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AGRO-ECONOMIC EVALUATION OF DIFFERENT FERTILITY SOURCES FOR MAIZE- WHEAT CROPPING SYSTEM UNDER RAINFED CONDITIONS OF PAKISTAN

Rashid Saleem[1], Zammurad Iqbal Ahmed[2], Ashiq Saleem[1] M. Ali Khan and Husnain Shah[3]

[1]*Maize, Sorghum and Millet Programme, National Agricultural Research Centre, Islamabad, Pakistan*
[2]*Department of Agronomy, Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi, Pakistan*
[3]*Social Science Institute, National Agricultural Research Centre, Islamabad, Pakistan*
[1]Corresponding author's e-mail: rashid479@gmail.com

ABSTRACT

An experiment was carried out to assess the economic feasibility of maize-wheat cropping system for five different fertility treatments (T1,control; T2, PGPR + PK (80-60 kg ha^{-1}), T3, (120-80-60 NPK kg ha^{-1}); T4, poultry manure at the rate of 15 t ha^{-1}, and T5, half poultry manure (7.5 t ha^{-1}) + half PK (40-30 kg ha^{-1}) + PGPR. According to statistical and economic analysis of the data revealed that maize plots treated with half poultry manure + half PK + PGPR gave 43% maize grain yield higher over control. Maximum wheat yield was recorded in plots previously treated poultry manure. Maize wheat cropping sequence accrued the highest net benefit of Rupees 78419.66 ha^{-1} than rest of the treatments. Likewise, considerable higher marginal rate of return 441.03 % was observed for maize wheat system with half poultry manure + half PK + PGPR and resulted in utmost residual value as verified through residual analysis in similar treatment. On the basis of agronomic as well as economic performance of maize it was well evident that combined use of organic, biofertilizers and chemical fertilizers proved to be more productive, sustainable and remunerative and can be recommended for maize growers to improve maize productivity and elevate their income.

Key words: Maize, NPK, grain yield, MRR, Partial budget, residual analysis

INTRODUCTION

Farmers use inorganic fertilizers injudiciously to surmount the problem of nutrient deficiency to boost their crop yields. The cost of inorganic fertilizer is very exorbitant for the resource poor farmers. Under such conditions an integrated approach is suggested through complementary use of inorganic and organic fertilizers to sustain soil fertility and crop productivity (Lampe, 2000). Although sole application of some organic sources to crops was found beneficial (Alam and Shah, 2003), however, complementary use of organic and inorganic fertilizers for crop production seems more productive and sustainable (Alam *et al.*, 2003, 2005, Khanam *et al.* 2001).

Poultry manure is recognized best organic manure, as it contains both macro and other essential nutrients. It improves chemical as well as physical properties of the soil (Sharif *et al.* 2004 and Deksissa *et al.* 2008). Similarly, poultry manure supplies P more readily to plants than other organic manure sources (Garg and Bahla, 2008). Organic manures like farmyard manure, poultry manure, sheep manure, and bio-fertilizer may be used for crop production as a substitute of chemical fertilizers (Khan *et al*., 2005 and Ayoola and Makinde, 2007). Organic fertilizers supply all the essential elements necessary for growth though not in equal proportion, and are readily decomposed by soil microorganisms (Afzal *et al*., 2005). Positive effects of organic waste on soil were reported in several studies (Odlare *et al*. 2007 and Jedidi *et al*. 2004).

Biofertilzers are low cost, environmentally safe and non bulky agricultural inputs as a supplementary and complementary factor to mineral nutrition (Sahai, 2004). Plant growth promoting rhizobacteria (PGPR) affect plant growth through different mechanisms like their ability to fix atmospheric nitrogen fixation and production of plant growth regulators (PGRs). Plant growth regulators (PGRs) are one of the major constituents through which PGPR affect the plant growth and development (Arshad and Frankenberger, 1998). In contemporary agriculture use of PGPR to improve crop productivity is apprehended to be a rising development in the stores (Pal *et al.,* 2000). Rhizobium strains enhance nodulation in the host plant component. It is an attempt to increase nitrogen fixation and the yield at all the sites of harsh climate. Therefore, it is possible to increase nodulation causing improvement in yield from marginal lands by inoculation with rhizobium (Aslam *et al.,* 2001).

