THE ECONOMICS OF USING MANURE STORED UNDER TWO DIFFERENT SYSTEMS FOR CROP PRODUCTION BY SMALL-SCALE FARMERS IN KWAZULU-NATAL

by

T.S. Mkhabela

Contributed Paper Presented at the 41st Annual Conference of the Agricultural Economic Association of South Africa (AEASA), October 2-3, 2003, Pretoria, South Africa

THE ECONOMICS OF USING MANURE STORED UNDER TWO DIFFERENT SYSTEMS FOR CROP PRODUCTION BY SMALL-SCALE FARMERS IN KWAZULU-NATAL

Mkhabela, T.S. Agronomy Section, KwaZulu-Natal Department of Agriculture & Environmental Affairs. Private Bag X9059, Pietermaritzburg, 3200. South Africa. Tel. (+27) 33 3559460; Fax (+27) 33 3559454; E-mail Address: mkhabelat@dae.kzntl.gov.za

ABSTRACT

Several manure use options were analysed for profitability using results from research and farmer participatory trials that were conducted in the small-scale farming sector in KwaZulu-Natal, South Africa. The options analysed for profitability were a) not using any manure b) using aerobically composted (heap stored) manure, c) using manure improved through anaerobic storage (pit-stored), d) different manure application methods i.e. banding, broadcasting and station placement and the use of manure in combination with inorganic fertiliser.

The use of manure provided a marginal rate of return (MRR) of at least 600% compared to not using manure. The marginal rate of return on manure use was increased significantly by composting manure in pits. Financial benefits obtained from pit- stored manure were much higher in the first year of manure application compared to those of heap- stored manure. Higher returns from heap- stored manure were obtained in the second and third season after manure application. Overall undiscounted financial benefits for the three years were marginally higher for heap- stored manure. Using a discount rate of 100% financial benefits from using pit-stored manure were much higher than those of heap stored manure as pit-stored manure provided much higher returns in the first year of application. Higher financial benefits were obtained from supplementing manure with inorganic fertiliser compared to using manure alone. Banding and placing manure on-station (applying the manure to the hill of maize) increased returns from using both pit and heap stored manure. The conventional practice of broadcasting manure was found not to be profitable.

Key Words

Marginal Rate of Return, Marginal Net benefit, Heap stored manure, Pit-stored Manure, Residual Effects, Net Present values, Discounting.

INTRODUCTION

Most communal areas in the KwaZulu-Natal midlands are located in areas of high rainfall (800 – 1600 mm per annum) with highly weathered soils and these soils are inherently low in fertility (Fey 1981). These highly weathered soils are deficient in phosphorus (P) are very acidic (with pH in water, as low as 3.90 and acid saturations of as high as 80%) and have high clay and low organic matter contents (Roberts and Smeda, 2002). The soils have been continuously cultivated without consistent and significant replenishment of soil nutrients (Mkhabela, 2002a; Metho, 2002). The low fertility status of the soils in the area manifest as low average yields of approximately 900 kg ha^{-1} for maize, the main crop in the small-scale farming sector. Low soil fertility in the small-scale sector is not only a result of limiting biophysico-chemical factors, socio-economic factors also contribute to low fertility and productivity in the small-scale sector. Low returns on investment in soil fertility management and the weakened ability of small-scale farmers to maintain the fertility status of their soils are the two main socio-economic factors contributing to the poor fertility of the soils and low crop productivity.

Manure is commonly used by small-scale farmers to address the problem of declining soil fertility in KwaZulu-Natal. Small-scale farmers are aware of the short and long term benefits of manure application on soil fertility and crop productivity. Studies done elsewhere have established that under continuous cultivation annual applications of 3 to 6 tonnes of manure per hectare increased the fertility of the soil by increasing N, P, K increasing the cation exchange capacity, exchangeable bases and pH (Grant, 1967). With inorganic fertilisers becoming more, most farmers have been forced to entirely rely on organic materials like manure for soil fertility management of their soils. Quantities of inorganic fertiliser used on crops such as maize are very low (Mkhabela, 2002b). Manure use has emerged to be one of the low cost options for sustaining crop productivity and increasing soil fertility in the small-scale farming sector of KwaZulu-Natal, South Africa.

