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Full Length Research Paper

A study of current farm practices about poultry manure and inorganic fertilizer utilization in Niger

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Low soil fertility and insufficient rainfall are the major constraints limiting pearl millet yields in Niger. Farmers use organic amendments from diverse sources as an integral component for meeting crop nutritional needs. In the Maradi region of Niger, a private poultry farm produces tons of poultry manure annually, much of which is applied to pearl millet in farmer's fields. A field survey was conducted in 2004 to assess farmers' perceptions, use and management of poultry manure. The survey results indicate that the poultry manure application rates varied from 1600 to 2300 kg ha^{-1}. However, the farmers were concerned about nutrient levels present, the best application procedure, and the crop response to applications of poultry manure in combination with inorganic fertilizer. On-farm studies conducted in 2004 through 2006 indicated that application of 2 t ha^{-1} poultry manure increased pearl millet grain yield by 56% and stover yield by 53%. Poultry manure plus 40 kg ha^{-1} of 15-15-15 (6 kg N ha^{-1} 6kg ha^{-1} P_2O_5 6 kg K_2O ha^{-1}) dry fertilizer increased grain yield by 117% and stover yield by 94%. The cost/value ratio was 3.59 for poultry manure alone and 3.92 when the inorganic fertilizer was added. On-station experiments in 2005 and 2006 examined the effects of adding 10, 20 and 30 kg P ha^{-1} to the 2 t ha^{-1} of poultry manure, no further increase in yield was found, likely due to relatively high P concentration in the poultry manure. These studies indicate that 2 t ha^{-1} of poultry manure is recommended for pearl millet production. Further research on the application of N fertilizer in combination with poultry manure is merited.

Key words: Chemical fertilizer, nitrogen, phosphorus, on-farm research.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is widely grown in Niger due to adaptation to low rainfall in tropical semi-arid to arid climates; in these areas, soils are predo-minately sandy with low organic matter and nutrient status, rainfall is limited and erratic, air and soil temperatures are high, and the growing season is short and varies greatly across years. Supplying needed nutrients is usually the limiting factor in pearl millet production (Bationo and Mokwunye, 1991), and research indicates that nutrient removal is greater than nutrient additions (Bagayoko et al., 1996; Smalling et al., 1997) in semi-arid West Africa.

Nutrient depletion is complicated by the low inherent nutri-ent status of many soils in Africa, and is a major factor in decreasing agricultural productivity since the 1960's (Sanchez et al., 1997). Agricultural soils in Niger are ge-nerally acid (pH 4.5 to 7) with low organic matter content (0.15 to 0.7%), available phosphorus (0.4 to 3.4 ppm), and nitrogen. Phosphorus is generally considered to be the most limiting nutrient, closely followed by N (Bationo and Mokwunye 1991). The per capita arable land is limi-ted due to high population growth rate, and the traditional use of fallow is not a viable method to increase soil

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nutrient levels (Schlecht and Buerkert, 2004). The level of inorganic fertilizer use is very low due to cost, availability, lack of credit, and low grain prices resulting from limited market options (Kadi et al., 1990). Efficient use of both organic and inorganic fertilizer is required to optimize crop yield to meet the food needs of a growing population and minimize soil degradation (Bationo and Buerkert, 2001; Palm et al., 1997; Pieri 1989). Maman et al. (2000) reported that pearl millet grain and stover yields were increased with application of a combination of cattle manure and P fertilizer.

Fertilizer point applications at planting (microdose or *zaï*) or to young seedling can reduce phosphorus fixation in the soil, and promote stand establishment and early season growth which includes increase in root and shoot growth, and enhance infection with vesicular arbuscular mycorrhizae further increasing nutrient uptake (Bagayoko et al., 2000; Valluru et al., 2010; Fatondji et al., 2001). This resulted in increased grain and stover yields (Bagayoko et al., 2011; Dimes et al., 2003; Muehlig-Versen et al., 2003; Fatondji et al., 2001) and has been widely adopted (Abdoulaye and Sanders, 2005).

Farmers in Niger use crop residues as an integral component of soil fertility management practices. Corralling animals facilitates composting manure and urine for field application to provide nutrients and improve soil physical properties (Bationo and Mokwunye, 1991), but these additives have low nutrient concentrations (Sanchez et al., 1997). The practice is labor intensive and there is inadequate manure supply to meet crop nutrient needs (Giller et al., 1997; Bationo et al., 1998; Fernandez-Rivera et al., 1995). However, Pieri (1989) reported that when sufficient quantity of manure is applied on a continuous basis, it might permit stable intensified crop production.

