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Improving wheat (*Triticum aestivum* L.) yield and quality by integration of urea with poultry manure

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Abstract

A field experiment was conducted with the objectives to improve nitrogen use efficiency, reduce the cost of production and improve the wheat yield and quality on sustained basis. Trial was conducted following randomized complete block design with split plot arrangement having three replications. In three main plots, randomization of manure was done as no poultry manure application, 1 t ha^{-1} layer poultry manure (N=3.96%, P=1.92%, K=1.5%) and 1 t ha^{-1} broiler poultry manure (N=3.12%, P=1.84%, K=1.5%). In five sub plots, randomization of nitrogen from urea source was done at 0, 25, 50, 75 and 100 kg ha^{-1}. Application of poultry manure (layer or broiler) increased yield components and grain yield significantly. Grain yield, grain crude protein contents, number of fertile tillers, spike length, flag leaf area, fresh weight, dry weight, plant height and number of grains increased with each increasing rate of applied nitrogen however, maximum agronomic nitrogen use efficiency (27.39 kg kg^{-1}), physiological nitrogen use efficiency (41.03 kg kg^{-1}) and 1000-grain weight (37.50 g) were observed in treatment where nitrogen was applied at the rate of 75 kg ha^{-1}. Maximum grain yield and benefit cost ratio were observed where layer poultry manure was applied in integration with 100 kg ha^{-1} nitrogen. However, economic analysis showed that farmers can get maximum benefits (BCR= 2.6) by applying layer poultry manure in integration with 100 kg N ha^{-1}, or by broiler poultry manure application along with 75 kg N ha^{-1} (BCR= 2.5).

Keywords: Wheat, sustainability, integrated nutrient management, nitrogen use efficiency, pollution

Introduction

In modern intensive cropping systems, N fertilizer is intensively used for high yields while use of organic source is ignored (Dinnes *et al*., 2002). Among different factors that affect yield in wheat, fertilizer is the most important factor (Dupont and Altenbach, 2003).

Use of fertilizers particularly nitrogenous fertilizer is increasing at an alarming rate and it will be doubled up to 2050 (Charlis *et al*., 2010). Application of excessive amount of fertilizer increases cost of production along with pollution (Derksen *et al*., 2002). Total demand of urea in Pakistan is 5655 thousand ton and importance of fertilizer can be determined by the fact that 8 kg of grains are produced by per kg of fertilizer applied (Govt. of Pakistan, 2013). Nitrification is an important part of N cycle and any form of nitrogen after applying to soil; converts to NO_3^- form, nitrification and denitrification are simultaneous processes (Nishizawa and Mori, 2001). Excessive use of N fertilizer along with rapid nitrification causes pollution; further synthesis of nitrogen fertilizer is energy consuming process (Subbarao *et al*., 2009).

Agriculture is one of the main anthropogenic activities which influence N cycle more than any other activity (Liu *et al*., 2010). Nitrous oxide emission from agricultural lands contributes 6% in climate change (IPCC, 2010). High nitrogen fertilizer use increases cost of production of wheat as nitrogen fertilizer is one of the costly inputs for wheat production (Campillo *et al*., 2010). It is the need of hour to reduce fertilizer use in wheat to reduce pollution and decrease cost of production (Shrawat *et al*., 2008). Different ways to reduce use of nitrogen fertilizer in wheat are (1) increasing nitrogen use efficiency (NUE) (2) provision of nitrogen through green manuring (3) provision of nitrogen through animal manures and enrichment of manures with other minerals (Reddy *et al*., 2008).

Poultry manure provides nutrients and its use can be preferred as it contains macronutrients in greater amount than other manures (Khaliq *et al*., 2004). Its proper application increases soil and plant nutrient status (Agbede *et al*., 2008) and is beneficial as it enhances soil fertility status, increases soil organic matter, soil biota activities and water holding capacity (Blay *et al*., 2002). Poultry manure contains 3-5% nitrogen; 1.5-3.5% phosphorus, 1.5-3% potassium, considerable amount of micronutrients and its pH is 6-7 (Chastain *et al*., 2001). In cereals, application of poultry manure in integration with urea improves yield components more than other organic manures (Khaliq *et al*.,

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2004). Integration of poultry manure and urea helps to restore degraded soils and is also more economical than sole application of urea (Mondero *et al*., 2004). It has been observed that improving nitrogen use efficiency increases yield, activates low affinity transport system of nitrogen uptake in which passive uptake of nitrogen takes place that results in high yield (Cui *et al*., 2008).

