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Response of Maize Hybrids to Composted and Non-composted Poultry Manure under Different Irrigation Regimes

WAJID FARHAD, MUMTAZ AKHTAR CHEEMA, MUHAMMAD FARRUKH SALEEM[1] HAFIZ MOHKUM HAMMAD AND MUHAMMAD FAISAL BILAL
Department of Agronomy, University of Agriculture, Faisalabad, Pakistan
[1]Corresponding author's e-mail: mfsuaf@yahoo.com

ABSTRACT

Poultry manure (PM) is enriched with uric acid and undigested protein however; the nutrient availability varies in fresh and composted PM. An incubation study was conducted during 2009 in green house at Agronomic Research Farm, University of Agriculture, Faisalabad to examine the changes in availability of nitrogen (N) to maize (*Zea mays* L.) hybrids with composted and non-composted PM under various irrigation regimes. The experiment was conducted following completely randomized design with factorial arrangement and each treatment was repeated five times. Pre-tested drought tolerant (Monsanto 919) and sensitive (FH-810) maize hybrids were planted at 100% and 75% of field capacity levels (FC). Performance of the maize hybrid (Monsanto 919) under composted PM was better for N content, which resulted in maximum number of leaves per plant (17.40), plant height (147.60 cm), leaf area index (4.99) and transpiration rate (8.50 m mol m^{-2} s^{-1}). In maize hybrid (FH-810), maximum photosynthesis rate (21.82 μ mol m^{-2} s^{-1}) was noted under composted PM at 100% FC, while the performance of this hybrid was poor in all other recorded observations at 75% FC. The nitrogen availability was more from composted PM under both conditions (normal & drought). This enhanced the morphological and physiological processes in maize crop.

Key Words: Field capacity; Photosynthesis rate; Poultry manure and nitrogen

INTRODUCTION

The response of maize hybrids to water and nutrient uptake varies due to different characteristic of plant (Widdicombe *et al.*, 2002) such as crowding stress tolerance (Tollenaar & Lee, 2002), plant morphology (Benga *et al.*, 2001; Farhad *et al.*, 2011), sink capacity (Gambin *et al.*, 2006), plant growth rate (Echarte *et al.*, 2000), grain filling (Echarte *et al.*, 2006), vertical leaf area profile, nutrient source their uptake and utilization (Valentinuz & Tollenaar, 2006).

Continuous use of synthetic nitrogenous fertilizers is not only polluting the water resource rather is toxic to human as well as for animal life (Oad *et al.*, 2004; Cheema *et al*., 2010). High cost and unavailability of fertilizer at the time of need further aggravate economic condition of farmers (Ahmad *et al*., 2006). While most of Pakistani soils contain organic matter less than 1% (Azad & Yousaf, 1982). Nutrient balance is an important consideration for crop response to applied fertilizers. Moreover, sole use of chemical fertilizers is causing deterioration in soil physico-chemical and biological properties. The applied N is not all taken by crop plant; the efficiencies of nitrogenous fertilizers are very low, approximately 32-35%. A large proportion is lost due to ammonia volatilization, denitrification and leaching (Zhang *et al*., 2009). Use of organic manure has been in practice for centuries worldwide (Clay *et al*., 2002; Lopez *et al*., 2008). Slow release nitrogenous fertilizers have capacity to improve yield and nitrogen use efficiency (Zemenchik & Albrecht, 2002; Huggins & Pan, 2003; Cahill *et al*., 2007). There is increasing interest in the use of organic manures due to depletion in the soil fertility. Organic manures are excellent nutrient source; contain N, phosphorus, potassium and other essential nutrients while economic value of organic grains also vary than inorganic products (Delate & Camberdella, 2004).

The application of organic manures to soil can stimulate N uptake (Velthof *et al*., 2003; Jones *et al*., 2007); among organic manures poultry manure can highly increase the growth and production of maize (Cooperband *et al*. 2002; Hirzel *et al*. 2004), because it contain more N compounds (Nahm, 2003).