Poultry production in Niger and throughout West Africa is increasing due to increased demand for eggs and meat, thereby increasing availability of poultry manure. Near Maradi, Niger a private poultry enterprise with more than 25,000 laying hens has been developed, making available large quantities of composted poultry manure with groundnut (*Arachis hypogaea* L.) shells which are used as bedding material. The enterprise started with around 200 layers in 1988 and increased to more than 25,000 hens in 2002. In 2008, the operation extended to provide 7,000 laying hens and 7,000 broilers per week to be sold to small size farms.

Farmers have broadcast applied this poultry manure to fields as a fertilizer source in the past, but have reported crop damage and now apply small amounts near the crop plants, sometimes with a sidedress application of inorganic fertilizer when the crops reach the tillering growth stage. However, research on use of this poultry manure resource had not been conducted. Most of the reported studies on poultry manure use as a nutrient source and to improve soil properties have been conducted in developed countries, but environmental problems have arisen (Mahimairaja et al., 1995; Robinson and Sharpley, 1995; Sharpley, 1996). In Africa, Bakayoko et al. (2009) examined the effects of cattle and poultry manure on the organic matter content and the adsorption complex on unsaturated sandy ferrallitic soils under cassava (*Manihot esculenta* Crantz) cultivation. They reported poultry manure had the greatest content of organic C, N, P, K, Ca and lowest C:N ratio. Studies on the effect of poultry manure on maize (*Zea mays* L.) in the 1500 to 2000 mm rainfall savanna zone of Ghana (Agyenim Boateng et al., 2006) and in the 1000 to 1400 mm rainfall savanna zone of Nigeria (Udom and Bello, 2009) found increased grain yields with its application. Knowledge about the use of poultry manure for pearl millet production in the Sahelian zone with 400 to 600 mm of rainfall is lacking, in Maradi 13°28'N; 07°25'E with: average rainfall of 491±143 mm with range of rainfall between 730 mm and 283 mm; T_{max}: 39.9°C (average 34.8 ± 3.1°C); and T_{min}: 12.8°C (average 19.7 ± 4.4°C) (Sivakumar et al., 1993).

To learn more about use of poultry manure for pearl millet production, a field survey, two on-farm experiments, and one on-station experiment were conducted from 2004 to 2006 in Maradi, Niger. The objectives of this research were to: 1) Characterize the nutrient content of poultry manure in Niger; 2) Document current farmer practices and perceptions about poultry manure use and 3) Determine the pearl millet grain yield response to poultry manure application alone and in combination with inorga-nic fertilizer.

MATERIALS AND METHODS

Preliminary field survey of farmers

A survey was conducted in 2005 with 10 farmers who use poultry manure as part of the soil fertility management practice for pearl millet near the village of Radi, around 5 km from INRAN/Tarna Research station, Maradi, Niger. A questionnaire was development (Table 1) and administered to learn the following: 1) Time, method and rate of manure applied, and crop receiving application; 2) Perception and experience with poultry manure impact on crop productivity and soil improvement and 3) Constraints to poultry manure use.

Eight (8) samples of poultry manure composted with groundnut shells, poultry dung, and cattle manure were randomly collected from fields and analyzed for nutrient content. Total N concentration was determined with Devarda's alloy method (Liao, 1981); P concentration using ascorbic acid and colorimetry (Watanabe and Olsen, 1965), and the exchangeable bases (K, Ca, Mg) were determined by extraction with ammonium acetate and atomic absorption spectrophotometry (Isaac and Kerber 1971).

On-farm experiments in 2004, 2005 and 2006

Farmers in the above survey indicated interest in studying the effects of using poultry manure combined with inorganic fertilizer on pearl millet grain and stover yields, and cost effectiveness. Ten farmers in 2004 and 2005, and six farmers in 2006 who already used this source of poultry manure participated in the on-farm study. All fields were contiguous and had Psammentic Paleustalf soil type with a sandy texture and low N, and low P. Fields had similar cultural practices, thus each farm was considered as a

Table 1. Poultry manure perception and use survey results (n = 10).

