2 = FH-810, respectively) were sown with three rate of CPM levels (L_1= control with recommended NPK, L_2 = 8, L_3 = 10 and L_4 = 12 t ha^{-1} CPM) under three irrigation levels (I_1 = 300, I_2 = 450 and I_3 = 600 mm). Statistical analysis revealed that H_1 showed maximum grain yield during both years (7.70 and 7.98 t ha^{-1} respectively) at I_3 with the application of recommended NPK. While the grain yield of H_1 during both years was greater at CPM than H_2 with the application of recommended NPK under I_2. In 2011 optimum biological yield equivalent to 18.20 t ha^{-1} was recorded in treatment $I_3H_1L_1$. Grain oil and protein contents were statistically at par in both maize hybrids fertilized with L_1 and L_4 under I_1 condition. The nitrogen uptake was similar in both hybrids under controlled condition. Moreover, water use efficiency (WUE) was significantly enhanced with the application of CPM. The highest net benefit ($1788 ha^{-1}) was achieved by recommended NPK treatment; contrarily, the highest marginal rate of return (35%) was obtained by application of 600 mm ha^{-1} depth of irrigation water and 12 t CPM ha^{-1}. © 2013 Friends Science Publishers

Keywords: Agricultural best management practices; Economic analysis; Water stress; Water use efficiency; *Zea mays* L.

Introduction

Nutrient balance is an important consideration for crop response to applied fertilizers. It requires formulation and adoption of the BMPs to improve crop yield as well as soil health. Maize (*Zea mays* L.) is an important cereal crop grown all over the world. It is nitro positive and needs ample quantity of nitrogen (N) for attaining high yield. Nitrogen deficiency is a key factor for controlling maize yields (Alvarez and Grigera, 2005). It is; therefore, imperative to use an optimum amount of N through a suitable and efficient source. Continuous use of synthetic nitrogenous fertilizers pollutes water resources subsequently toxic to animal and human lives (Oad *et al.,* 2004; Zhao *et al*., 2009; Cheema *et al*., 2010).

Worldwide, there is growing interest in adoption of BMPs since these agricultural practices include the use of organic manures, which recover the soil health and fertility. Organic manures are excellent nutrient source, as they contain both macro and micronutrients, while economic values of organic grains vary than inorganic products (Delate and Camberdella, 2004). In contrast to mineral fertilizer, they add organic matter to soil (Tiwari *et al.*, 2002; Edmeades, 2003), which improves soil structures, nutrient retention capability, aeration, soil moisture holding capacity and water infiltration (Efthimiadou *et al.*, 2009). Similarly, organic sources of N fertilizer are reportedly better alternate under semi-arid environments (Prabu *et al*., 2003). The application of organic manures to soil can stimulate plants N uptake (Velthof *et al*., 2003; Jones *et al*., 2007). Among organic manures, the application of poultry manure (PM) can particularly increase the growth and production of maize (Hirzel *et al*., 2004; Sharpe *et al.* 2004; Tambone *et al.,* 2007). In addition, N in PM is known to be readily available for plant uptake (Kitta *et al.,* 2002; Hidaka *et al.,* 2004).

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Poultry manure has a drawback due to moist, bad odor, transportation, inconsistent nutrient content and release (Chadwick *et al*., 2000; Georgakakis, 2000; Linquist *et al*., 2011). Excessive soil application of PM has resulted in water quality problems (Huang and Lu, 2000). These constraints could be controlled with the composting of PM (Semple *et al*., 2001; Farhad *et al*., 2011). Composting of manures is beneficial in organic farming (Berry *et al*., 2002). Similarly, composted manures enrich macronutrients (Warren *et al*., 2006), micro-nutrients (Warman and Cooper, 2000b; Shah and Anwar, 2003), lower C:N ratio (Zia *et al*., 2003), enhance CEC of soil (Alabadan *et al*., 2009) and lowers adverse impacts (Hara *et al*., 2003). Composting of organic manures is recommended for deodorization (Eghball *et al*., 1997). Composted manures release phytotoxic compounds that suppress weed germination (Liebman *et al*., 2004; Menalled *et al*., 2004). Since the amount of available N varies widely with the composition of the PM compost, it is important to evaluate existing BMPs to determine N optimum rates of composted manures (Tanahashi and Yano, 2004).

Water resources are become meager due to climate change, population growth, competition from other water users, drought, and water quality degradation (Bacon, 2004; Farahani *et al.,* 2007). Eventually, drought stress is one of the major causes for crop loss worldwide (Farooq *et al*., 2009; Jaleel *et al*., 2009; Golbashy *et al.,* 2010) reducing average yield by 50% (Wang *et al*., 2003). Maize has been reported to be very sensitive to drought stress (Farre *et al*., 2000). It requires about 500 to 600 mm of water during its lifecycle (Norwood and Dumler, 2002). Water deficit at any growth stage of maize reduces the crop growth and productivity (Moser *et al.,* 2006) reportedly due to inhibited cell expansion and reduced biomass production under such conditions (Ashraf and Mehmood, 1990).

Limited information is available regarding the effects of CPM on N availability to plant in soils treated with composted and raw manures under different irrigation levels (Eghball, 2000). However, CPM is not used at large scales in developing countries due to little knowledge, limited research and farmers' ignorance regarding the use of BMPs for productive farming. More information about CPM is needed to extend to farmers for enhanced and quality yield (Boateng *et al*., 2006). The study, therefore, seeks (i) the possible role of CPM in improving maize grain yield and quality under normal and limited water supply (ii) conduct economic analysis for recommending an optimum dose of N derived from CPM. We hypothesized that poultry manure compost would help in drought tolerance by improving water use efficiency.