Thus, it can be hypothesized that use of synthetic N fertilizer can be reduced by supplementing with poultry manure. The experiment was conducted to look into nitrogen uptake behavior, economics of nitrogen use and quantity and quality of wheat produce as influenced by different types of poultry manure.

Materials and Methods

The experiment was conducted to evaluate the effect of integration of poultry manure and different nitrogen doses on wheat from urea source. The experiment was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad situated at latitude 31˚ north, longitude 73˚ east and at altitude of 184.4 meter during winter season 2012-13. The experiment comprised of three poultry manure (PM) treatments [no PM application (P_0), application of 1 t ha^{-1} layer PM (P_1), application of 1 t ha^{-1} broiler PM (P_2)] and five nitrogen application rates (0, 25, 50, 75, 100 kg ha^{-1}).

The crop was sown on November 28, 2012 in randomized complete block design (RCBD) with split plot arrangement having three replications. Mixing of poultry manure in the soil was made on November 10, 2012. In three main plots poultry manure was randomized and in five sub plots nitrogen rates were randomized. Net plot size used was 4 m × 1.8 m having eight rows of wheat in each sub plot with row to row distance of 22.5 cm and seed rate used was 100 kg ha^{-1}.

Seed of wheat variety Sehar-2006 was sown with the help of single row hand drill. Soil samples were collected before sowing of crop from experimental area randomly at a depth of 15 and 30 cm with soil auger to determine soil physiochemical properties (Table 1). Chemical analysis of manures was done to quantify different nutrients present in manures (Table 2). Weather data during the whole crop season were recorded and weekly averages of different agro-meteorological parameters are represented graphically (Figure 1). Irrigations were applied at four critical growth stages viz. crown root initiation, tillering, spike initiation and flowering. Same recommended amount of phosphorus and potassium was added in all treatments by using SSP and SOP in all treatments by considering phosphorus and potassium provided by layer and broiler poultry manures. Half of the nitrogen fertilizer according to different treatments and all the phosphate and potash fertilizers were applied as basal dose at the time of sowing. Remaining half of the nitrogen fertilizer was applied with first irrigation. Two hoeing were done in all treatments to control weeds; first after 40 days of sowing and second after 60 days of sowing.

Table 1: Soil characteristics of experimental site

Characteristic	Unit	Value
Organic matter	%	0.72
Total nitrogen	%	0.046
Phosphorus	mg kg^{-1}	13.3
Potassium	mg kg^{-1}	170
pH	-	7.9
EC_e	dS m^{-1}	1.78
Soil textural class	-	Loam
Saturation	%	33

Table 2: Quantitative analysis of poultry manure for nutrients (NPK)

Manure	N (%)	P (%)	K (%)
Layer poultry manure	3.96	1.92	1.5
Broiler poultry manure	3.12	1.84	1.5