Use of organic composts in agricultural areas is increasing because these improve soil health and nutrient status (Cuevas *et al*., 2003; Ahmad *et al*., 2006; Pandey & Shukla, 2006). Composting of manures is suggested in organic farming for human health (Berry *et al*., 2002) due to decrease in phyto-toxic substances (Gil *et al*., 2007). Similarly compost is more intense in macronutrients (Warren *et al*., 2006), micro nutrient (Warman & Cooper, 2000b; Shah & Anwar, 2003), narrow in C: N ratio (Zia *et al*., 2003), CEC

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of soil (Alabadan *et al*., 2009) and is free from adverse characteristics (Hara *et al*., 2003). The quality of compost can be enhanced with synthetic fertilizer (Banger *et al*., 1988; Mishra, 1992) and its extra handling can decrease the nutrient losses (Eghball *et al*., 1997; Tiquia *et al*., 2002). Moreover, composts also release phytotoxic compounds that suppressed weed germination (Ozores-Hampton *et al*., 1999; Liebman *et al*., 2004; Menalled *et al*., 2004).

Water resources have become meager due to climate change and competition from other water users (Farahani *et al.,* 2007). Drought stress is a major abiotic factor that limits agricultural crop production (Jaleel *et al*., 2009). Maize crop requires 600 millimeters of water during its lifecycle (Singh, 1991) and water deficit at any growth stage can reduce growth and yield of the crop (Paudyal *et al*., 2001). Lower yield of maize was found when the crop was subjected to drought with high N dose (Moser *et al.,* 2006) indicating a close relationship between nutrient availability and soil moisture.

Nonetheless, to best of our knowledge, most studies have been undertaken to unravel the nitrogen uptake through composted versus non-composted poultry manure under non-stressed environment. Here, we hypothesized that nitrogen availability under drought can be enhanced if manures are applied as compost.

MATERIALS AND METHODS

Soil physico-chemical analysis: The soil used for experiment was completely analyzed for the various physico-chemical properties before the pot filling as shown in Table I.

Composting of poultry manure: Poultry compost was made with the help of composter; PM was collected from the poultry farm University of Agriculture Faisalabad. Collected fresh PM was sorted to remove feather and unwanted materials. The sorted 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 up to 48 h. The oven dried manure was ground into finer particles (<2.0 mm) with the help of an electric grinder. The crushed PM was shifted into a locally fabricated mechanical unit (vessel of 1000 kg capacity) under controlled temperature and ventilation (shaking at 50 rpm). A moisture level of 40% (v/w) of the compost was maintained during this process. The moisture was controlled by using previously extracted moisture as well as water. Temperature was increased from 35 to 70^{o}C in the composting unit during 3rd and 4th day of this process and then reduced gradually up to 30^{o}C after 4th day. Before and after composting the PM was analyzed to observe the status of NPK as well as C:N ratio as shown in Table II.

Field capacity (FC): Field capacity of each pot was controlled according to the treatments after germination. Soil moisture in pots was measured on daily basis. Each time pots were irrigated when there was a reduction in moisture contents by about 30% (from 100 or 75% field capacity as per treatment). This procedure was carried out up to the tasseling stage.

Crop husbandry: According to treatments two maize hybrids drought tolerant and sensitive (Monsanto 919; FH-810, respectively) using two nutrient organic source non-composted and composted PM under two field capacity levels 75% and 100% experiment was planted on 10th November 2009 at Agronomic Farm in Green House, University of Agriculture Faisalabad using completely randomized design (CRD) with factorial arrangement and the each treatment was replicated five times. Green house was maintained at 26 (±2)^{o}C (day) and 18 (±2)^{o}C (night) under a relative humidity of 70 (±5)% throughout the period of study using an electrical fan and wet wall cooling system. The earthen pots (45 cm high with 25 cm diameter from the neck & 20 cm from bottom) were used having the capacity of 20 kg soil and five seeds were planted initially in each pot but later thinned to keep only three. An amount of 112 g composted and 124 g of non-composted PM was added before sowing as per treatment; no inorganic fertilizer was added.