Materials and Methods

Experimental Site

The experiment was conducted during spring season of 2010 and repeated in 2011 at Agronomic Research Area, University of Agriculture Faisalabad, Pakistan. The experimental site lies at 31º 26´ N latitude and 73º 06´ E longitude while the elevation of land is about 184.2 m above level of sea. The soil on the experiment site was sandy clay loam with characteristics shown in Table 1. The meteorological data during each growing season of crop was collected from Meteorological Observatory, Department of Crop Physiology, University of Agriculture, Faisalabad (Fig. 1).

Experimental Design and Treatments

This experiment followed randomized complete block design (RCBD) with split-split arrangement where the experiment treatments were replicated three times. The irrigation treatments (I_1: 300 mm; I_2: 450 mm; I_3: 600 mm) were kept in main plots and previously screened maize hybrids (drought tolerant Monsanto-919; sensitive FH-810) were kept in sub plots and CPM levels were kept in sub-sub plots. The sub-sub net plot size was 3 m × 5 m and in each replication among the main plots a buffer plot was kept to avoid moisture effects.

Composting of Poultry Manure

Poultry compost was prepared with the help of an electrical composter. Fresh PM was collected from the poultry farm of the University of Agriculture Faisalabad. Collected PM was sorted to remove unwanted materials and feathers. The material was sun dried for two days, and then passed through a crusher to extract extra moisture. The material was oven dried at 60^{o}C for up to 48 hr. The oven dried PM was ground into finer particles (< 2.0 mm) with an electric grinder. The crushed PM was shifted into a locally fabricated mechanical unit (vessel of 1000 kg capacity) under controlled ventilations and temperature (shaking at 50 rpm). A moisture level of 40% (v/w) of compost was maintained during this process. The moisture was controlled by using water as well as previously extracted moisture. Temperature was increased from 30 to 70˚C in the composting unit during 4th and 5th day of this process followed by a gradual reduction up to 30˚C after 5th day of composting. Prior composting status for NPK, moisture and C:N ratio of the PM were determined (Table 2).

Crop Husbandry

Maize seeds were sown on February 21, 2010 and 2011 using. The sowing was done by dibbling method maintaining a plant to plant distance of 0.25 m and row to row distance of 0.75 m. Total N requirements were met through CPM. The CPM per treatment calculation and extra quantity of phosphorus and potassium were applied at the time of sowing as TSP (Triple Super Phosphate) and K_2SO_4 (Potassium Sulphate), respectively. Plant population was

Table 1: Soil Physico-chemical analysis (on dry weight basis)

Determination	2010	2011
Mechanical analysis		
Sand (g kg^{-1})	660	660
Silt (g kg^{-1})	160	170
Clay (g kg^{-1})	180	170
Soil Texture	Sandy clay loam	
Chemical Analysis		
Saturation (%)	38	37
Field capacity (%)	20.1	19.5
Wilting point (%)	6.12	6.50
EC (dS m^{-1})	1.67	1.71
pH	7.90	7.96
Organic Matter (%)	0.68	0.74
Total N (g kg^{-1})	0.61	0.67
Available P (g kg^{-1})	6.82	6.95
Available K (g kg^{-1})	19.21	19.74

Table 2: Chemical analysis of poultry manure

Year			2010			
Determination	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Moisture (%)	C:N	pH
Non-composted PM	2.00	1.39	1.50	57	17:1	5.58
Composted PM	2.02	1.40	1.57	40	12:1	7.5
Year			**2011**			
Non-composted PM	2.04	1.54	1.59	52	16:1	6.3
Composted PM	2.05	1.56	1.73	35	11:1	7.8

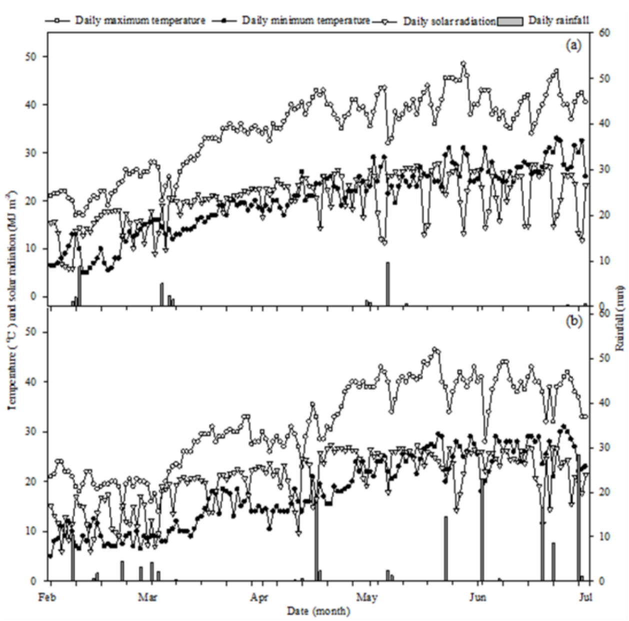

Fig. 1: Weather summary of experimental site during (a) 2010 and (b) 2011

maintained through thinning at 3 to 4 leaf stage resulting in one plant per hill. Weeds were controlled by hoeing twice to avoid the crop nutrient competition in each plot. All the