According to the estimates 9 4% farmers use NPK fertilizers 32.6 % farmers use FYM, 2.3% crop residues, 1.6 % micronutrient and less than 1% use biofertlizers. Poultry manure is gaining popularity due to expanding poultry industry in Pakistan, it is a rich source of plant nutrients may be good alternative source for enhancing soil fertility and organic matter. Poultry manure available in the country can contribute101, 58 and 26 thousand tones of N, P and

K respectively (Bari, 2003). Poultry manure is low-priced source of both macro nutrients and micronutrient and improve soil properties and faunal activity (Ghose *et al.*, 2004). Organic fertilizers has been a valuable source of nutrients for crop growth for many years and usually applied based on the N crop requirements (Qian *et al.*, 2004). According to Ano and Agwu, (2005), poultry manure is categorized better organic manure compared to rest of organic materials. However, this manure is under utilized across the country and needs to be explored for its impact in crop production.

Maize (*Zea mays* L.) remains at third position among the cereals after rice and wheat across the globe. Maize is widely grown cereal and is categorized the primary staple food in many developing countries. Maize has a high yield potential and is suited to various climatic zones. At present in Pakistan maize occupies third position after wheat and rice and 98% of the crop is grown in Punjab and KPK with average annual grain production of 4.04 million tones and average yield of 3.62 tones ha^{-1} (Govt. of Pakistan, 2009). In Pakistan the potential of crop is not being exploited satisfactorily due to a number of constraints. Soaring outlay of crop husbandry, diminishing soil fertility, appalling environment and public health are important reasons for use of organic manures, bio-fertilizers. Therefore, a study was devised to evaluate agronomic implications and economic feasibility of maize under different fertility treatments.

MATERIALS AND METHODS

The trial outlined below was conducted under rainfed conditions for two years (2007 and 2008-09) in the experimental area of National Agriculture Research Center (NARC) Islamabad. The metrological data for 2007 and 2008 is presented in Fig.1. and Fig.2. The site lies in a subtropical, sub humid continental highland climatic zone characterized by long summers and cold winters. Soil of the area was inceptisol and loess in nature, slightly alkaline with pH 8.2 having low organic matter (0.5 %). The mean annual rainfall is 1000 mm, 70% of which is received during summer monsoons while rest of 30 % is distributed remaining part of the year (Sultani *et al.*, 2007). Different soil properties like soil pH, organic matter, nitrate nitrogen, extractable potassium and available P by using standard laboratory methods. Salicylic acid method was used for determination of NO_3- Nitrogen (Vendrell and Zupancic, 1990). Available phosphorus was determined by Olsen and Sommers (1982) and soil pH (Mc Lean, 1982) method. Organic matter was determined by using Walkely and Black (1947) method.

Maize was tested to five fertility treatments (control; inoculation of maize seed with plant growth promoting rhizobacteria (PGPR) + PK (80-60 kg ha^{-1}), (120-80-60 NPK kg ha^{-1}); poultry manure at the rate of 15 t ha^{-1}, and half poultry manure (7.5 t ha^{-1}) + half PK (40-30 kg ha^{-1}) + inoculation with PGPR.. The biozote containing PGPR was taken from soil biology laboratory NARC, Islamabad. The trial was laid out in strip block design with three replications. The cropping systems were kept in vertical blocks and fertility treatments in horizontal blocks. Wheat was planted on November 11, 2007 and November 5, 2008 in winter.

The data obtained was compared and analyzed for yield, input cost and output costs. Data were analyzed using descriptive and inferential statistics, partial budgeting, Dominance analysis, Marginal Analysis and Analysis using Residual Analysis recommended by International Maize and Wheat Improvement Center (CIMMYT 1988, Madan *et al.*, 2007, Shah *et al.*, 2009).

Partial budget analysis was done as follows.
Gross field benefits were calculated as (GB_f).

$$GB_f = P_f \times Y_{adj}$$

Where,
GB_f = gross field benefits
P_f = field price
Y_{adj} = adjusted yield
Net benefits were calculated as

$$NB = GB_f - TCV$$

Where,
NB = net benefit
TCV = total cost that vary

Dominance analysis was carried out by listing the treatments with higher cost that vary (CIMMYT, 1988).