Observations: The plant height of each plant was periodically measured after the interval of ten days with the help of measuring tape, whereas leaf number per plant at tasseling was manually counted. Leaf area of same plants was measured periodically with the help of portable laser leaf area meter (Laser Area Meter CI-203, LCi Bio Scientific, USA) and then converted in to leaf area index following Watson (1978).

Observations regarding number of days to tasseling in each pot were observed, the length of tassel of same plants was recorded with the help of measuring tape. Photosynthesis and transpiration rates were measured at vegetative stage before tasseling in the penultimate fully expanded third leaf from top with the help of Infra Red Gas Analyzer (LCi Analyser with Broad Head, Part Number LCi-002/B & Serial Number 32455, USA) during 09:00 to 11:00 am with following adjustments: molar flow of air per unit leaf area 395.40 mmol lol^{-1} 1 m^{-2} s^{-1}, leaf chamber water pressure was 0.33 MPa, photosynthetically active radiation (PAR) was up to 911 mol m^{-2} s^{-1} at leaf surface, temperature of leaf ranged 25 to 26^{o}C, ambient temperature was 24 to 25^{o}C, CO_2 concentration of ambient was 371.5 mol mol^{-1} and relative humidity (RH) was 70% and mean values were deputed. At tasseling leaf samples were taken, dried in oven at 70^{o}C till constant weight and then ground. The 0.5 g of ground sample was taken for nitrogen contents determination following Kjeldahl method (Bremner, 1964).

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.

RESULTS

The number of leaves per plant recorded at tasseling was significantly affected by composted and non-composted PM. According to Table III maximum number of leaves (17.40) was noted in maize hybrid Monsanto 919 with composted PM at 100% FC, while minimum (12.40) was recorded in FH-810, where non-composted PM was used at 75% FC. Periodic data presented in Fig. 1 (a & b) showed that in non-composted PM maximum plant height (134.60 cm) was found, when Monsanto 919 was planted with 100% FC and lowest (84.40 cm) was recorded in FH-810 when grown at 75% FC. In case of composted PM, again Monsanto 919 gained more plant height (147.60 cm) at 100% FC than lowest (105.60 cm) with FH-810 at 75% FC. Leaf area index (LAI) of maize hybrids recorded at 10 days interval, was significantly affected by composted and non-composted PM under different irrigation regimes as shown in Fig. 2 (a & b). Performance of composted PM was better in attaining more LAI than non-composted PM. With both types of manures, LAI was maximum when Monsanto 919 was grown with 100% FC as compared with minimum in FH-810 when grown at 75% FC.

Rate of photosynthesis differed statistically (P=0.05) with the application of composted and non-composted PM under different field capacities. In composted PM maximum photosynthesis rate (21.82 µmol m^{-2} s^{-1}) was recorded with Monsanto 919 at 100% FC and minimum photosynthesis rate (9.60 µmol m^{-2} s^{-1}) with FH-810 at 75% FC (Table III). While with the application of non-composted PM Monsanto 919 showed maximum photosynthesis rate (16.39 µmol m^{-2} s^{-1}) at 100% FC. Minimum rate of photosynthesis (7.53 µmol m^{-2} s^{-1}) was recorded with FH-810 at 75% FC. Data in Table III showed that the application of composted and non-composted PM affected the rate of transpiration. The performance of composted PM was better in this regard. Monsanto 919 showed more maximum transpiration rate (8.504 m mol m^{-2} s^{-1}) with 100% FC and minimum transpiration rate (4.806 m mol m^{-2} s^{-1}) with FH-810 was observed at 75% FC. While the result revealed that under the application of non-composted PM maximum transpiration rate (6.304 m mol m^{-2} s^{-1}) and minimum (2.812 m mol m^{-2} s^{-1}) at vegetative growth stage ware recorded when Monsanto 919 and FH-810 planted with 100% FC and 75% FC, respectively. Day to tasseling differed with the application of composted and non-composted PM (Table III). The application of composted PM resulted in early tasseling (52.6 days) in Monsanto 919 at 75% FC and it was delayed up to 60.5 days in FH-810 at 75% FC. The data revealed that days to tasseling with the application of non-composted PM in Monsanto 919 was delayed to 57.2 DAS at 75% FC, while it was completed in 63.3 days in FH-810 at 100% FC. Tassel length of maize hybrids was also affected by the application of manure and stress. Results revealed that in composted PM the tassel length was 18.00 cm in Monsanto 919 and 11.20 cm in FH-810 at 100% FC