Question	Response			
1. Age of interviewed farmers (years)	Minimum**:** 23; Average: 45; Maximum: 65			
2. Years of using poultry manure (years)				
3. Crop species receiving poultry manure	Pearl millet, sorghum, cowpea, groundnut			
4. Effect of this manure on	Soil: improve fertility and quality (100% of the farmers) Crops: increase crop vigor and yield (100% of the farmers)			
5. Comparison with other source of fertilizers (% of opinions)	better	same	less	Don't know
Livestock manure	80%	10%	.	10%
Household waste	80%			20%
Inorganic fertilizer	20%	20%	.	60%
6. Application manure and rate of the poultry	Broadcast	Point		Both (½ – ½)
Method Used	20%	50%		30%
Method Best	10%	80%		10%
Quantity Used (kg ha^{-1})	2040 ± 285	1600 ± 325		2360 ± 485
Satisfaction	100 %	Because good yields obtained		
7. Application time	Pre-planting	At 1st weeding		After thinning
Used	10%	70%		20%
Best	10%	80%		10%
8. Necessity to add inorganic fertilizer	Yes = 20 %	No = 50% (because good yields obtained)		Don't know **=** 30%
9. Do you use inorganic fertilizer?	Yes = 60% (but only on cash crop)			No = 40%
10. Constraints related to the use of this fertilizer	None	Transport	Labor	Drought
	50 %	20 %	10 %	20%
11. Willingness to buy poultry manure as fertilizer	Yes	What price		
	100%	Any price = 60%	10 FCFA/kg =40%	

replicate. Soil characteristics in surface top 20 cm were as follows: sand: 95.55 ± 0.48%; clay: 0.38 ± 0.47%; silt: 4.11 ± 0.47%; pH (H_2O): 4.88 ± 0.21; P_{ass}: 1.83 ± 0. 92 mg kg^{-1}; organic matter: 1.60 ± 1.10 g kg^{-1}; and Total N: 0.017 ± 0.012 g kg^{-1}.

The cultural practices were identical in all the farms' fields. The fields were cleared of shrubs and stubble before the first rain. All the fields were plowed to depth of 40-50 cm using animal traction. With the first rain of 13.5 mm, 8 to 10 seeds were hand planted at 5 cm depth in hills spaced 1 m x 1 m, thereby giving 10 000 hills ha^{-1}. Farmers thinned to 3 plants per hill approximately 14 days after emergence giving a final population of 30,000 plants ha^{-1}. Two hand weedings were used for weed control. All farmers planted the local pearl millet land race variety "*Dan aika*", and used their own farming practices.

Plot size was 25 m x 15 m with 2 m alleys between plots. The planting dates were 6 to 9 June 2004, 16 June 2005 and 10 June in 2006, for all the farmers. The three experiment treatments maintained were (1) Control (no fertilizer), (2) 2 t ha^{-1} of poultry manure, and (3) 2 t ha^{-1} of poultry manure + 4 g 15-15-15 per hill (6 kg N ha^{-1} 6kg ha^{-1} P_2O_5 6 kg K_2O ha^{-1}). Poultry manure application rate was on dry weight basis. A research technician assisted the farmers with fertilizer application to assure treatment levels were uniformly applied to all fields. Poultry manure was applied and incorporated near the pearl millet hill during the first weeding operation at the four-leaf vegetative growth stage. The inorganic fertilizer was added at the tillering stage during the second weeding.

Data collected included the date of the different field operations, and the four central rows 10 m long were harvested for grain and stover yield calculation. The fresh stover weights were determined in the field and samples were taken and dried in an oven at 65°C for 48 h for constant dry weight. The profitability of the poultry manure and fertilizer inputs were estimated by a simple economic analysis based on the value cost/ratio of their costs divided by the value of the production.

The price of the grain was 160 FCFA kg^{-1}, and 10 FCFA kg^{-1} for the stover at the harvest time in 2006. The cost of the fertilizer 15-15-15 was 250 FCFAkg^{-1} and the price of poultry manure was fixed at 10 FCFA kg^{-1} with the farmers and the employees of the poultry plant. The data were subjected to analysis of variance (ANOVA) and

Fisher's least significant difference (LSD) mean separation procedure by using the general linear model (GLM) procedure of the SAS software (SAS, 1994).

On-station experiment in 2004

The pearl millet improved variety Zatib was planted 16 June 2004 on the INTARNA research station in a sandy, infertile soil with a pH of 4.9 and containing 1.6 g kg^{-1} organic matter, 1.8 mg kg^{-1} assimilable P, and 0.017 g kg^{-1} total N. Plant density was 10 000 hills ha^{-1} with 3 plants $hill^{-1}$. Hand weeding was done at GS1, GS2 and GS3 (Maiti and Bidinger, 1981). Yields were reduced by three weeks of drought in July, and during grain fill in September and in October (Table 1).