The MRR tells what farmers can expect gain from their investment when they decide to change from one practice to another. It was calculated by following formula:

$$MRR = \frac{\partial NB}{\partial TCV} \times 100$$

Where,
∂ NB = change in net benefit
∂ TCV = change in total cost that vary

The conclusions of a marginal analysis can be checked by using the concept of "residuals." Residuals (as the term is used here) were calculated by subtracting the return that farmers required (the minimum rate of return multiplied by the total costs that vary) from the net benefits. Of course this residual is not the profit, and it is the comparison between the residuals, rather than their absolute value, that was of interest. The treatment with highest value of residual was recommended in this study.

Data thus recorded on various aspects were subjected to statistical analysis and treatment means was compared using Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez1984) by employing STAT package (Freed and Eisensmith. 1986)

RESULTS AND DISCUSSION

The analysis of variance for grain yield of maize varied significantly by different fertility treatments. Year effect was significant in response to different fertility treatments. (Table 1). Half poultry manure + half PK + inoculation with plant growth promoting rhizobacteria (PGPR) treated plots out yielded (4858 kg ha^{-1}) in comparison to control (2761 kg ha^{-1}) and other treatments. The maize grain yield with sole poultry manure (PM) incorporated was statistically at par with treatments where only NPK and PK + PGPR in combination were applied.

Maximum grain yield of wheat (2913.09 kg ha^{-1}) was recorded in plots previously treated with sole poultry manure @15 t ha^{-1} followed by half poultry manure + half PK + inoculation. NPK and PK + inoculation showed statistically similar yields. Lowest grain yield was observed in control plots (Table 2). The highest grain yield obtained after poultry manure was attributed to balance supply of nutrients from poultry manure which improved yield components that contributed to final yield.

Table 1. Agronomic yield (kg. ha^{-1}) of maize under different fertility treatments.

Fertility protocols	2007	2008	2-Year mean
Control	3277	2245	2761 D
PGPR + PK	4620	3376	3998 C
NPK	5088	3483	4286 B
Poultry manure (PM)	4835	3383	4109 BC
1/2 PM + 1/2 PK+ PGPR	5628	4087	4858 A
LSD			244.00
Mean over years	4690 A	3315 B	

Means sharing a common letter in a column or a row did not differ significantly at 5 % probability level

Table 2. Agronomic yield (kg. ha^{-1}) of wheat under different fertility treatments.

Fertility protocols	2007	2008	2-Year mean
Control	2656.42	2629.67	2643.04 B
PGPR + PK	2890.08	2870.93	2880.51 A
NPK	2779.46	2752.95	2766.21 AB
Poultry manure (PM)	2902.22	2923.95	2913.09 A
1/2 PM + 1/2 PK+ PGPR	2785.21	2825.00	2805.11 A
LSD			151.40
Mean over years	2802.678	2800.5	

Means sharing a common letter in a column or a row did not differ significantly at 5 % probability level

Table 3. Partial budget analysis of sole maize cropping systems under different fertility treatment with wheat in succession.

Partial Budget Analysis					
	T1	T2	T3	T4	T5
Dose of Inoculation (kg/ha)	-	1	-	-	1
Field Price (Rs.)		100	100	100	100
Cost of Inoculation(Rs.)		100	-	-	100
Dose of PK (kg/ha)		140			70
Field Price of PK (Rs.)		56.057			56.057
Cost of PK (Rs.)		7847.98	-	-	3923.99
Dose of NPK(kg/ha)			260		
Field Price of NPK Rs./kg			42.18		
Cost of NPK (Rs.)			10967.996	-	-
Dose of PM(tones/ha)				15	7.5
Field Price of PM (Rs.)				666.66	666.66
Cost of PM (Rs.)				10000	5000
Application Cost of Nutrients (Rs.)	-	96.7	98.8	225	185.85
Seed Rate of Maize(kg/ha)	25	25	25	25	25
Price of Seed (Rs.)	35	35	35	35	35
Cost of Seed Maize (Rs.)	875	875	875	875	875
Sowing Cost(Rs./ha)	300	301	302	303	304
Total Cost That Vary (Rs.)	1175.00	9220.68	12243.79	11403.00	10388.84
Yield Maize (kg/ha)	2761	3998	4286	4109	4858
Yield Adjusted (kg/ha)	2208.80	3198.40	3428.80	3287.20	3886.40
Output Price(Rs./kg)	11	11	11	11	11
Gross Field Benefits from maize (Rs./kg)	24296.80	35182.40	37716.80	36159.20	42750.40
Net Benefit from maize(Rs./kg)	2643	2881	2766	2913	2805
Yield Adjusted	2114.40	2304.80	2212.80	2330.40	2244.00
Output Price Rs./Kg	20.52	20.52	20.52	20.52	20.52
Benefit fromWheat'	43398.06	47306.02	45417.72	47831.46	46058.1
Gross Field Benefits	67694.86	82488.42	83134.52	83990.66	88808.5
Net benefits	66519.86	73267.74	70890.724	72587.66	78419.66
Dominance analysis	T1	T2	T5	T4	T3
TCV	1175	9220.68	10388.8	11403	12243.8
Net benefits	66519.86	73267.74	78419.66	72587.66	70890.72
Dominated treatments		6747.88	5151.92	-5832 D	-1696 D
Marginal Analysis	T1	T2	T5	T4	T3
Marginal Cost		8045.68	1168.16		
Marginal Net Benefits		6747.88	5151.92		
MRR (%)		83.87	441.03		
Analysis using Residuals	65344.86	64047.06	68030.82		