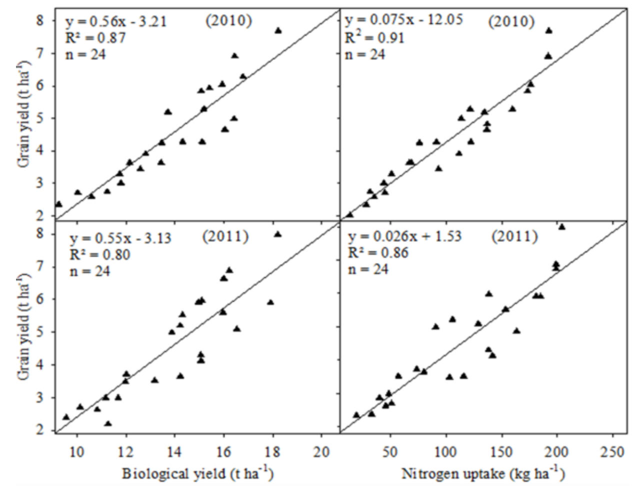

Fig. 2: Correlation coefficients of grain yield with biological yield and nitrogen uptake kg ha^{-1} of maize hybrid

other agronomic practices were kept uniform in all treatments. Harvesting was done manually separately for each plot on June 4, 2010 and 2011. Irrigation was controlled through Cut Throat Flume. The size of flume was 0.75 m × 0.90 m, that was installed in the main water channel of the field. Free flow conditions were adopted and table of free flow was used for calibration and discharge measurements. The following formula was used to calculate time of irrigation for a specific depth:

$$t = \frac{(A \times d)}{Q}$$

Where, *t* is time to irrigate given area (s), *Q* is discharge measured through Cut Throat Flume ($m^3 s^{-1}$), *A* is area to be irrigated (m^2) and *d* is depth of water applied (m).

Yield Observations

After shelling, grain weight of each plot was recorded with the help of portable balance and grain yield on hectare basis was calculated. Crop was harvested and sun dried for 25 days. After drying, overall biomass yield of each plot was obtained with the help of weighing balance and then converted to t ha^{-1}.

Quality Observations

From the grain lot of each plot 5 g grain sample was collected. The grains were oven dried 70˚C for 48 h and ground. Two sub samples (2 and 0.5 g) were used for the measurement of grain oil content (Low, 1990) and grain N contents following micro-Kjeldhal method (Bremner, 1964), respectively. Crude grain protein contents were calculated by the following formula.

Crude grain protein = grain nitrogen content × 6.25.

For straw N content 10 g sample was collected from the sun dried biomass of each plot and oven dried at 70˚C for 48 h then ground. After grinding 1 g sub sample was used for the measurement of straw N contents following the method described by Bremner (1964). N uptake was calculated by multiplying dry weight of plant parts by N concentration of that part and summing over parts for total plant uptake (Jackson, 1973).

Water use Efficiency

Water use efficiency was determined by dividing the grain yield (GY) in kg ha^{-1} with total evapotranspiration (ET) in mm during the crop season (Latiri-Souki *et al*., 1998).

$$WUE = \left(\frac{\text{GY}}{\text{ET}}\right)$$

ET was calculated by using a Decision Support System; Agro-technology System Transfer Model (Hoogenboom *et al*., 2011), which was calibrated by using weather and soil data of the study region.

Statistical Analysis

All the obtained data were subjected to statistical analysis by using M STAT-C package. Fisher's analysis of variance technique was used to test the significance of means and treatments' means were compared using least significant difference test (Steel *et al.,* 1997). Pearson's correlations were drawn between various parameters using Microsoft Excel Program. The computer package EXCEL GRAPHICS was used to prepare the graphs.

Economic Analysis

Economic analysis and marginal rate of return test were performed on the basis of cost, which varied among the treatments by following procedure given by Byerlee (1988). Individual treatment inputs and outputs were considered to work out the contribution of gross expenditure and income of the crop.

Table 3: Impact of composted poultry manure on the yield of maize hybrids under different irrigation levels

Treatment	Grain yield (t ha^{-1})		Biological yield (t ha^{-1})	
	2010	2011	2010	2011
$I_1H_1L_1$	4.99 ±0.18†	5.09 ±0.43†	16.22 ±0.61†	16.52±0.62†
$I_1H_1L_2$	2.74 ±0.21	2.19 ±0.03	11.10±0.66	11.26 ±0.85
$I_1H_1L_3$	3.29 ±0.29	2.99 ±0.04	11.60±0.47	11.16 ±1.72
$I_1H_1L_4$	3.63 ±0.16	3.72 ±0.02	12.02 ±0.46	12.01 ±0.06
$I_1H_2L_1$	3.01 ±0.27	2.99 ±0.01	11.65 ±0.71	11.67 ±1.19
$I_1H_2L_2$	2.01 ±0.19	2.34 ±0.12	8.63 ±0.61	8.48 ±0.86
$I_1H_2L_3$	2.35 ±0.16	2.38 ±0.10	9.14 ±0.66	9.55 ±0.53
$I_1H_2L_4$	2.71 ±0.17	2.70 ±0.52	9.91 ±1.04	10.12 ±1.83
$I_2H_1L_1$	6.28 ±0.13	5.90 ±0.02	16.58 ±0.83	17.90 ±0.87
$I_2H_1L_2$	3.63 ±0.22	3.65 ±0.01	13.27 ±0.73	14.22 ± 0.28
$I_2H_1L_3$	4.28 ±0.16	4.13 ±0.42	14.93 ±0.67	15.06 ±1.72
$I_2H_1L_4$	5.93 ±0.18	5.60 ±0.01	15.22 ±0.50	15.96 ±1.75
$I_2H_2L_1$	4.66 ±0.26	4.30 ±0.27	15.85 ±1.21	15.05 ±0.89
$I_2H_2L_2$	2.58 ±0.23	2.63 ±0.10	10.47 ±0.73	10.82 ±0.52
$I_2H_2L_3$	3.44 ±0.17	3.48 ±0.11	12.43 ±0.68	11.97 ±0.13
$I_2H_2L_4$	3.91 ±0.21	3.52 ±0.15	12.65 ±0.99	13.16 ±0.13
$I_3H_1L_1$	7.70 ±0.24	7.98 ±0.02	18.00 ±0.76	18.20 ±0.15
$I_3H_1L_2$	4.28 ±0.39	5.22 ±0.43	14.14 ±0.72	14.21 ±1.06
$I_3H_1L_3$	5.29 ±0.26	5.97 ±0.02	15.01 ±0.64	15.09 ±0.10
$I_3H_1L_4$	6.04 ±0.08	6.73 ±0.03	15.74 ±0.50	15.99 ±1.71
$I_3H_2L_1$	6.91 ±0.14	6.87 ±0.40	16.24 ±0.55	16.21 ±0.69
$I_3H_2L_2$	4.25 ±0.31	4.99 ±0.43	13.30 ±1.06	13.87 ±1.20
$I_3H_2L_3$	5.20 ±0.15	5.52 ±0.63	13.55 ±0.72	14.30 ±1.59
$I_3H_2L_4$	5.84 ±0.18	5.92 ±0.02	14.89 ±0.83	14.96 ±0.15
LSD (5%)	0.36	0.37	1.15	1.24
EMS	0.04	0.01	0.49	0.56
Block	Ns	ns	ns	Ns
I	**	**	**	**
Error a	-	-	-	-
H	**	**	**	**
I × H	Ns	**	*	*
Error b	-	-	-	-
L	**	**	**	**
I × L	**	**	**	**
H × L	**	ns	ns	**
I × H × L	*	*	*	**
Error c	-	-	-	-