A lot of research work on manure has been done with the overall objective of improving the effectiveness and utilization of organic materials on the farm by improving manure storage and handling, supplementing manure with inorganic fertiliser and identifying most profitable application methods. Farmer participatory trials were conducted in Nkwezela, North West of KwaZulu-Natal, to assess the promising technologies under small-scale farmer circumstances. This paper is an economic appraisal of the promising technologies that were tested in the small-scale farming environment. The measurements were on manure and inorganic fertiliser combinations, comparison of anaerobically (pit) and aerobically (heap) stored manure and their residual effects and comparison of the different manure application methods and identifying economically feasible options.

MATERIALS AND METHODS

Manure and Inorganic Fertiliser Combinations

Field observations and measurements were conducted in Nkwezela for two seasons, 2000/01 and 2001/02 season. In all the trials maize was used as the test crop. The amount of manure applied was kept constant at 5 tonnes per hectare whilst the rate of inorganic nitrogen was varied from 0, 20, 40, 80 to 100 kg N ha^{-1}. The inorganic nitrogen was applied twice as Urea (46% N), at 6 weeks and at 10 weeks after planting. A blanket application of P and K was done on all plots at 40 kg ha^{-1} and 35 kg ha^{-1} respectively.

Comparisons of the effectiveness of pit and heap stored manure

Field trials were conducted for three years at Cedara, from the 1999/00 season to 2001/02 to establish responses of maize to differently stored manure, that is, anaerobically stored (pit) and that aerobically stored (heap). The response to residual N availability from manures applied at a rate of 10t ha^{-1} in the first season trials was also measured over a period of two years in 1999/00 and 2000/01 seasons. Land preparation was done using an ox-drawn plough. All sites were weeded at two and five weeks after crop emergence. The sites on which the trials were conducted had no history of manure use for at least the three previous years.

Effectiveness of different Manure Placement Methods

The experiment was conducted in 1999/00 season at 3 sites on a Hutton clay soil. Three methods of applying manure were tested in the trial namely broadcasting, banding and station placement. Cattle manure from host farmers was used in the trial. The cattle manure was composted or put on a heap for three months. An application rate of 100 kg N ha^{-1} equivalent basing upon the total N concentrations of the manures was used. The application rate of manure per hectare ranged from 3.85 t (for manure with 2.6% N) to 10 t (for manure with 1% N content). Maize grain was harvested at maturity.

Benefit - Cost Analysis

A financial analysis was conducted to appraise the different trials or options under trial. The full budget for the maize enterprise under the different treatments or trials was done based on marketable output. Farm gate prices were used for all the inputs namely inorganic fertiliser, seed and insecticides. The number of labour days per operation was obtained from discussions with farmers and from a survey that was conducted to collect data on labour costs in the communal areas. The use of pit-stored manure requires additional labour in the digging of the pits. From discussions with farmers two additional days are incurred when they pit store their manure for the whole operation. Farmers also indicated that heap stored manure has a lot of weed seed compared to pit-stored manure and farmers allocate more labour days on weeding fields where heap stored manure is applied compared to where pit-stored manure is applied. All the yields obtained from the field were adjusted by 10% to cater for field losses. Field losses generally include grain eaten by rodents, termites and mechanical losses (grain accidentally left in the field during harvesting). The net financial benefit and the marginal rate of returns were then calculated from the enterprise budgets. For the trial on residual effects of heap and pit-stored manure the Net Present Values (NPV) were calculated to get values for the future benefit streams.

The Net Present Value (NPV) is the present value of expected future earnings or benefits (Gittinger, 1982). A discounting rate is used to calculate or discount future benefits into today's values. Normally the going interest rate is used as the discount rate (Gittinger, 1982). The Net Present Values were calculated using the formulae;
Net Present Value = $A/(1 + R)^n$ where A is the future benefit, R is the interest rate expressed as a decimal and n is the number of years for which the investment is made.
The results of the analysis are discussed in light of results that came out of a farmer survey that was implemented to characterise manure use strategies by small-scale farmers. The survey was conducted in Nkwezela, a high rainfall area and in Dundee, a relatively low rainfall area.

RESULTS

Inorganic Fertiliser and Manure Combinations

Greater benefits were obtained when manure was supplemented with some inorganic fertilisers than using manure alone. A 45% increase in yield was obtained by just adding one 50kg bag of Urea fertiliser to 5 t ha^{-1} of manure (Fig. 1). The yield increased with every additional bag of inorganic fertiliser. The benefits were much greater compared to just using manure alone.