Fig. I: Periodic changes in plant height of maize hybrids by (a) non-composted PM and (b) composted PM under different irrigation regimes (H1=Drought tolerant hybrid Monsanto 919, H2= Drought sensitive hybrid FH-810, I1=75% Field capacity I2=100% Field capacity)

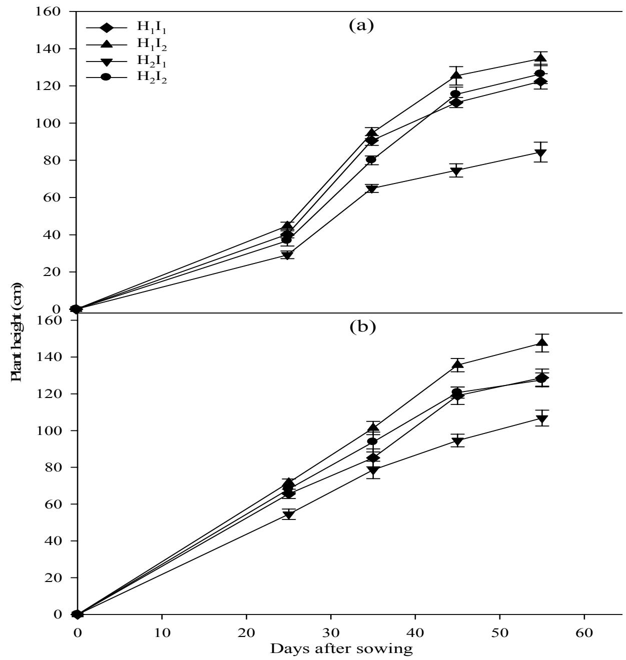

Fig. 2: Periodic changes in leaf area index of maize hybrids by (a) non-composted PM and (b) composted PM under different irrigation regimes (H1=Drought tolerant hybrid Monsanto 919, H2=Drought sensitive hybrid FH-810, I1=75% Field capacity I2=100% Field capacity)

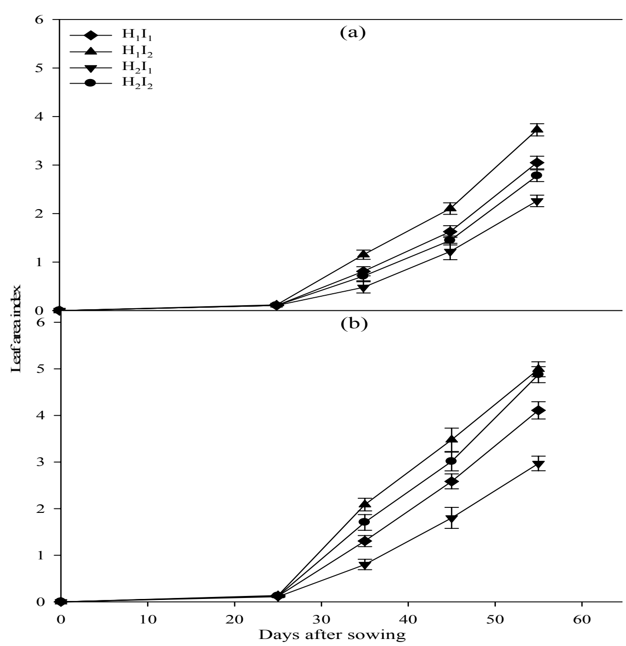

Table I: Mechanical and chemical analysis of experimental soil

Nitrogen (%)	Potassium (ppm)	Phosphorus (ppm)	Organic mater (%)	pH	EC (dSm^{-1})	Texture	Field capacity (%)
0.048	5.07	178	0.68	7.9	1.6	Sandy clay loam	22