Means within columns sharing different letters vary significantly at P≤0.05
† = mean ± stander error of the means, n = 3
I_1 =300 mm, I_2 = 450 mm, I_3 = 600 mm, H_1 = Drought tolerant, H_2 = Drought sensitive
L_1 = Control NPK, L_2 = 8 t ha^{-1} CPM, L_3 = 10 t ha^{-1} CPM, L_4 = 12 t ha^{-1} CPM
LSD = Least significant difference, EMS = error mean square, ns: non-significant, * Significant at the 0.05 level, ** Significant at the 0.01 level

Results

During the two growing seasons the two hybrids' grain yield was significantly affected by irrigation levels as well as by the levels of CPM; the yield during the second year, being more than that during the first year (Table 3). Under I_3 irrigation level maximum grain yield (7.70 and 7.98 t ha^{-1} during 2010 and 2011, respectively) was recorded in Monsanto-919 with the application recommended dose of NPK followed by $I_3H_2L_1$; during the second year the yield of later was statistically at par with $I_3H_1L_4$. While in this irrigation level the minimum grain yield (4.25 and 4.99 t ha^{-1} during 2010 and 2011, respectively) was recorded in maize hybrid FH-810 planted with the application of 8 t ha^{-1} CPM. On the other hand in I_2 irrigation level the maximum grain yield (6.28 and 5.90 t ha^{-1} during 2010 and 2011, respectively) was recorded in maize hybrid Monsanto-919 by the application of recommended rate of NPK and it was statistically at par with treatment $I_2H_1L_4$. The minimum grain yield under I_2 and I_1 irrigation levels was recorded in maize hybrid FH-810 planted with the application of 8 t ha^{-1} during both years (Table 3).

The biological yield of both maize hybrids was significantly influenced with the application of different CPM levels under different irrigation levels (Table 3). Maximum biological yield (18.00 and 18.20 t ha^{-1} during 2010 and 2011, respectively) was recorded in maize hybrid Monsanto-919 planted with the application of recommended rate of NPK under normal irrigation (I_3= 600 mm) and this was followed by the treatment $I_3H_2L_1$. While the minimum biological yield (13.30 and 13.87 t ha^{-1} during 2010 and

Table 4: Impact of composted poultry manure on the quality of maize grain under different irrigation levels

Treatment	Grain oil contents (%)		Grain protein contents (%)	
	2010	2011	2010	2011
$I_1H_1L_1$	2.29 ±0.22†	2.34 ±0.22†	6.40 ±0.59†	6.34 ±0.32†
$I_1H_1L_2$	2.34 ±0.20	2.35 ±0.21	5.39 ±0.54	5.54 ±0.23
$I_1H_1L_3$	3.27 ±0.21	3.31 ±0.22	5.87 ±0.63	5.98 ±0.23
$I_1H_1L_4$	2.08 ±0.25	2.10 ±0.37	6.33 ±0.54	6.49 ±0.35
$I_1H_2L_1$	1.95 ±0.18	1.98 ±0.11	4.19 ±0.47	4.30 ±0.33
$I_1H_2L_2$	2.26 ±0.22	2.30 ±0.23	4.03 ±0.57	4.16 ±0.38
$I_1H_2L_3$	2.09 ±0.31	2.13 ±0.22	4.36 ±0.55	4.52 ±0.46
$I_1H_2L_4$	2.29 ±0.19	2.35 ±0.23	5.36 ±0.61	5.47 ±0.22
$I_2H_1L_1$	2.99 ±0.18	3.02 ±0.33	7.14 ±0.54	7.28 ±0.45
$I_2H_1L_2$	2.59 ±0.12	2.60 ±0.23	6.11 ±0.57	6.27 ± 0.46
$I_2H_1L_3$	3.54 ±0.45	3.94 ±0.32	7.39 ±0.46	7.51 ±0.46
$I_2H_1L_4$	3.24 ±0.22	3.25 ±0.24	7.90 ±0.54	8.02 ±0.53
$I_2H_2L_1$	2.97 ±0.23	2.97 ±0.22	7.14 ±0.52	7.29 ±0.53
$I_2H_2L_2$	2.59 ±0.29	2.60 ±0.22	4.59 ±0.48	4.74 ±0.57
$I_2H_2L_3$	2.88 ±0.20	2.90 ±0.22	6.64 ±0.54	6.78 ±0.38
$I_2H_2L_4$	2.93 ±0.15	2.94 ±0.24	6.87 ±0.60	7.00 ±0.58
$I_3H_1L_1$	4.29 ±0.39	4.32 ±0.33	9.38 ±0.74	9.77 ±0.25
$I_3H_1L_2$	4.07 ±0.40	4.12 ±0.32	6.88 ±0.63	7.00 ±0.42
$I_3H_1L_3$	4.51 ±0.29	4.55 ±0.35	7.68 ±0.69	7.80 ±0.45
$I_3H_1L_4$	3.96 ±0.21	3.98 ±0.22	8.40 ±0.54	8.53 ±0.82
$I_3H_2L_1$	4.19 ±0.36	4.22 ±0.32	8.94 ±0.63	9.19 ±0.87
$I_3H_2L_2$	3.78 ±0.22	3.80 ±0.22	6.21 ±0.54	6.34 ±0.52
$I_3H_2L_3$	3.99 ±0.27	4.03 ±0.31	7.3 ±0.51	7.44 ±0.68
$I_3H_2L_4$	4.14 ±0.29	4.16 ±0.32	8.19 ±0.57	8.31 ±0.72
LSD (5%)	0.33	0.13	0.68	0.59
EMS	0.04	0.01	0.17	0.13
Block	ns	ns	ns	Ns
I	**	**	**	**
Error a	-	-	-	-
H	**	**	**	**
I × H	ns	**	*	*
Error b	-	-	-	-
L	**	**	**	**
I × L	**	**	**	**
H × L	**	ns	ns	**
I × H × L	*	*	*	**
Error c	-	-	-	-