Generally, combined use of chemical fertilizers, poultry manure and biofertilizers displayed an increasing trend for grain yield of maize followed by NPK application. Since animal manures have the dual role of improving soil structure and enhancing soil nutrient status. Poultry manure application reduced the bulk density, enhanced porosity and moisture content. Secondly, manure enhanced soil organic matter and soil nutrients which were released slowly and steadily and efficiently utilized during latter growing stages of maize as evidenced post harvest analysis of soil. The highest grain yield obtained was partly attributable to increase in moisture regime in root zone and partly due to inorganic fertilizer because nutrients were released from chemical fertilizers and maize was able to utilize it for its growth, supplemented by essential nutrients released from decomposition of added manure. PGPR facilitate directly or indirectly rooting and growth of plants Mayak *et al.* (1999). Results are in conformation with findings of Shata *et al.* 2007; Sial *et al.* 2007; Rehman *et al.* 2008; Adeniyan and Ojeniyi, 2005) who reported that application of biofertilizers and organic manure improved maize grain yield. Busari *et al.* (2008) concluded that the combined application of PM, lime and NPK fertilizer was the most efficient in raising the soil total N, available P and exchangeable cation concentrations. Kumar *et al.* (2008) reported that growth parameters, yield attributes, grain yield, maize grain equivalent yield and total N uptake by maize increased significantly with increasing N rate in combination with PGPR + organic manure. Likewise, Ayoola, and Adeniyan. (2006) reported that application of NPK and poultry manure in combination significantly increased grain yield of maize gave the highest values for other parameters investigated. Likwise, Ayoola and Makinde (2007) investigated that complementary application of reduced rates of 2.5 tons ha of manure with 400 kg of NPK 15-15-15 fertilizer ha^{-1}, gave comparable yields as sole inorganic fertilizer application. The results also were also in consistent with the findings of Ibeauchi, *et al.*,(2007) who elucidated that combined application of NPK and PM gave significantly higher maize grain yield, dry matter and leaf area. On an average, the maize gave 27.00 % more yield in 2007 than 2008. Higher grain yield in 2007 is attributed to favorable climatic conditions prevailed during growing season as 39.77% more rainfall received in 2007 than 2008 as given in Figures 1and 2.

Table 4. Post harvest soil analysis 2007.

Fertility treatment	**pH**	**NO_3N ppm**	**P ppm**	**K ppm**	**O.M %**
Control	8.25 (0.0)	3.49 (-9.35)	5.85 (-13.33)	58.31 (-21.53)	0.58 (-7.94)
PGPR + PK	8.25 (0.0)	3.62 (-5.97)	6.27 (-7.11)	62.24 (-16.24)	0.61 (-3.17)
NPK	8.25 (0.0)	3.61 (-6.23)	6.23 (-7.70)	62.24 (-16.24)	0.61 (-3.17)
PM	8.26(+0.1)	3.52 (-8.57)	7.21 (+6.81)	67.58(-9.06)	0.66 (+4.76)
½ PM + ½ PK+ PGPR	8.25 (0.0)	3.53 (-8.31)	7.15 (+5.92)	66.15(-10.98)	0.66 (+3.17)
Original values	8.25	3.85	6.75	74.31	0.63

Table 5. Post harvest soil analysis 2008.