Observations

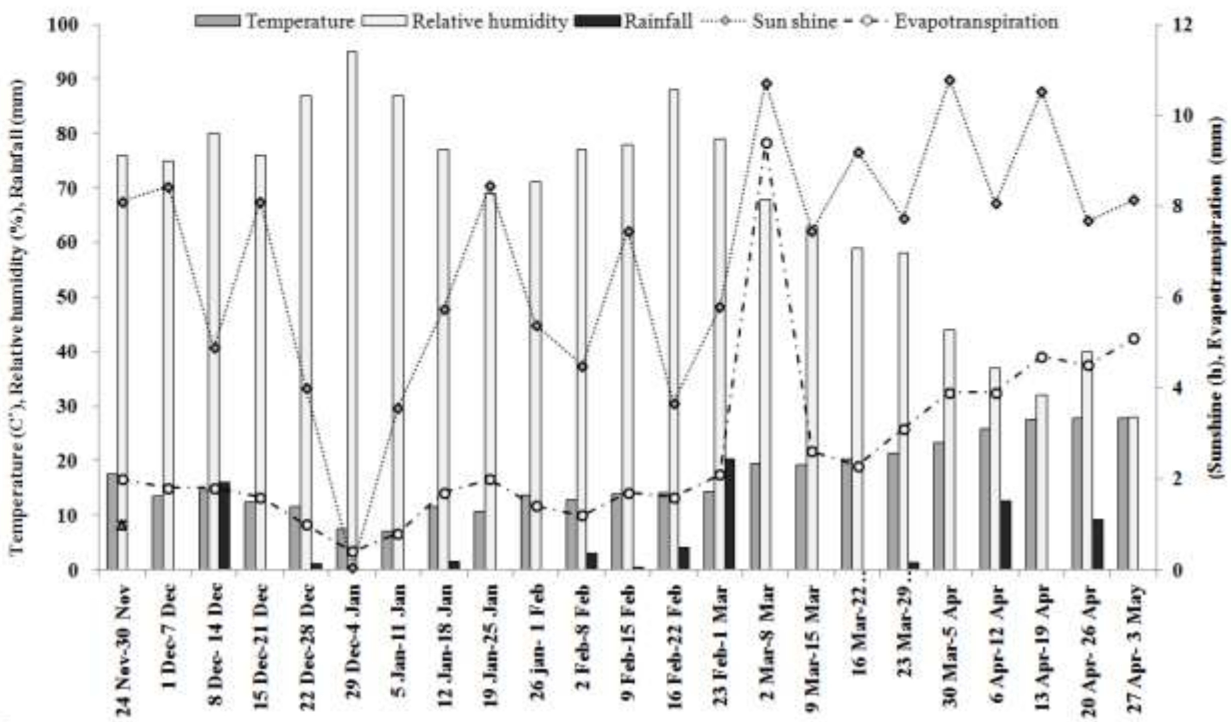
Flag leaf fresh weight was recorded by harvesting flag leaves of 30 cm row length and converted into m^{-2} by unitary method. Thereafter sub sample of 5 g fresh leaves was taken from each treatment and recorded oven dried weight. Similarly, leaf area of 5 g sub samples of flag leaves was measured by using leaf area meter (CI-202). Recorded leaf area and dry weight of sub samples of flag leaves were converted into m^{-2} by using their already calculated respective fresh weights.

Ten plants were randomly selected from each experimental unit at maturity and height was measured with the help of meter rod from ground surface to the tip of spike and averaged; similarly ten spikes were randomly selected from each treatment and spike length was measured with scale and averaged. Number of grains of ten spikes was manually counted and averaged. Three places of 30 cm row length were randomly selected in each treatment at maturity; number of productive tillers in these selected lines was counted and converted into tillers for one square meter area by unitary method. The grain yield of each plot was weighed after threshing and was converted into tons per hectare.

Determination of nitrogen in poultry manure and grains

Nitrogen in grains and manure samples was determined according to Kjeldhal method and distilled by Markam Still apparatus using concentrated sulphuric acid as reagent (Ryan *et al*., 2001). Digestion mixture used was K_2SO_4 + $FeSO_4$ + $CuSO_4$ in 85: 10: 5 (g), respectively. Other reagents used were 40% sodium hydro oxide (NaOH), 0.1 g methyl red as indicator and standardized sulphuric acid solution of concentration 0.1 normal.

Figure 1: Weekly weather data during crop period



Grain crude protein contents

Grain crude protein contents in percent were calculated as % Crude protein = % N × 6.25, where: 6.25 = Constant for wheat (Bremner and Mulvaney, 1982).

Phosphorus (P) and potassium (K) determination in poultry manure

Samples were digested by using wet digestion method using nitric acid-per chloric acid (HNO_3-$HClO_4$) as reagent (Jackson, 1960) and absorbance was recorded at 410 nm, using spectrophotometer for phosphorus (P) determination while potassium (K) was analyzed using flame photometer.

Agronomic and physiological nitrogen use efficiency (kg kg^{-1})

Agronomic and physiological nitrogen use efficiency (kg kg^{-1}) was calculated by using formulae (Anonymous, 1994).

ANUE (kg kg^{-1}) = [Yield of F treatment (kg) – Yield of C treatment (kg)] / [Nitrogen applied]

PNUE (kg kg^{-1}) = [Yield of F treatment (kg) – Yield of C treatment (kg)] / [N uptake of F treatment (kg ha^{-1}) – N uptake of C treatment (kg ha^{-1})]

Where:
F = Fertilized
C = Control

Economic analysis was carried out using methodology described by CIMMYT (1988).