Means within columns sharing different letters vary significantly at P≤0.05

† = mean ± stander error of the means, n = 3

I_1 =300 mm, I_2 = 450 mm, I_3 = 600 mm, H_1 = Drought tolerant, H_2 = Drought sensitive

L_1 = Control NPK, L_2 = 8 t ha^{-1} CPM, L_3 = 10 t ha^{-1} CPM, L_4 = 12 t ha^{-1} CPM

LSD = Least significant difference, EMS = error mean square, ns = non-significant, * Significant at the 0.05 level, ** Significant at the 0.01 level

Table 5: Enhancement of nitrogen uptake and water use efficiency with the application of CPM under different irrigation levels

Treatment	Nitrogen uptake (kg ha^{-1})		Water use efficiency (%)	
	2010	2011	2010	2011
$I_1H_1L_1$	119.10 ±14.58†	128.94 ±11.37†	9.90 ±1.41†	10.92 ±1.21†
$I_1H_1L_2$	33.93 ±8.00	40.36 ±5.43	6.26 ±0.89	6.71 ±0.57
$I_1H_1L_3$	54.03 ±7.22	57.19 ±8.95	7.62 ±0.82	8.14 ±0.89
$I_1H_1L_4$	70.53 ±9.62	73.68 ±3.74	11.65 ±0.96	11.33 ±0.93
$I_1H_2L_1$	46.87 ±6.94	48.69 ±1.89	6.99 ±0.44	6.64 ±0.60
$I_1H_2L_2$	15.10 ±5.74	19.82 ±3.23	4.80 ±0.58	5.53 ±0.52
$I_1H_2L_3$	30.37 ±3.17	33.28 ±5.25	5.65 ±0.38	5.85 ±0.41
$I_1H_2L_4$	47.77 ±12.08	51.09 ±10.98	6.60 ±0.60	7.50 ±1.32
$I_2H_1L_1$	167.0 ±8.68	184.79 ±10.35	12.56 ±0.65	11.76 ±1.34
$I_2H_1L_2$	72.53 ±10.90	80.28±6.24	8.19 ±0.66	8.49 ±1.03
$I_2H_1L_3$	128.0 ±12.89	141.79 ±14.24	9.70 ±0.78	9.95 ±1.12
$I_2H_1L_4$	143.3 ±14.16	163.43 ±13.68	12.56 ±1.39	12.18 ±1.33
$I_2H_2L_1$	143.0 ±8.33	138.16 ±11.46	10.45 ±0.34	10.25 ±0.79
$I_2H_2L_2$	37.77 ±9.99	45.88 ±7.04	5.92 ±0.60	6.12 ±0.80
$I_2H_2L_3$	97.90 ±14.07	103.15 ±12.04	8.10 ±1.31	8.12 ±0.70
$I_2H_2L_4$	117.1 ±17.82	115.87 ±15.82	9.29 ±1.64	8.38 ±0.63
$I_3H_1L_1$	200.90 ±15.83	204.00 ±16.56	15.01 ±1.91	14.53 ±1.49
$I_3H_1L_2$	95.93 ±10.79	105.86 ±13.76	9.61 ±1.85	12.14 ±1.10
$I_3H_1L_3$	127.30 ±13.60	138.49 ±12.43	12.24 ±1.68	14.26 ±1.55
$I_3H_1L_4$	183.9 ±13.83	198.83 ±15.95	13.90 ±1.55	15.30 ±1.73
$I_3H_2L_1$	200.3 ±17.90	198.83 ±17.34	15.16 ±1.37	16.16 ±1.58
$I_3H_2L_2$	80.17 ±11.13	90.89 ±8.13	9.70 ±1.98	12.52 ±1.22
$I_3H_2L_3$	140.9 ±13.31	153.44 ±14.72	11.96 ±1.17	13.39 ±1.55
$I_3H_2L_4$	181.1 ±15.60	180.94 ±10.06	13.60 ±1.29	14.46 ±1.58
LSD (5%)	16.18	16.19	0.90	1.03
EMS	95.38	66.87	0.29	0.39
Block	ns	ns	ns	Ns
I	**	**	**	**
Error a	-	-	-	-
H	**	**	**	**
I × H	**	**	**	*
Error b	-	-	-	-
L	**	**	**	**
I × L	**	**	ns	*
H × L	ns	**	ns	**
I × H × L	**	**	**	*
Error c	-	-	-	-