A randomized complete block design (RCBD) with four replications was used. Plot size was 150 m^2 (15 m x 10 m). Treatments were (1) control (no fertilizer); and 2, 4 and 6 t ha^{-1} poultry manure. Data collected included the date of the different field operations and grain and stover yield harvested from the four center rows. The fresh stover weights were determined in the field and samples were taken and dried in an oven at 65° C for 48 h to determine moisture content and calculate dry weight. The data were subjected to analysis of variance (ANOVA) and Fisher's least significant difference (LSD) mean separation procedure by using the general linear model (GLM) procedure of the SAS software (SAS, 1994).

On-station experiment in 2005 and 2006

The pearl millet improved variety Zatib was initially planted on 17 June 2005 but insect damage required that the experiment be replanted on 15 July 2005. In 2006, the same pearl millet variety was planted on 10 June. The experimental design was a Randomized Complete Block Design (RCBD) with four replications and eight treatments: (1) Control (zero fertilizer); 2 t ha^{-1} poultry manure (dry weight basis) with 10, 20, and 30 kg ha^{-1} P_2O_5; and 2 t ha^{-1} poultry manure with 100, 150 and 200 kg ha^{-1} of finely ground rock phosphate (Phosphate Naturel de Tahoua - PNT) containing 18 to 22% of P_2O_5. Single super phosphate (SSP) was applied at 10, 20, and 30 P_2O_5 kg ha^{-1}. Data collected included the date of the different field operations and the four central rows 10 m long were harvested for grain and stover yield. The fresh stover weights were determined and samples were taken and dried in an oven at 65° C for 48 hours, weighed and used to calculate the stover dry weight. The data were subjected to analysis of variance (ANOVA) and Fisher's least significant difference (LSD) mean separation proce-dure by using the general linear model (GLM) procedure of the SAS software (SAS, 1994).

RESULTS AND DISCUSSION

Preliminary field survey

The survey results indicate that farmers of all ages growing the primary crops in the region applied poultry manure (Table 1). All the farmers perceived that poultry manure application improved the soil and increased crop yields, but were unsure if it was better or worse than inor-ganic fertilizer. Most farmers applied poultry manure as a point application at weeding at a rate of 1600 kg ha^{-1}. Comments indicated that farmers generally apply inorga-nic fertilizer only to cash crops like vegetables and cotton (*Gossypium hirsutum* L.) and that poultry manure gives best results when incorporated, which is easiest to do during the first weeding. Despite the increased work associated with manure application, only one farmer consi-dered labor as the major constraint for using this manure. At the time of the survey, all farmers were receiving the poultry manure free since they were employed or family members of the poultry producer. All the farmers agreed that they will purchase poultry manure when it is no lon-ger free, but comments indicated that the price would influence the application rate.

Laboratory analysis (dry matter basis) of collected samples indicated that poultry manure, which was a mixture of poultry dung and groundnut shells used for bedding, had higher concentrations of N, P, and K than cattle manure (Table 2). Poultry manure and dung had greater P and N concentrations and lower K than samples from Nigeria (Udom and Bello, 2009). Fertilizer recommendations in Niger for pearl millet are 100 kg ha^{-1} of simple super phosphate (SSP -18 kg P_2O_5 ha^{-1}) before planting and split application of 100 kg ha^{-1} of urea (46 kg N ha^{-1}) (INRAN 1987). This shows that the nutrients in 500 kg ha^{-1} of poultry manure would meet the P_2O_5 recommendation, while 2 875 kg ha^{-1} would be needed to meet the N recommendation. Nitrogen availability in composted materials is reduced (Brouwer and Powell, 1995), so higher rates would be necessary to supply the recommended level of N. These analyses indicate that poultry manure in this study was a valuable nutrient source for pearl millet and other crops.