Statistical analysis

The data were analyzed statistically using the Fisher's analysis of variance technique (Steel *et al*., 1997) and treatment means were compared by using least significant difference (LSD) test at 5% probability level.

Results

Flag leaf fresh weight, flag leaf dry weight and flag leaf area were significantly affected by poultry manure (PM) and nitrogen (N) rate (Table 3). Maximum values of all these parameters were observed with layer PM application. However, layer poultry manure was closely followed by broiler PM application (Table 4). Among nitrogen rates, highest flag leaf fresh weight (462.7 g m^{-2}), flag leaf dry weight (159.5 g m^{-2}) and flag leaf area (2.4 m^2 m^{-2}) were recorded with 100 kg ha^{-1} nitrogen followed by 75 kg ha^{-1} nitrogen for flag leaf fresh weight and flag leaf area (Table 4).

fertilizers makes an instant supply of nutrients, in this regard; increasing levels of nitrogen increased plant height and fertile tillers of wheat plant so, lowest plant height (97.8 cm) and number of fertile tillers (181.2) were recorded in plots where no nitrogen was applied (Table 4).

Table 3: Analysis of variance for different growth and yield parameters of wheat

SOV	**MSS Replication**	**MSS (PM)**	**MSS Error 1**	**MSS Nitrogen (N)**	**MSS PM × N**	**MSS Error 2**
DF	2	2	4	4	8	24
Flag leaf fresh weight (g m^{-2})	2919.0	86911.5**	884.3	11113.8**	4046.3^{NS}	2346.9
Flag leaf dry weight (g m^{-2})	895.3	5834.9**	153.6	4220.9**	126.4^{NS}	207.3
Flag leaf area (m^2 m^{-2})	0.08	2.72**	0.05	0.55**	0.02^{NS}	0.09
Plant height (cm)	6.35	3.76^{NS}	23.13	154.73*	2.64^{NS}	39.57
Spike length (cm)	30.98	40.54**	0.92	14.95*	0.35^{NS}	5.05
Number of fertile tillers (m^{-2})	30	739^{NS}	893	20925**	402^{NS}	811
Number of grains per spike	0.09	163.82**	4.06	52.11*	2.63^{NS}	16.96
1000-grain weight (g)	1.23	61.61*	3.73	26.55*	0.68^{NS}	9.41
Grain yield (t ha^{-1})	0.16	2.20**	0.04	8.40**	0.15^{NS}	0.09
Grain crude protein contents (%)	0.07	5.50**	0.26	22.60**	0.31^{NS}	0.31
Agronomic nitrogen use efficiency (kg kg^{-1})	63.41	241.22*	33.53	1073.63**	22.39^{NS}	32.54
Physiological nitrogen use efficiency (kg kg^{-1})	37.5	131.6*	12.9	2621.1**	10.7^{NS}	16.8

Where: *= Significant; **= Highly significant, NS= Non-significant; MSS= Mean sum of square; PM = Poultry manure; SOV= Source of variation; DF= Degree of freedom; N= Nitrogen

Table 4: Effect of poultry manure and nitrogen rate on flag leaf, plant height, spike length and number of fertile tillers of wheat

Poultry manure (PM)	**Flag leaf fresh weight (g m^{-2})**	**Flag leaf dry weight (g m^{-2})**	**Flag leaf area (m^2 m^{-2})**	**Plant height (cm)**	**Spike length (cm)**	**No. of fertile tillers (m^{-2})**
No poultry manure (PM)	332.2 B	106.2 B	1.6 B	102.9	16.2 B	239.3
Layer PM	467.6 A	143.5 A	2.4 A	103.9	19.2 A	252.9
Broiler PM	460.2 A	136.1 A	2.2 A	103.4	18.9 A	248.9
LSD (5% probability)	30.15	12.56	0.21	NS	0.97	NS
Nitrogen rate (kg ha^{-1})						
0	379.4 B	106.0 C	1.8 B	97.8 B	16.4 B	181.2 D
25	390.8 B	110.1 C	1.9 B	101.2 B	17.2 B	215.7 C
50	422.3 AB	131.1 B	2.1 B	103.5 AB	18.2 AB	264.5 B
75	444.8 A	136.4 B	2.2 AB	106.1 AB	19.2 AB	271.0 B
100	462.7 A	159.5 A	2.4 A	108.5 A	19.5 A	302.8 A
LSD (5% probability)	47.13	14.01	0.30	6.12	2.19	27.71