Means within columns sharing different letters vary significantly at P≤0.05

† = mean ± stander error of the mean, n = 3

I_1 =300 mm, I_2 = 450 mm, I_3 = 600 mm, H_1 = Drought tolerant, H_2 = Drought sensitive

L_1 = Control NPK, L_2 = 8 t ha^{-1} CPM, L_3 = 10 t ha^{-1} CPM, L_4 = 12 t ha^{-1} CPM

LSD = Least significant difference, EMS = error mean square, ns= non-significant., * Significant at the 0.05 level, ** Significant at the 0.01 level

2011, respectively) was recorded under this irrigation condition in maize hybrid FH-810 with the application of 8 t ha^{-1} CPM. Similarly, under the irrigation condition where 450 mm irrigation water was applied (I_2), the maximum biological yield (16.58 and 17.90 t ha^{-1} during 2010 and 2011, respectively) was recorded in the maize hybrid Monsanto-919 planted with the application of recommended rate of NPK fertilizer and this treatment, during first year, was followed by the treatment $I_2H_2L_1$ and during second year by the treatment $I_2H_2L_4$. Moreover, under this irrigation level the minimum biological yield (10.47 and 10.82 t ha^{-1} during 2010 and 2011, respectively) was noted in the maize hybrid FH-810 with the application of 8 t ha^{-1} CPM. While under water stress condition (I_1 = 300 mm) during both years maximum biological yield (16.22 and 16.52 t ha^{-1} during 2010 and 2011, respectively) was recorded in maize hybrid Monsanto-919 planted with the application of recommended rate of NPK fertilizer and this was followed by the treatment $I_1H_1L_4$. Again, the minimum biological yield (8.63 and 8.48 t ha^{-1} during 2010 and 2011, respectively) under this irrigation condition was observed in drought sensitive maize hybrid (FH-810) grown with the application 8 t ha^{-1} CPM however, during both years it was statistically at par with $I_1H_2L_3$.

Grain oil contents of maize hybrids during both years were significantly affected with the application of different compost levels under different moisture levels (Table 4). Grain oil contents were more during the second year as compared to first year. According to data under normal irrigation condition ($I_3 = 600$ mm) the maximum oil contents (4.51 and 4.55% during 2010 and 2011, respectively) were recorded in maize hybrid Monsanto-919 with the application 10 t ha^{-1} CPM and this was followed by $I_3H_1L_1$ treatment. Under the normal irrigation the minimum grain oil contents (3.78 and 3.80% during 2010 and 2011, respectively) were observed in maize hybrid FH-810 with the application 8 t ha^{-1} CPM and during first year it was statistically at par with the treatment $I_3H_1L_4$. Similarly, with the irrigation level I_2 (450 mm) the maximum oil contents (3.45 and 3.94% during 2010 and 2011, respectively) were noted in maize hybrid Monsanto-919 planted with the application of 10 t ha^{-1} CPM and first year it was statistically at par with the treatment $I_2H_1L_4$ but during second year it was followed by the treatment $I_2H_1L_4$. While the minimum oil contents (2.59 and 2.60% during 2010 and 2011, respectively) during this irrigation condition was recorded in the maize hybrid FH-810 with the application of 8 t ha^{-1} CPM and this was similar with the treatment $I_2H_1L_2$. On the other hand, According to the table 4 under water stress condition (I_1 = 300 mm) the maximum oil contents (3.27 and 3.31% during 2010 and 2011, respectively) were recorded in the drought tolerant maize hybrid Monsanto-919 planted with the application of 10 t ha^{-1} CPM and was followed by the treatment $I_1H_1L_2$. The minimum oil contents (1.95 and 1.98% during 2010 and 2011, respectively) were recorded in drought sensitive maize hybrid FH-810 with the application of recommended rate of NPK.

The grain protein contents were significantly influenced with the application of recommended rate of NPK and different rate of CPM under different irrigation levels (Table 4). The maximum grain protein contents (9.38 and 9.77% during 2010 and 2011, respectively) under normal irrigation condition ($I_3 = 600$ mm) were recorded in maize hybrid Monsanto-919 with the application of recommended rate of NPK, which was statistically at par with the $I_3H_2L_1$ treatment and was followed by $I_3H_1L_4$. While the minimum grain protein contents (6.21 and 6.34% during 2010 and 2011, respectively) were recorded in the maize hybrid FH-810 with the application of 8 t ha^{-1} CPM under the normal irrigation condition ($I_3 = 600$ mm). While, with the application of I_2 = 450 mm irrigation water the maximum grain protein contents (7.90 and 8.02% during 2010 and 2011, respectively) were recorded in drought tolerant maize hybrid (Monsanto-919) with the application of 12 t ha^{-1} CPM and during both years it was statistically at par with the treatment $I_2H_1L_3$. While with the application same irrigation level the minimum seed protein contents (4.59 and 4.74% during 2010 and 2011, respectively) were recorded in the maize hybrid FH-810 with the application of 8 t ha^{-1} CPM. On the other hand, under water stress condition ($I_3 = 300$ mm) the maximum seed protein contents (6.40% during 2010) in maize hybrid Monsanto-919 were observed with the application of recommended rate of NPK but during second year the maximum seed protein contents (6.49%) were recorded in treatment $I_1H_1L_4$. The minimum grain protein contents (4.03 and 4.16% in 2010 and 2011, respectively) were noted in drought sensitive maize hybrid FH-810 with the application of 8 t ha^{-1} CPM and it was statistically at par with the treatments $I_1H_2L_1$ and $I_1H_2L_3$ during both years of study.