Fertility treatments	**pH**	**NO_3N ppm**	**P ppm**	**K ppm**	**O.M %**
Control	8.26 (0.0)	3.42 (-9.76)	5.64 (-15.95)	57.32 (-20.98)	0.61 (-6.15)
PGPR + PK	8.26 (0.0)	3.48 (-8.18)	6.12 (-8.79)	65.16 (-10.17)	0.63 (-3.08)
NPK	8.26 (0.0)	3.54 (-6.60)	6.01 (-10.43)	63.76 (-12.10)	0.62 (-4.62)
PM	8.27(+0.1)	3.94 (+3.96)	7.20 (+7.60)	71.58 (-1.13)	0.71 (+9.23)
½ PM + ½ PK +PGPR	8.26 (0.0)	3.86 (+1.85)	7.13 (+6.25)	71.43 (-4.17)	0.69 (+6.15)
Original values	8.26	3.79	6.71	72.54	0.65

Bodruzzaman, *et al*. (2002) reported significant increase in yields of wheat after residual effect of poultry manure. Secondly, poultry manure application not only supplied residual nutrients for the following crop but also reduced the bulk density of soil. Mbah and Onweremadu (2009) concluded that on the average, poultry droppings gave the highest grain yield by improving aggregate stability and reducing bulk density indicating that these parameters contributed to final grain yield. The minimum wheat yield after non legume maize was due to the fact that maize being an aggressive feeder depleted the nutrients from soil and reduced supply of plant nutrients in the control plots which were already deficient in nutrients. It seems logical, that subsequent wheat would give minimum yield. The result of the partial budget analysis indicated maize with half poultry manure + half PK + PGPR with wheat in sequence accrued the highest net benefit of Rs. 78419.66 ha^{-1} .This was followed by maize treated with PK + PGPR with wheat in succession gave the net benefit of Rs. 73267.74 (Table 3).

Better understanding of how farmers' objectives change over time with higher returns and increased market surplus appears to be a necessary input into more economic evaluation of new technology

A treatment was dominated, denoted by "D" if its variable cost was higher but net benefit was lower than the preceding treatment. Therefore, dominance analysis was carried out to proceed further for marginal analysis and to find out the most economical treatment. Therefore, all the treatments were arranged in their ascending order of total variable cost. According to dominance analysis sole poultry manure and NPK were eliminated against the backdrop that no rational farmer will choose a farming practice, which has a comparatively lower benefit at higher cost. Therefore, these treatments were eliminated for further consideration in calculating Marginal Rate of Return (MRR) (Table 3).

Perusal of data from Table 3 revealed that highest MRR value of 441.03 % was observed for maize treated with half poultry manure + half PK + PGPR with wheat in sequence resulted in followed by PK + PGPR treatment with 83.87 % of MRR value (Table 3). This implied that for every 100 rupees invested in maize production, the farmers can expect to recover an additional amount of Rs. 441.03 with half poultry manure + half PK + PGPR treatment while Rs. 83.87 in PK + PGPR. The results as presented gives indication that farmers stand to gain in return for their investment when they decided to change from one practice to other having MRR higher than minimum rate of return (100%) in two years. Results were in conformation to the findings made by Arif and Malik (2009).