On-farm experiments in 2004, 2005 and 2006

The rainfall data recorded from INRAN/Tarna Research Station, located 5 km from the experimental fields are presented in Table 3. Seasonal rainfall was less than the 10-year average in 2004 and above the average in 2005 and 2006. Grain and stover yields were not influenced by year x treatment interaction, thus the response of pearl millet to the applied poultry manure was similar across years. Year and treatment main effects were significant. Higher grain and stover yields occurred in 2006 when rainfall was greater than in the other years (Table 4). Application of poultry manure alone (2 t ha^{-1}) increased grain yield by 56% and stover yield by 53%, similar to results with maize reported in Nigeria (Udom and Bello, 2009) and in Ghana (Agyenim Boateng et al., 2006). Application of 40 kg ha^{-1} of 15-15-15 with the 2 t ha^{-1} of the poultry manure increased the grain yield by 117% compared to the control while the stover yield increased by 94%. Maman et al. (2000) reported similar increases in pearl millet grain yield (65 and 176%) and stover yield increase (74 and 260%) using the same plant population (10 000 hills ha^{-1}), 5 t ha^{-1} of manure plus 18 kg ha^{-1} P and 23 kg ha^{-1} of N. Grain yield increase of this magnitude are important to meeting increasing food needs in West Africa, resulting from human population growth and changing food consumption patterns (Delgado, 2003). Increases in stover yield are important to meet increasing animal feed and fuel demand (Ejigu, 2008) as well as for

Table 2 .Mean nutrient content (n = 8 samples) of the poultry manure compared to cattle manure.

Parameter	Total N	P_2O_5	K_2O	Ca	Mg
	g kg^{-1}				
Poultry manure	13.0 ± 1.7	39.0 ± 2.9	2.78 ± 0.59	0.28 ± 0.06	0.22 ± 0.06
Cattle manure	9.0 ± 2.0	27.5 ± 3.4	0.26 ± 0.09	0.20 ± 0.04	0.04 ± 0.01
Poultry dung	11.9 ± 2.4	33.2 ± 3.2	2.72 ± 0.48	0.21 ± 0.04	0.48 ± 0.04

Table 3. Rainfall during the 2004, 2005 and 2006 growing season and 10-year average (1997-2006) with in brackets number of rain evens at Tarna Station, Maradi.

Year	May	June	July	August	September	October	Total
	mm						
2004	33 (6)	63 (6)	64 (8)	179 (13)	12 (5)	1 (1)	352 (39)
2005	4 (3)	137 (4)	97 (11)	147 (11)	147 (5)	8 (1)	540 (35)
2006	6 (2)	14 (4)	167 (12)	261 (16)	177 (12)	0 (0)	625 (46)
10-year average	11 (3)	74 (7)	122 (10)	190 (12)	91 (7)	7 (2)	495 (42)

Table 4. Effect of poultry manure alone or in combination with inorganic fertilizer on pearl millet production in 2004, 2005 and 2006 on-farm with 6 farmers near Maradi.

Parameter	Yield	
	Grain (kg ha^{-1})	Stover(kg ha^{-1})
Year		
2004	574	2 064
2005	649	2 056
2006	958	4 170
Treatments		
Control	461	1 855
2 t ha^{-1} poultry manure	721	2 831
2 t ha^{-1} poultry manure + 40 kg ha^{-1} 15-15 -15	999	3 604
LSD (5%)	198	710
Probabilities F-test (P > F)		
Year	< 0.01	< 0.01
Treatment	< 0.01	< 0.01
Farmer	0.03	0.04
Year*Treatment	0.61	0.24
Treatment*Farmer	0.87	0.86
CV (%)	40	38

soil maintenance, especially due to soil degradation and nutrient depletion present in West Africa (Smalling et al., 1993; Sanchez et al., 1997). The analysis of the value to cost ratio (Table 5) indicated that the application of poultry manure alone and in combination with 40 kg ha^{-1} of 15-15-15 were both cost effective, but the poultry manure alone had the highest economic return.

On-station experiment in 2004

Rainfall was below long-term average in 2004 growing season (Table 1). Applied poultry manure had no signi-ficant influence on grain and stover yield, however, appli-cation of 2 t ha^{-1} was cost effective with a return of 10.28 FCFA for each FCFA invested to purchase poultry manure. Higher rates of poultry manure were not as effective, at least partially due to drought limiting the yield potential of pearl millet. The limited effect of higher rates of poultry manure may also be due to losses of nutrients mostly to volatilization. Brouwer and Powell (1995), from a study on the effect of manure application on soil nutrients cycling, reported large losses of N and P measured with high

Table 5. Effect of poultry manure alone or in combination with inorganic fertilizer on pearl millet production and efficiency on-farm.