The water use efficiency of crop was significantly affected by irrigation levels, maize hybrids and different levels of CPM and all the interactions were significant (Table 5). According to the interaction (irrigation × maize hybrids × CPM levels) the maximum WUE (15.16 and 16.16% during 2010 and 2011, respectively) under normal irrigation condition (I_3 = 600 mm) was recorded in plots, where the maize hybrid FH-810 was grown with the application of recommended rate of NPK through fertilizer. This was statistically at par with treatment $I_3H_1L_1$ during 2010 but during 2011 with the treatment $I_3H_1L_4$. While under this irrigation levels, the minimum WUE (9.61 and 12.14% during 2010 and 2011, respectively) was recorded in the plots where maize hybrid Monsanto-919 was planted with the application of 8 t ha^{-1} CPM and during both years this was statistically at par with the treatment $I_3H_2L_2$. Similarly, under the irrigation condition of I_2 = 450 mm the maximum WUE (12.56 and 11.76% during 2010 and 2011, respectively) was recorded in plots where the drought tolerant maize hybrid Monsanto-919 was planted with the application of recommended rate of NPK and it was statistically at par with treatment $I_2H_1L_4$. While the minimum water use efficiency (5.92 and 6.12% during 2010 and 2011, respectively) was recorded in drought sensitive maize hybrid FH-810 which was planted with the application of 8 t ha^{-1} CPM. On the other hand, under water stress condition I_1 = 300 mm the maximum WUE (11.65 and 11.33% during 2010 and 2011, respectively) was noted in drought tolerant maize hybrid (Monsanto-919) planted with the application of 12 t ha^{-1} CPM and during 2010 it was followed by the treatment $I_1H_1L_1$ but during second year it was statistically at par with the same treatment. While the minimum WUE (4.80 and 5.53% during 2010 and 2011, respectively) was recorded in drought sensitive maize hybrid (FH-810) grown in plots where the 8 t ha^{-1} CPM was applied with the application of water stress condition (I_1 = 300 mm) and during both year trial this treatment was statistically at par with treatment $I_1H_2L_3$.

Nitrogen uptake of maize hybrids during both years was significantly affected by different levels of CPM under different irrigation levels (Table 5). The maximum N uptake (200.90 and 204.00 kg ha^{-1} during 2010 and 2011, respectively) was recorded in maize hybrid Monsanto-919 grown with the application of recommended rate of NPK through inorganic fertilizer under the normal irrigation level (I_3 = 600 mm) and it was followed by the treatment $I_3H_2L_1$. On the other hand, under same irrigation condition (I_3= 600 mm) the minimum N uptake (80.17 and 90.89 kg ha^{-1} during 2010 and 2011, respectively) was noted in drought

Table 6: Economic analysis of experimental treatments using grain yield

Treatments	I_1L_1	I_1L_2	I_1L_3	I_1L_4	I_2L_1	I_2L_2	I_2L_3	I_2L_4	I_3L_1	I_3L_2	I_3L_3	I_3L_4	Remarks
Grain yield	5.09	2.19	2.96	3.72	5.89	3.65	4.13	5.60	7.98	5.20	5.97	6.64	t ha^{-1}
Adjusted yield	4.58	1.97	2.66	3.35	5.30	3.29	3.72	5.04	7.18	4.68	5.37	5.98	To bring at farmer's level (10% decrease)
Gross income	1374	591	799	1004	1590	985	1115	1512	2154	1404	1611	1792	$ 300 t^{-1}
I_1	25	25	25	25	-	-	-	-	-	-	-	-	$ 1.33 cost for 10 mm
I_2	-	-	-	-	36	36	36	60	-	-	-	-	irrigation water depth
I_3	-	-	-	-	-	-	-	-	50	50	50	50	
L_1	317	-	-	-	317	-	-	-	317	-	-	-	Applied NPK cost
L_2	-	188	-	-	-	188	-	-	-	188	-	-	
L_3	-	-	235	-	-	-	235	-	-	-	235	-	$ 23.5 cost for 1 ton
L_4	-	-	-	282	-	-	-	282	-	-	-	282	CPM
Total cost	342	213	260	307	353	224	271	342	367	238	285	332	$ ha^{-1}
Net benefit	1032	378	539	697	1237	762	844	1170	1788	1166	1327	1461	$ ha^{-1}

I_1= 300 mm, I_2= 450 mm, I_3= 600 mm, L_1= Control NPK, L_2= 8 t ha^{-1} CPM, L_3= 10 t ha^{-1} CPM, L_4= 12 t ha^{-1} CPM
Net benefit = gross income - variable cost, $= US
All prices of inputs and outs were considered of June, 2011 in Pakistan

sensitive maize hybrid (FH-810) with the application of 8 t ha^{-1} CPM and during both years it was statistically at par with the treatment $I_3H_1L_2$. Under the irrigation condition I_2 (450 mm) N uptake was significantly maximum (167.00 kg ha^{-1} and 184.79 kg ha^{-1} during 2010 and 2011, respectively) in the drought tolerant maize hybrid (Monsanto-919) planted with the application of recommended rate of NPK fertilizer and during both years it was followed by the treatment $I_2H_1L_4$. While the minimum N uptake (37.77 kg ha^{-1} and 45.88 kg ha^{-1} during 2010 and 2011, respectively) was recorded in the maize hybrid FH-810 with the application of 8 t ha^{-1} CPM and both years this treatment was followed by the treatment $I_2H_2L_2$. During the water stress condition (I_1 = 300 mm) the N uptake was significantly affected and the maximum N uptake (119.10 kg ha^{-1} and 128.94 kg ha^{-1} during 2010 and 2011, respectively) was noted in drought tolerant maize hybrid (Monsanto-919) with the application of recommended dose of NPK fertilizer and this treatment was followed by the treatment $I_1H_1L_4$. Moreover, the minimum N uptake (15.10 kg ha^{-1} and 19.82 kg ha^{-1} during 2010 and 2011, respectively) was observed in the drought sensitive maize hybrid (FH-810) with the application of 8 t ha^{-1} CPM.