Means not sharing common letters are statistically different at 5% level of probability; NS= Non-significant

Poultry manure application did not affect number of fertile tillers and plant height (Table 4). This may be due to delayed availability of nutrients from poultry manure after adding in soil, while nitrogen rates did show significant effects (Table 3) as nitrogen application from synthetic

Application of poultry manure and different nitrogen rates increased spike length significantly (Table 3). For poultry manure, no difference was observed between two manures while layer poultry manure gave more promising results than broiler poultry manure. Among different nitrogen rates, nitrogen at 100 kg ha^{-1} produced more spike length (19.5 cm) and it was statistically similar with 75 and 50 kg ha^{-1} nitrogen (Table 4).

Table 5: Effect of poultry manure and nitrogen rate on grains per spike, 1000-grain weight, grain yield, grain protein, agronomic and physiological nitrogen use efficiency in wheat

Poultry manure (PM)	No. of grains per spike	1000-grain weight (g)	Grain yield (t ha^{-1})	Grain crude protein contents (%)	Agronomic nitrogen use efficiency (kg kg^{-1})	Physiological nitrogen use efficiency (kg kg^{-1})
No PM	43.3 C	32.4 B	3.0 C	10.0 B	13.9 B	26.4 B
Layer PM	49.9 A	36.0 A	3.7 A	11.1 A	21.5 A	32.0 A
Broiler PM	47.5 B	35.7 A	3.5 B	10.9 A	19.9 A	31.1 A
LSD (5% probability)	2.04	1.96	0.21	0.52	5.87	3.65
Nitrogen rate (kg ha^{-1})						
0	43.7 B	33.8 B	2.2 D	8.3 E	0 C	0 C
25	46.0 B	33.7 B	2.7 C	10.2 D	17.7 B	31.4 B
50	46.6 AB	35.1 AB	3.5 B	10.9 C	25.1 A	39.3 A
75	48.1 AB	37.5 A	4.3 A	11.6 B	27.4 A	41.0 A
100	50.1 A	33.3 B	4.4 A	12.5 A	21.9 AB	37.4 A
LSD (5% probability)	4.01	2.98	0.29	0.54	5.55	3.99

Means not sharing common letters are statistically different at 5% level of probability

Table 6: Economic analysis of various treatments combinations (PM × N)

Treatment	P_0N_0	P_0N_1	P_0N_2	P_0N_3	P_0N_4
Net Income (Rs. ha^{-1})	22880	29918	42920	59440	62690
BCR	1.4	1.5	1.7	2.0	2.1
Treatments	P_1N_0	P_1N_1	P_1N_2	P_1N_3	P_1N_4
Net Income (Rs. ha^{-1})	84880	44668	67620	71440	98490
BCR	1.7	1.8	2.2	2.2	2.6
Treatments	P_2N_0	P_2N_1	P_2N_2	P_2N_3	P_2N_4
Net Income (Rs. ha^{-1})	34930	41518	63570	88090	87740
BCR	1.7	1.7	2.1	2.5	2.4

Cost of poultry manure= Rupee 250 per ton, P_0= No poultry manure, P_1= 1 t ha^{-1} Layer poultry manure P_2= 1 t ha^{-1} Broiler poultry manure, N_0= 0 kg ha^{-1}, N_1= 25 kg ha^{-1}, N_2= 50 kg ha^{-1}, N_3= 75 kg ha^{-1}, N_4= 100 kg ha^{-1}

Statistically different number of grains per spike and grain yield was observed in all main plots (Table 3). For layer poultry manure, significantly higher number of grains per spike (49.9) and grain yield (3.7 t ha^{-1}) was recorded. Nitrogen at 100 kg ha^{-1} produced highest number of grains per spike (50.1) and grain yield (4.4 t ha^{-1}). Nitrogen at 100 kg ha^{-1} and 75 kg ha^{-1} showed no statistical differences for grain yield. Application of poultry manure significantly enhanced 1000-grain weight than control but different types of poultry manures showed no effect on 1000-grain weight and were statistically similar (Table 5).