A significant proportion of small-scale farmers at Nkwezela do not apply anything on their soils to improve the fertility status of their soils and from the results, this practice is not profitable at all (Table 1). Addition of five tonnes of manure alone was still not enough to make maize production profitable (marginal benefit greater than marginal cost). Maize production only became profitable after an addition of a bag of ammonium fertiliser (Urea-46%N) that offered a marginal rate of return of more than 400% (Table 1). The marginal rate of return declined thereafter with every additional bag of inorganic fertiliser that was added. The combination of 5 tonnes of manure with 6 bags of inorganic fertiliser had the highest net financial benefit (Table 1).

The marginal net benefit (the financial benefit obtained by each additional bag of inorganic fertiliser) first increased with the first bag of fertiliser but declined with successive bags of inorganic fertiliser. On the other hand the marginal variable cost, which is the extra cost incurred by using an additional bag of inorganic fertiliser, remained constant, since it is the price of each additional bag of fertiliser. On the basis of the Marginal Approach in evaluating profitable level of input use, the most profitable level of fertiliser is given where the marginal benefit will be equal to the marginal cost (Hill, 1990). The trial only considered 5 levels of fertiliser use, no fertiliser, one , two, five or six bags of fertiliser. The other levels of use, three bags or four were not considered and these levels were then extrapolated using the production function ($Y = -0.086X^2 + 0.972X + 2.2288$) obtained from the trial results.

The farmer makes a profit as long as the Marginal Benefit is greater than the Marginal Cost. The most profitable option was obtained where the Marginal

Benefit was equal to the Marginal Cost and this was at about 3.5 bags of Urea (Fig. 1) and this represented the optimum combination of manure and fertiliser N.

Comparisons of the effectiveness of pit and heap stored manure

In the first year of manure application, manure stored anaerobically in pits produced a much higher yield compared to that aerobically stored on a heap (Fig. 2). Manure stored in the pit gave a 100% yield gain compared to that stored on a heap in the first year of application. Storing manure in pit is anaerobic and results in quicker mineralisation (composting), which in turn, makes more of the N in the manure available for uptake by plants in the season of application. Heap stored manure offered a 20% and 100% yield gain in the second and third seasons respectively compared to pit-stored manure.

The storing of manure in pits had positive net financial benefits in the first seasons after manure application (Table 2). Storing manure on the heap produced positive financial benefits in the second and third season after application. The financial net benefit of using heap-stored manure was substantially higher than that of pit-stored manure in the second and third year after application. As was expected not applying anything is not a viable option at all for sandy soils in the communal areas. Investment in the use of heap stored manure provided a more than 600% marginal rate of return compared to not applying any manure at all. A marginal rate of return of more than 10000% was obtained from pit-stored manure in the first year of application compared to heap stored manure (Table 2). The marginal rate of return for pit-stored compared to heap stored manure declined in the second and third season after application. Undiscounted cumulative three-year benefits were marginally higher for heap than for pit-stored manure (Table 3). Using a discount rate of 100%, cumulative three-year benefits of pit-stored manure became much higher than those for heap stored manure (Table 3). A sensitivity analysis on how discount rates affect profitability of the different manure storage systems was done and it was established that heap stored manure was more profitable than pit-stored manure when a discount rate of less than 10% was used. At discount rates of more than 10% discounted benefits of using pit-stored manure were much higher compared to those of heap-stored manure.

Effect of Manure Placement Methods on Maize Yield

Banding and placing manure on- station produced higher yields for both pit and heap stored manure compared to broadcasting (Table 4). Pit-stored manure yielded more than heap-stored manure in all the different placement methods, banding, broadcasting and station placement. Banding heap-stored manure yielded more compared to placing it on station or broadcasting it. On-station application of pit-stored manure marginally outperformed banding in terms of yield, though it was not statistically significant. Banding was done by placing and burying manure in a 30cm wide band along the row of maize. Broadcasting manure gave the least yield compared to the other two methods, banding and station placement.

Application of heap-stored manure was not profitable, whether banded, broadcasted or placed on station (Table 4). The use of pit-stored manure offered a positive net financial benefit when banded or applied on-station. Broadcasting pit-stored manure was not profitable as well though it resulted in a higher marginal rate of return compared to broadcasting heap-stored manure. It does not make economic sense for a farmer to shift from broadcasting pit-stored manure to station placement of heap stored manure as indicated by the negative marginal rate of return (Table 4).