Economic Analysis

Finally effectiveness of the study treatments was checked by economic and marginal analysis. Clear difference among the treatments was observed due to variation in cost and yield. Decrease in net benefit was observed by reduction of irrigation amount and CPM (Table 6). Under all irrigation levels the highest net benefit was achieved with the application of recommended rate of NPK through inorganic fertilizer while the minimum was recorded with the application of 8 t ha^{-1} CPM. However, in marginal analysis this treatment could not perform better due to high cost of input as compared to other treatments (Table 7). In marginal analysis most of studied treatments failed due to less benefits than preceding treatments. The highest marginal rate of return (30%) was achieved by applying of 12 t ha^{-1} marginal rate of return with 600 mm depth of irrigation water, this was closely followed by the MRR of 29% with the application 12 t ha^{-1} CPM under limited water supply (I_1=300 mm).

Table 7: Marginal analysis of experimental treatments using grain yield

Treatments	Net benefit ($ ha^{-1})	Cost that vary ($ ha^{-1})	Change in cost ($ ha^{-1})	Change in net benefit ($ ha^{-1})	Marginal rate of return (%)
$I_1 L_2$	378	213	-	-	-
$I_1 L_3$	539	260	47	161	29
$I_1 L_4$	697	307	47	158	30
$I_2 L_2$	762	224	D	-	-
$I_2 L_3$	844	271	D	-	-
$I_1 L_1$	1032	342	35	188	19
$I_3 L_2$	1166	238	D	-	-
$I_2 L_4$	1170	342	D	-	-
$I_2 L_1$	1237	353	11	67	-
$I_3 L_3$	1327	285	D	-	-
$I_3 L_4$	1461	332	47	134	35
$I_3 L_1$	1788	367	14	327	4

Variable cost = Cost of inputs, ha^{-1} that varied among the experimental treatments
D = Dominated due to less benefits than preceding treatments
Marginal rate of return (%) = (Change in net benefit ÷ Change in cost) × 100
I_1 = 300 mm, I_2 = 450 mm, I_3 = 600 mm, L_1 = Control NPK, L_2 = 8 t ha^{-1} CPM, L_3 = 10 t ha^{-1} CPM, L_4 = 12 t ha^{-1} CPM, $ = US

Discussion

The significant increase of grain yield with increased CPM rates under limited amount of irrigation water may be due to improvement in water holding capacity of soil which increased the nutrient uptake (Ying *et al.*, 2000; Echarte *et al.*, 2006; Muñoz *et al*., 2008). Moreover, N availability by the PM is known to be the most spectacular in maize plant growth and development (Udom and Bello, 2009). With increased N availability from the application of CPM, dry matter production is significantly enhanced (Adamtey *et al*., 2010; Adeniyan *et al*., 2011). The quality of maize grain improved with the application of CPM which resulted in increase in grain oil and grain protein contents (Moss *et al*., 2001). The higher rate of CPM and recommended NPK reduced the oil content possibly due to increase of N supply. The increase of N supply resulted in formation of N containing protein, which competes strongly for the fat synthesis (Mishra *et al*., 1990; Hati *et al*., 2001). While it improved the protein contents (Table 5), this might be due to increase in N contents of leaves, which are rapidly converted to protein and during grain development leaf N is transferred to grain for protein production. Similar findings were reported by other researchers (Jackson and Smith, 1997; Khan *et al*., 2008). The increase of N uptake with increased amount of irrigation water might be due to the increase of nutrient availability under moist conditions (Moss *et al*., 2001). Moreover, in PM two main N components are uric acid and undigested protein, which are about 70 and 30% of the total N, respectively (Nahm, 2003). Therefore, the N uptake by plants increased with application of high rate of CPM. This increase in both maize hybrids could be due to the reason that compost is generally more concentrated in nutrients and narrow in C:N (Farhad *et al*., 2011). Amanullah *et al*. (2006) found that CPM yielded more than fresh manure. The PM can be effectively used with BMPs, while composting increased the available soil N progressively. On the other hand lower uptake of N by plants through inorganic source might be due to volatilization of ammonia-N and immobilization. Similarly, Ahmad *et al.* (2008) reported that N uptake increased by composting in maize hybrid due to the increased mineralization rate in compost.

With the increase of WUE the uptake of N as well as other nutrients availability increased (Oktem, 2008; Berenguera *et al*., 2009; Garcia *et al*., 2009), because water plays important role in availability of nutrients (Kumara and Deyb, 2011). The higher nutrients uptake (Bafna *et al*., 1993) and excellent soil–water–air relationships should be considered while formulating the BMPs of PM. Moreover, with the increase of CPM application rate, the water loss through evaporation from the surface of soil was much lower; hence, WUE was higher as compared to lower rate of CPM (Abd-El-Kader *et al*., 2010). The increased yield and WUE achieved under higher rate of CPM may be due to excellent soil–water–air association with higher oxygen concentration in the root zone and well-organized utilization of water and nutrients with BMPs (Biradar, 2007). With the application of CPM marginal benefit significantly increased; this increase was submitted to the low price of PM and its composting charges.

In conclusion, maximum grain yield, oil and protein contents were obtained with the application of 12 t composted poultry manure (CPM) and 600 mm irrigation water ha^{-1}. CPM also improved maize hybrid yield and quality under limited water (i.e., 450 mm) supply as compared to the inorganic source of nutrient. Water use efficiency was enhanced with the application of CPM. The above BMPs also resulted in the highest marginal rate of return (i.e., 35%). The farmer can get more marginal benefits with the application CPM as compared to inorganic fertilizer.

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