Treatment	Yield		Fertilizer cost	Production value			Value/cost
	Grain (kg ha^{-1})	Stover (kg ha^{-1})	(F CFA ha^{-1})	Grain (160F kg^{-1})	Stover (5F kg^{-1})	Total	ratio
Control (0 fertilizer)	461	1 855	-	73 760	18 550	92 310	-
2 t ha^{-1} poultry manure	721	2 831	20 000	115 360	28 310	143 670	7.18
T_2 + 40 kg ha^{-1} 15-15-15	999	3 604	30 000	159 840	36 040	195 880	6.52
LSD (5%)	198	710	-	-	-	-	
CV (%)	40	38	-	-	-	-	

Table 6. Effect of poultry manure rate on pearl millet production in 2004 at Tarna station (Maradi, Niger).

Treatment	Yield	
	Grain (kg ha^{-1})	Stover (kg ha^{-1})
Control	1 010	5 625
2 t ha^{-1} poultry manure	1 100	5 912
4 t ha^{-1} poultry manure	977	6 125
6 t ha^{-1} poultry manure	1 142	7 225
LSD (5%)	383	2 823
Probabilities F-test (P > F)		
Replication	0.225	0.345
Treatments	0.665	0.456
CV (%)	23	28

Table 7. Effect of poultry manure alone or in combination with inorganic P fertilizer on pearl millet production in 2005 and 2006 on-station at INRAN/Tarna Station, Maradi, Niger.

Parameter	Yield	
	Grain (kg ha^{-1})	Grain (kg ha^{-1})
Year		
2005	457	2 616
2006	682	2 039
Treatment		
T_1 = Control	445	1 543
T_2 = 2 t ha^{-1} poultry manure	588	2 493
T_3 = T_2 + 10 kg P_2O_5 ha^{-1}	629	2 653
T_4 = T_2 + 20 kg P_2O_5 ha^{-1}	602	2 381
T_5 = T_2 + 30 kg P_2O_5 ha^{-1}	580	2 831
T_6 = T_2 + 100 kg PNT ha^{-1}	557	2 364
T_7. = T_2 + 200 kg PNT ha^{-1}	623	2 372
T_8. = T_2 + 300 kg PNT ha^{-1}	532	1 986
LSD (5%)	126	351
Probabilities F test (P > F)		
Year	< 0.01	< 0.01
Treatments	0.10	< 0.01
Year*Treatment	0.91	0.32
CV (%)	22	15

rates of applied manure. They suggested that the more frequent application of small amounts may be more efficient than the prevailing less labour demanding practice of manure application at the high rates every few years (Table 6).

On-station experiment in 2005 and 2006

Application of poultry manure increased pearl millet grain yield by 32% and stover yield by 62% (Table 7), while the addition of P had no further influence on grain yield. Application of an additional 30 kg ha^{-1} P_20_5 further increased stover yields over those produced with PNT. The limited response to the additional P application was likely due to the low yield levels produced (low plant demand for P) combined with the relatively high P concentration in the poultry manure (Table 2).

Conclusions

Poultry manure is an important organic nutrient source used to increase pearl millet grain and stover yields. Farmers using poultry manure recognize its value for soil improvement and crop productivity. Poultry manure contains higher concentrations of N, P, and K than cattle manure. Most farmers apply sidedress nutrients near the crop hill during the first weeding and subsequent thinning operation. The average amount applied was 1600 kg ha^{-1} when sidedress applied and 2300 kg ha^{-1} when broadcast. On-farm research indicated that 2 t ha^{-1} of poultry manure increased pearl millet grain and stover yields, and the addition of 40 kg 15-15-15 (6kg N ha^{-1} – 6kg ha^{-1} P_2O_5 - 6 kg K_2O ha^{-1}) fertilizer further increased yields but not the cost/value ratio. On-station research also indicated that 2 t ha^{-1} poultry manure increased grain and stover yields, while additional application of P had no influence on grain yield. This was likely the result of low crop demand due to low grain and stover yields combined with the relatively high P concentration of the poultry manure. This research clearly shows the value of poultry manure application to increase pearl millet grain and stover yields in the Sahelian climatic zone, which would help address human food, animal feed, and fuel and soil maintenance issues in one of the poorest regions in the world. Additional research on storage, composting and application methods of poultry manure is merited, as well as research on application of N fertilizer in combination with poultry manure as this is the second most limiting nutrient and the N concentration of the poultry manure was low.

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