DISCUSSION

The use of manure is one of the low cost options being used by farmers to increase maize productivity in the small-scale sector of KwaZulu-Natal. Manure has been found to be cheaper than inorganic fertiliser in the area (Mkhabela, 2003) and most small-scale farmers in the study areas are able to procure manure free of charge. Most small-scale farmers face severe resource constraints and are unable to purchase large quantities of inorganic fertilisers. Increase in household numbers and incidents of stock theft have significantly reduced cattle herds in the small-scale sector of Nkwezela. The quantity of manure available for use by small-scale farmers has become severely limited. The use of manure with little supplements of inorganic fertilisers, offers much larger benefits to farmers. This confirms why most farmers have been supplementing their manure with limited quantities of N fertiliser, a bag or less per hectare. It is not only a cost cutting option but also an economically viable one. To these farmers what is more critical is how much of inorganic fertiliser should supplement the manure for maximum benefit.

Results from other research work being done on combinations of manure and inorganic fertiliser indicate that combinations yield much better than the soles, inorganic fertiliser only or manure only (Mkhabela, 2003). Limited quantities of inorganic fertiliser, 1 or 2 bags of urea, may not be the most profitable level of use but farmers are able to realise some more profit compared to not using N fertiliser at all. This study established the most profitable level of inorganic fertiliser to add on 5 tonnes of manure per hectare to be 3.5 bags of urea. Given the variability of the communal area manure in terms of the nitrogen content it is unpractical to have one blanket recommendation to farmers. The nitrogen content for communal area manure varies from 1% to 2.6% depending on the management and handling of the manure (Mkhabela and Smeda, 2003). More than 80% of the manures have less than 1% nitrogen content. Most farmers realise these quality variations. A basket of options can provide farmers with a choice of management strategies on the basis of their resource endowments and understanding of the quality of their manure. Developing decision guides (Fig. 3) on supplementing inorganic fertiliser to manure of different quality would make it possible for farmers to make informed decisions. However such decision guides need to be farmer friendly and take account of available quantities of manure and fertiliser N, farmer perceptions of quality and other management factors like soil type and methods of application.

Manure storage and handling is very critical as it has a large bearing on the quality of the manure in terms of its nitrogen content. More than 65% of small-scale farmers who use manure in Nkwezela and Dundee store their manure on a heap and the proportion is even larger in other areas that have not been exposed to better manure storage methods (Fig. 4). About 20% of the farmers use the deep stall method where manure is removed from the kraal and immediately transported to the field. However, the manure is commonly not immediately buried which results in more than 50% of N being lost as ammonia (Murwira et al., 1993; Sims and Wolf, 1994). This method may also result in as much as 75% N in heap-stored manure being lost through volatilisation (Kirchmann, 1985; Murwira and Kirchmann, 1993). The storing of manure in pits was first introduced to small-scale farmers in Nkwezela in 2000 and already about 11% of farmers have adopted the technology. The use of a covered heap came in as an alternative to the pit storage system.

The most important reasons commonly cited by farmers for storing their manure on a heap are that manure decomposition is enhanced and all residues will be decomposed, heaping is the only method farmers have been exposed to and that heaping burns weed seed (personal communication). The knowledge constraint or access to information seems to be a much bigger problem as most farmers have not been able to get more information on improving manure quality through storage. In participatory appraisals that were conducted in Nkwezela most farmers expressed ignorance of other manure storage methods except storing manure on a heap or using the deep stall method.

One of the reasons given by farmers for storing manure on a heap is the residual (recalcitrant) effect in the second and third seasons after application. Residual effect here refers to the nutrients, especially N, that is released from the soil as a result of manure application in previous season(s). Farmers rotate the application of manure on the various plots planted to maize and most farmers take up to three years before applying manure on the same plot or field (personal observations). Heap stored manure gives farmers a chance to apply manure on other fields whilst benefiting on residual effect on previously applied sections. Pit-stored manure does the same but the benefits are lower in the second and third season after application compared to heap stored manure. Undiscounted benefits of heap-stored manure were marginally higher than those for pit-stored manure. When these benefits were discounted, pit-storing manure became more profitable over the three years as it provided larger benefits in the first season of application.

