The Application of Cattle Manure to Improve Soil Fertility for Crop Production in Uganda

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Abstract

Declining per capita food production and soil fertility depletion are threatening the livelihoods of many small-holder farmers in East Africa, including Uganda. High demand for food due to the increase in population has necessitated the need to improve crop yields where synthetically manufactured fertiliser use in the production system is often scarce and expensive. Cattle manure provides essential plant nutrients (mainly nitrogen, phosphorous and potassium) and is available locally; however, there is little information in Uganda on soil fertility status, the most effective rates of cattle manure, methods of application, crop requirements for specific nutrients and limiting factors to crop production. A survey was conducted on selected small-holder farmers in Uganda, in the central districts (Kampala and Wakiso) in January 2010 to identify socio-economic factors influencing the use of fertiliser and the current level of soil fertility as constraints that were most limiting to plant production. It was apparent from the survey and soil sampling that soil physicochemical values varied greatly amongst the soils and sites investigated. Unfortunately, in many situations the application of fertilisers being used didn't target specific nutrients most limiting to crop production. The main findings from the soil survey will be presented in this paper and subsequent field research and nitrogen modelling that has been conducted to better assist farmers in Uganda improve crop productivity through more effective fertiliser practice.

Keywords: cattle manure; fertiliser; nitrogen; urea

Introduction

Declining soil fertility coupled with minimal nutrient inputs has contributed to low crop yields in sub-Saharan Africa (Kanonge et al., 2009); a major constraint to food security and economic development in Uganda (Zaake et al., 2005). Crop production needs to be intensified to increase food production to meet these challenges which requires a supply of nutrients; however, the annual inorganic fertiliser application rates in Uganda contain less than a kilogram of nutrients per hectare. Consequently, many farms suffer from negative nutrient imbalances (Wortman et al., 1999; Nkonya et al., 2002). Fertiliser application level is low compared to 9 kg ha^{-1}, the average for sub-Saharan Africa, which in turn is only 5% and 20% of that used in East Asia and Latin America, respectively (Panda, 2008). Cattle manure provides nutrients and can improve the fertility of the soil to sustain crop growth and increase food production. The aim of the study was to assess the current situation of small-holder crop-livestock farms in central Uganda with respect to the requirements and options for nutrient applications including cattle manure. This information presented aims to establish the production function to generate recommendations for optimal resource use in small-holder crop-livestock farming systems regarding cattle manure N management decisions in order to meet the nutrient requirements for crop production.

Methods

Data for the study were collected through a farmer survey using a semi structured interview, focus group discussions, field observations, collection and laboratory analysis of soil samples and cattle manure from farms in Uganda and field and glass house experiments in Australia during 2009-2010. The survey study design was cross-sectional and descriptive aimed at capturing the different methods of cattle manure application, information on crop production and reasons for non-use or limited use of inorganic fertiliser in the study area. The field experimental site was established on dark yellowish-brown sand under a dry temperate climate. A systematic design (Cleaver et al., 1970; Morris et al., 2003; Rigby, 2008) was used with six rates of application of cattle manure, stored for 12 months and six rates of urea as sources of nitrogen (N) to establish the relative effectiveness of cattle manure N compared to synthetic inorganic fertiliser N. Basal amounts of all nutrients required for plant growth, except N were applied at the start of the experiment. Select your nitrogen (SYN) model was used to predict N availability following Diggle et al. (2003).

Results and discussion

Cattle manure and inorganic fertiliser use by surveyed farmers

Results of the survey indicated that 95% of the respondents used organic manure, particularly cattle manure, as a source of fertiliser, whereas only 5% used urea. Fifty-five percent of the farmers reported that cattle manure was not adequate to fertilize the whole farm in a single cropping season due to few animals kept because of limited land holdings of 0.2 ha to 0.8 ha (88%) and inadequate fodder (69%). A number of challenges associated with cattle manure use included its heavy and bulky nature (25%), lack of labour (23%) and insufficient manure (19%). High transportation and application costs (13%) and lack of storage facilities (11%) to maintain quality attributes of manure worsened the situation.

Relative effectiveness of cattle manure-N compared with inorganic-N for plant growth

Inorganic N (urea) was a more effective source of N for dry matter yield of canola at 93 days after sowing (DAS) compared to equivalent rates of N as aged cattle manure (Figure 1) as demonstrated by field experiment research in Western Australia.