Application of poultry manure enhanced grain crude protein contents, agronomic nitrogen use efficiency (ANUE) and physiological nitrogen use efficiency (PNUE) over control; although both types of PMs were statistically similar, performance of layer poultry manure was better than broiler PM in this regard (Table 5). Application of nitrogen at 100 kg ha^{-1} increased grain crude protein contents (12.5%) significantly than other treatments while application of 75 kg ha^{-1} nitrogen gave highest ANUE (27.4 kg kg^{-1}) and PNUE (41.0 kg kg^{-1}), being at par with the nitrogen application rates of 50 and 100 kg ha^{-1} (Table 5). Maximum benefit cost ratio (2.6) was obtained from plots where 100 kg ha^{-1} nitrogen was applied in integration with layer poultry manure (1 t ha^{-1}) as mentioned in Table 6.

Discussion

The challenge for agriculture in the next decade will be to feed increasing masses together with preservation of environment (Weinkauf, 2008). Integration of poultry manure with inorganic fertilizers can be done to improve nitrogen use efficiency, reduce cost of production and improve wheat yield and quality on sustained basis.

Increase of flag leaf area is due to enhanced nitrogen availability for cell elongation, growth, photosynthesis and metabolism and accumulation of nitrogen along with other assimilates in flag leaf and culm (Haberle *et al*., 2008). When there is increased availability of nitrogen, allocation of nitrogen to flag leaf is increased causing its rapid growth while dry matter accumulation makes it stay green for longer period of time (Gaju *et al*., 2014). Maintenance of high availability of nitrogen throughout life cycle of plant is required to establish plant photosynthetic capacity and nitrogen availability throughout plant life can be maintained by integration of synthetic fertilizers with manures (Bulut *et al*., 2013).

Increase in spike length with increasing nitrogen availability in presence of manures can be attributed to increase partitioning of nitrogen for growth of ridges at double ridge stage and nitrogen then plays role in cell division (Baresel *et al*., 2008). Increased availability of nitrogen up to maturity, due to reduced losses, plays role in establishment of sink capacity (Mader *et al*., 2007)**.** Moreover, about 70-75% of wheat endosperm contains starch and nitrogen availability is the most important environmental factor that affects starch composition. Sufficient nitrogen increased A-type starch granule accumulation (Kindred *et al*., 2008). A-type starch granules are higher in amylose contents; increase of amylose made grain more round and bold for greater starch accumulation (Wei *et al*., 2010). Increase in wheat grain yield with PM and N application can be attributed to more number of tillers and grains (Pedro *et al*., 2011) and more grain weight (Masoni *et al*., 2007).

At higher nitrogen application rate supply is more and influx transporter causes more nitrogen active uptake and also increases activity of efflux carriers which creates more demand for nitrate uptake, it increases expression of ammonium and nitrate transporters which results in greater agronomic nitrogen use efficiency (ANUE). Decrease of ANUE after certain level of nitrogen is due to nitrogen losses that are more at higher nitrogen rate and less nitrogen availability decreases expression of ammonium transporters, nitrate transporters, influx and efflux carriers which decrease nitrogen assimilation and ANUE (Subbarao *et al*., 2009). Increase of ANUE by application of poultry manure can be attributed to reduced losses of nitrogen which increases uptake of nitrogen.

Integration of synthetic nitrogen fertilizers with manures maintains higher nitrogen availability in rhizosphere which activates low affinity transport system in which nitrogen uptake is mostly passive; plant uses no energy and PNUE of plant increases (Ibrahim, 2008). Furthermore, partitioning of nitrogen towards spike and grain becomes priority at appropriate nitrogen supply (Pask *et al*., 2012). Grain acts as most important sink for nitrogen at senescence; increased allocation of nitrogen to grains improves nitrogen contents of grain which improves PNUE (Gaju *et al*., 2014).

In the present scenario of intensive agriculture, importance of manure application is increasing to get high yield on sustainable basis (Ekop *et al*., 2011). Application of inorganic fertilizers in integration with manures reduces soil pH and enhances soil microbial activities and ultimately improves yield components and grain protein contents (Aslam *et al*., 2010).

Conclusion

Broiler poultry manure was less effective than layer poultry manure as nitrogen and phosphorus contents of layer poultry manure are higher than broiler poultry manure. Application of 100 kg ha^{-1} nitrogen in integration with layer poultry manure gave more benefit cost ratio (BCR) (2.6) but still broiler poultry manure can be used with 75 kg N ha^{-1} (BCR= 2.4) to reduce dependence on inorganic nitrogen, thus saving environment and energy.

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