Technologies that offer larger benefits in the first season of adoption are likely to be adopted than those which yield benefits later in the project cycle (Gittinger, 1995). The implications from this analysis are that if the future discounted benefits are very limited farmers are not likely to invest in long term soil fertility management strategies which produce higher yields in the long term. A favourable economic climate would make it possible for farmers to invest in the long-term sustainable soil fertility management practices. Pit storing manure is one technology that yields greatly in the first year after application and if information on the technology is widely circulated more farmers would adopt it given the current circumstances in KwaZulu-Natal.

Results from this analysis need to be validated by looking at long term effects of the rotation of manure application on different fields for the two types of manure storage systems, heap and pit, through simulation modelling. Such analysis should include simulating yields for the whole maize enterprise taking residual effects into consideration and for at least three cycles of manure application where the manure is applied on an annual basis but on different patches of the field. Under such scenarios storing of manure in pits is likely to be more profitable than heap storing manure.

The yield benefits from manure application can be increased for both heap and pit-stored manure if the appropriate method of application is used. Most farmers in South Africa broadcast their manure and results from this analysis shows that this is not a profitable option. More than 60 % of the farmers in high rainfall areas and more than 80% in the low rainfall areas broadcast their manure (Figure 5). About 23% and 5.4% of farmers in the high and low rainfall areas respectively band their manure and about 8% or less in both regions use station placement when applying their manure. Most farmers are aware of the benefits of banding compared to broadcasting but due to labour constraints on the farm are not able to adopt the profitable options. Limited labour requirements and that it is very easy (not time consuming) to broadcast manure are some of the important reasons cited by farmers who broadcast their manure. An analysis of the labour data reveals that only an average of 3 people is available for full time farm work per household (De villiers et al., 1999). The average farm size for small-scale farmers in the area is 2.9ha (Mkhabela, 2002a).

Most farmers who band their manure mainly do so due to limited manure quantities and that banding allows them to apply manure only where it is required and they therefore are able to apply manure on a larger area. About 10% or less of the farmers band their manure for the yield advantage it offers compared to other methods of application. In some communal areas like Nkwezela in the KwaZulu-Natal midlands, farmers have formed groups to assist each other with manure removal and application and this has reduced individual household labour limitations. The implications of this is that in as much as some options offer very high rates of return other constraints facing the farmers can limit adoption of viable options. There is therefore a need to provide more options and information to farmers to enable them to adopt options that suit their circumstances (available resources, labour constraints etc).

Improving Information Packaging and Dissemination

Most of the information from research findings remains inaccessible to most small-scale farmers and if available the information is not appropriately packaged for easier understanding by farmers. The information on profitable options should be relayed in the form that relates to what small-scale farmers use on a day-to-day basis. For example most farmers we discussed with in a survey to identify manure use practices did not have a very good idea of how big a hectare is and yet most information coming out of research is in terms of rates per hectare, yield per hectare, etc. Different dissemination tools have been used in making farmers aware of research findings and these include brochures, farmer feed back workshops, farmer magazines, radio programs, demonstrations by extension personnel, farmer field schools, just to mention a few. The effectiveness of each of these channels has not been established and there is a need to have an evaluation of the dissemination tools being used by different institutions to identify those that are effective in improving availability of information about available options to farmers. Decision guides as suggested earlier (Fig. 3) will need to be simple but sufficiently informative.

Improving Access to Inorganic Fertilisers and Reducing Transaction Costs

Small-scale farmers face severe constraints in accessing affordable inorganic fertilisers. Most farmers face huge transaction costs in the purchase of inorganic fertilisers, the farm gate price of the fertiliser becomes very high and unaffordable. Improvement in fertiliser availability from rural dealers would greatly reduce the transactions costs incurred by small-scale farmers. There is a need to make fertilisers more affordable if significant productivity gains are to be realised in the small-scale sector. Packaging fertilisers in small yet well labelled bags is a promising prospect.

Improving Linkages between Research Scientists, Extension and Policy Makers

Greater productivity gains will be achieved by a coordinated approach by research, extension and policy makers. Extension has a comparative advantage in terms of representation in the small-scale sector compared to research institutions and as such should play a major role in the provision of information on viable options to farmers. A coordinated approach by research, extension and policy will greatly improve access to information and adoption of viable options by farmers.

There is also a need to characterise investment priorities for small-scale farmers in soil fertility management. The profitability of both short and long term investment priorities is affected by the policy environment and prices of both inputs and outputs. Technologies offering high returns in the first year of adoption are likely to be adopted by most farmers compared to those which yield higher returns in the long run. A whole farm investment analysis will be essential in identifying investment priorities on the farm.