Table II: Chemical analysis of poultry manure

Sources	Nitrogen (%)	Potassium (%)	Phosphorus (%)	C:N ratio	pH
Fresh poultry manure	2.01	1.07	1.67	16:1	6.3
Composted poultry manure	2.23	1.14	1.73	11:1	7.2

Table III: Response of maize hybrids to composted and non-composted poultry manure under different irrigation regimes

Treatments	Parameters					
	Number of leaves per plant	Photosynthesis rate ($\mu mol\ m^{-2}\ s^{-1}$)	Transpiration rate (m mol $m^{-2}\ s^{-1}$)	Days to tasseling	Length of tassel (cm)	Leaf nitrogen contents (%)
$P_1H_1I_1$	15.40 c	8.52 g	4.504 f	57.2 e	14.70 d	0.480 f
$P_1H_1I_2$	16.40 b	16.39 c	6.304 c	58.2 d	15.40 c	1.070 d
$P_1H_2I_1$	12.40 e	7.53 h	2.812 g	62.7 b	10.70 g	0.456 f
$P_1H_2I_2$	15.39 c	13.41 d	5.306 d	63.3 a	13.30 e	1.046 d
$P_2H_1I_1$	16.20 b	12.18 e	5.306 d	52.6 g	14.60 d	1.346 b
$P_2H_1I_2$	17.40 a	18.55 b	8.504 a	57.3 e	18.00 a	1.934 a
$P_2H_2I_1$	13.40 d	9.60 f	4.806 e	54.5 f	11.20 f	0.768 e
$P_2H_2I_2$	16.40 b	21.82 a	7.010 b	60.5 c	17.40 b	1.160 c
CV	**3.49**	**2.44**	**0.10**	**0.61**	**1.86**	**4.06**

Figures sharing the same letter do not differ statistically at P≤0.05 by LSD test

P_1: Non-composted poultry manure, P_2: Composted poultry manure, H_1: Drought tolerant hybrid Monsanto 919, H_2: Drought sensitive hybrid FH-810, I_1: 75% Field capacity I_2: 100% Field capacity, C.V.: Coefficient of variation

Table IV: Correlation coefficient (r^2) among important morphological and physiological characteristics of maize hybrids (n=8)

Parameters		r^2
X-Range	Y-Range	
Leaf Area Index	Photosynthesis Rate	0.74**
	Transpiration Rate	0.81**
	Nitrogen Contents	0.69*
Photosynthesis Rate	Leaf Transpiration Rate	0.78**
Transpiration Rate	Leaf Nitrogen Contents	0.78**

= Significant at *, P<0.05 and **, P<0.01

and 75% FC respectively, while in non-composted PM Monsanto 919 gave tassel length of 15.40 cm at 100% FC and FH-810 produced 10.70 cm long tassels at 75% FC.

The N contents in maize hybrids varied with the application of composted and non-composted PM under various irrigation regimes (Table III). Monsanto 919 showed N contents 1.934% at 100% FC and 1.346% at 75% FC when it was grown with composted PM while same hybrid attained N contents 1.070% at 100% FC and 0.480% at 75% FC when grown with non-composted PM. Similarly, the Nitrogen contents in drought sensitive FH-810 was recorded maximum under composted PM (1.160 & 0.768% at 100 & 75% FC, respectively) than non-composted PM (1.046 & 0.456% at 100 & 75% FC, respectively).