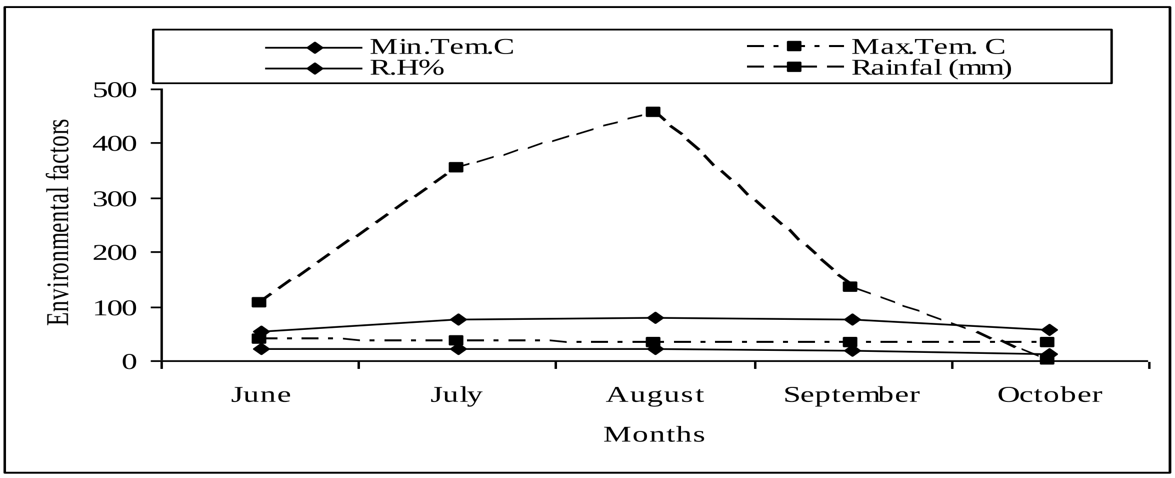

Fig.1. Metrological data during growing season 2007.

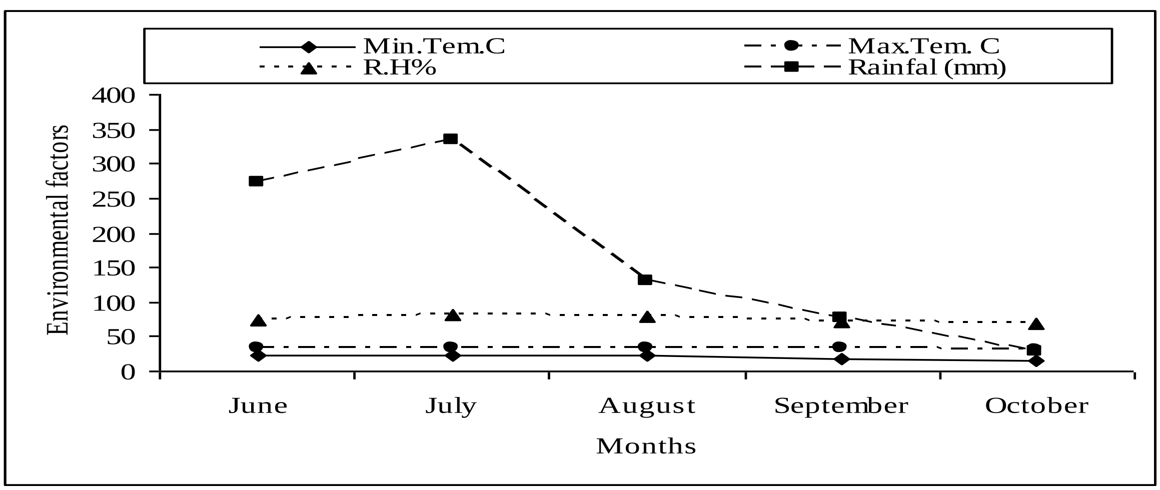

Fig.2. Metrological data during growing season 2008.

The results of the marginal analysis were supported with the Analysis Using Residual as the farmers are mostly interested in the treatment with highest residual value. The results of the analysis using residuals exhibited similar picture, as the maximum residual value was recorded with half poultry manure + half PK + inoculation with PGPR amended plots. Hence, this treatment can be recommended for the farmers, to maximize financial returns of their investment for maize production (Table 3).

Taking into account soil analysis at the end of experiment it was found that there was an increasing trend of soil pH, nitrate nitrogen, phosphorus, potassium and organic matter in poultry manure amended plots either sole application or in combination with other fertility sources in both years. This might be due to higher calcium content of poultry manure. Maximum depletion of nutrients was observed in control plots (Table 4-5). The favorable increases in soil fertility and improved soil physical condition adduced to PM is consistent with findings of earlier findings that amendment of soil using poultry manure improved soil OM, N, P, K, Ca and Mg (Adeniyan and Ojeniyi, 2005; Adenawoola and Adejoro, 2005). Wenhui *et al.,* (2010) reported that the application of organic manure (OM) and OM + NPK increased soil fertility, soil carbon and modified soil reaction. The higher Ca content of the PM used was probably responsible for increase in the pH of soils with organic manure incorporation have also been related to the addition of basic cations (Melero *et al*., 2007 and Busari *et al.,* 2008).

CONCLUSION

Although in economic terms application of both the chemical fertilizers and poultry manure were not supported, yet complementary application of chemical fertilizers and poultry manure exceeded maize grain yield and achieved the sustainability by improving soil fertility. The combined application of poultry manure with chemical fertilizers and biofertilizers proved to be most promising treatment in terms of profitability and sustainability of the soil.

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