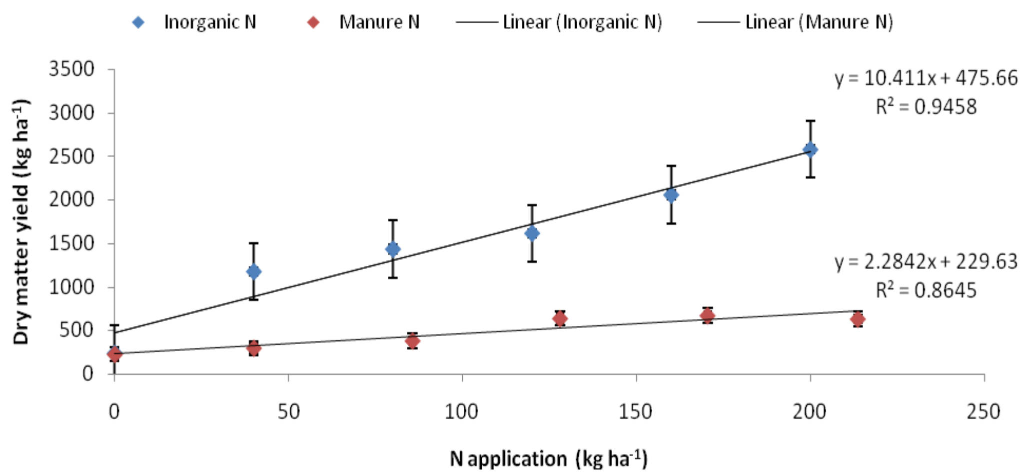

Figure1: Effect of nitrogen in cattle manure and urea on dry matter yield kg ha^{-1} of canola (Brassica *napus*)

Nitrogen equivalency values of cattle manure for each measure of crop response (fresh, dry and N uptake) for canola based on linear regression coefficients with inorganic-N followed a Mitscherlich equation (Table1).

Table 1: Equivalent values for nitrogen in cattle manure compared to inorganic fertiliser

Source	**Days after sowing (DAS)**	**Yield/parameters**			
Cattle manure N		Fresh	Dry	N uptake	Mean
	63	0.15	0.16	0.13	0.15
	93	0.23	0.22	0.18	0.21

The relative effectiveness of cattle manure N increased over the growing season, which was attributed to increased levels of manure N availability following mineralisation of organic forms of N with time. Nitrogen efficiency slightly increased from 15% to 21% as the season progressed for each measure of crop response. Linear responses to application of cattle manure and inorganic N over the range 0 to 200 kg N ha^{-1}, equivalent to an additional 3.0 and 12.9 kg

DM biomass per one kilogram added manure N and inorganic N, respectively were measured. A second field experiment has since been repeated to validate these results and to measure the effect of cattle manure stored for shorter time periods also. A maximum of 80.5 and 20 kg N ha^{-1} were taken up by the canola crop from urea and cattle manure, respectively, at an application rate of 200 kg N ha^{-1}; corresponding to 40% and 10% of the total N applied, respectively. A subsequent glasshouse experiment demonstrated that N uptake in canola was similar to that in two species of cabbage (Table 2). Because there is always limited experimental yield data available for analysis, this study has used both experimental and simulation data in the SYN model (Diggle et al., 2003) to evaluate the functional forms of canola and cabbage (data not shown). The SYN model, which predicts crop N availability, N uptake, potential yield and economic returns has been calibrated and developed for possible adoption for Ugandan conditions to improve fertiliser use including cattle manure N and/or inorganic fertiliser N.

Table 2: Nitrogen uptake (g plant^{-1}) of three Brassica *spp* at five sampling days

	Days after sowing (DAS)				
Crop	70	80	90	100	110
Canola	0.13	0.30	0.39	0.45	0.63
White cabbage	0.17	0.40	0.46	0.41	0.54
Tronchunda cabbage	0.15	0.34	0.41	0.46	0.49

Potential cabbage production with nitrogen fertiliser application

The simulated results show the practical approach of N rate and the price effects on the economic optimum N rate (data not shown). The data shows cabbage yield response to applied N and assumes a constant cabbage price of $0.25 kg^{-1}. The size of the yield increase and its value along with N fertiliser cost at the two N prices is shown for 40 kilograms increments of added N. In this study, N fertilisation on N deficient soils would be profitable at all of the N prices shown through the 440 kg ha^{-1} for manure N and 560 kg N ha^{-1} for inorganic N; however, the practical application of spreading this amount of cattle manure may be a constraint to production.

Conclusion

The results indicated that aged cattle manure-N was 21% effective as top dressed inorganic-N (urea), and therefore approximately five time more total N equivalent in cattle manure is required to obtain comparative N uptake to urea, where all other nutrients are not limiting. The canola crop was able to take up more of N over the season, with RE for N uptake increasing from 13% to 18% for dry matter production. Using the experimental data set, SYN model simulated fresh yield potentials of cabbage for the Ugandan conditions. This needs to be adequately tested in the field however, for the successful replication of the SYN model. The basic model has been developed to predict N availability, potential yield and N uptake for cabbage , but further refinement is required to better explain N dynamics under high N supply.
There is need for validation of the model against a wide range of independently collected experimental data from cattle manure applications to vegetable crops mainly cabbage and amaranthus *spp* and other arable crops to benefit a wider community including cereals, root crops, bananas, and cash crops for Ugandan conditions. This will provide a reliable estimate of the fertiliser N value of cattle manure and/or urea for crop production in Uganda.

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