DISCUSSION

Data achieved from the experiment showed a noticeable increase in plant growth in all treatments with application composted PM as compared to non-composted PM. The higher growth due to poultry manure (PM) may be due to the fact that the manures supply direct available nutrients such as nitrogen to the plants and these organic manures improve the proportion of water stable aggregates of the soil. In present study, more number of leaves was recorded under composted PM than non-composted; this might be due to stunted plant growth in later case. The stunted growth might have resulted from decreased nitrogen availability from non-compost (Baloyi *et al*., 2010), which ultimately decreased the plant height of maize hybrids (Farhad *et al.,* 2009); while increased plant height by composted PM might be due to readily available nitrogen to plant that improved the morphological growth of plants (Ahmad *et al*., 2008). Among different organic sources Ahmad *et al*. (2006) obtained maximum plant height and maximum nutrient uptake with compost under controlled condition. Aziz *et al*. (2010) found Poultry manure enhanced the leaf area index (LAI). Under drought more LAI was decreased in FH-810 hybrid than Monsanto 919, which was the drought sensitive maize hybrid. Drought stress decreased two important physiological processes i.e., photosynthesis and transpiration rates. Jarvis and Davies

(1998) found decrease of transpiration rate resulted photosynthesis decrease; this might be due to less chlorophyll formation due to decreased nutrient uptake. Anjum *et al.* (2011) reported that transpiration rate of maize hybrids decreased under drought condition due to decrease of enzymatic activities, same results were reported by Walker (2003) who observed 9.7 m mol m^{-2} s^{-1} transpiration in maize hybrid at 55 DAS under normal conditions.

The manure as well as water significantly affected the growth rate of maize hybrids; with the application of composted PM vegetative growth was completed early and crop took minimum days to tasseling while under non-composted PM tasseling started later. Under drought condition early tasseling started in both maize hybrids Khadem *et al.* (2010) observed significant effect of manure and irrigation on days to tasseling, similarly Olaoye *et al.* (2009) reported early (50 days) tasseling under drought condition in maize hybrid.

The two main nitrogen components in faeces are uric acid and undigested protein, which are about 70 and 30% of the total nitrogen (Nahm, 2003). The nitrogen contents in both maize hybrids was more in composted PM under both well water and drought conditions because compost is generally more concentrated in nutrients and narrow in C: N ratio. Amanullah and Yassin (2006) found PM composting yielded more than fresh manure. The PM can be effectively used by composting to increase the available soil N progressively, while lower uptake of N through fresh PM might be due to volatilization of ammonical-N and immobilization. Similarly Ahmad *et al.* (2008) reported that maximum N uptake occurred by compost in maize hybrid. From the result it assumed that in composted PM with 100% FC availability of nitrogen as well as other nutrients was increased, because water plays important role in availability of nutrients.

According to the correlation analysis the relationship of LAI with photosynthesis rate, transpiration rate and nitrogen uptake was significant. The Table IV showed that there was strong positive association between LAI vs photosynthesis rate, transpiration rate and nitrogen uptake. Similarly Cha-um *et al.* (2010) found significant correlation between LAI and photosynthesis rate. The rate of photosynthesis increased with significant increase in LAI under composted PM. Efthimiadou *et al.* (2010) reported this increase in photosynthesis rate is due to more availability of nitrogen and also correlation analysis of photosynthesis rate with transpiration was positive and significant (Table IV; r^2= 0.78). Aslam and Tahir (2003) also observed significant association between transpiration and photosynthesis rate in maize. Nitrogen contents decreased with the decrease of transpiration in maize hybrids. Novak and Vidovic (2003) observed correlation coefficient (r^2) between N contents and transpiration rate as 0.77. Correlation analysis indicated strong positive association of N contents in maize hybrids with rate of transpiration (r^2= 0.78; Table IV).

CONCLUSION

Poultry manure can be effectively used by composting to increase N availability; It improved performance of maize hybrids than with non-composted both in well watered and drought stressed plants.

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