CONCLUSION

The most important finding coming out of this analysis is that there is a great variance between the profitable options identified and the actual practices by farmers. Most farmers broadcast their manure but from results it is not profitable. Most farmers heap store their manure but again this is not profitable from the results of the analysis. Most farmers should be supplementing their manure with inorganic fertilisers for greater benefits but only a few farmers have access to and can afford the inorganic fertilisers. The most important question coming out of this is how we address the situation where what research has identified as economically viable is not widely practiced by farmers. Several options are available for addressing this variance a) improvement in information packaging and dissemination b) improving access to inorganic fertilisers and reducing transaction costs and c) improving linkages between research scientists, extension and policy makers.

Table 1: Marginal rates of return from maize for manure and inorganic fertiliser combinations

Variables	*No Manure + no fertiliser*	*5* t ha^{-1} *manure + no fertiliser*	*5* t ha^{-1} *manure + 1 bag* fertiliser*	*5* t ha^{-1} *man 2 bags ferti*
Yield (t ha^{-1})	1.18	2.17	3.14	3.96
Adjusted yield (10%)	1.06	1.95	2.83	3.564
Selling Price(R t^{-1})	700.00	700.00	700.00	700.0
Gross Benefit (R)	742.00	1365.00	1981.00	2494.8
Total Variable Costs (R ha^{-1})	1080.86	1188.02	1269.49	1350.9
Net Benefit (R ha^{-1})	-338.86	176.98	711.51	1143.8
Net Benefit/RVC	-0.31	0.15	0.56	0.85
Marginal Net Benefit (R)	NA	161.88	534.53	432.32
Marginal Variable Cost (R)	NA	107.16	81.47	81.48
Marginal Rate of Return (MRR) %	NA	151%	656%	531%

***1 bag of fertilizer = 50 kg**

Table 2: Analysis of the profitability of using pit and heap stored manure and residual effects over 3 years at maize grain prices deflated for inflation

Variables	*1999/00 Season*			*2000/01 Season*		
	Control	Heap	Pit	Control	Heap	Pit
Yield (t ha^{-1})	0.94	2.89	5.88	0.69	3.71	3.34
Adjusted yield (10%)	0.84	2.60	5.29	0.62	3.34	3.01
Selling Price (ZAR t^{-1})	900.00	900.00	900.00	700.00	700.00	700.00
Gross Benefit (ZAR)	756.00	2340.00	4761.00	434.00	2338.00	2107.00
Total Variable Costs (ZAR ha^{-1})	248.66	269.95	272.32	248.28	252.82	250.55
Net Benefit (ZAR ha^{-1})	507.34	2070.05	4488.68	185.72	2085.18	1856.45
Net Benefit/RVC	2.04	7.67	16.48	0.75	8.25	7.41
Marginal Net Benefit	NA	1562.71	2418.63	NA	1899.46	-228.73
Marginal Variable Cost	NA	221.29	2.37	NA	4.54	-2.27
Marginal Rate of Return (MRR)	NA	706%	1021%	NA	418%	101%
Net Present Values (NPV)	507.34	2070.05	4488.68	172.72	1939.22	1726.50

Table 3: Overall benefits over 3 years of using pit and heap stored manure on maize

Factor	*Control*	*Pit*	*Heap*
Total harvest (tonnes)	1.83	9.82	8.79
Total Gross Benefit (ZAR)	552.24	2835.35	2885.87
Total Variable Cost (ZAR)	1748.22	1814.25	1818.32
Total Financial Benefit (ZAR)	-1195.98	1021.10	1067.55
Net Present Values (NPV)	-801.46	767.04	497.64

Table 4: Marginal rates of return for pit and heap stored manure using different application methods (banding, on-station and broadcasting) for maize production

Variables	*Heap, Broadcasted*	*Pit Broadcasted*	*Heap, On-station*	*Pit On-station*	*Heap,*
Yield (t ha^{-1})	1.01	2.76	1.39	3.30	
Adjusted yield (10%)	0.91	2.48	1.25	2.97	
Selling Price (ZAR t^{-1})	1200.00	1200.00	1200.00	1200.00	12
Gross Benefit (ZAR)	1090.80	2980.80	1501.20	3564.00	19
Total Variable Costs (R ha^{-1})	1350.97	1362.88	1398.60	1410.50	13
Net Benefit (ZAR ha^{-1})	-260.17	1617.92	102.60	2153.50	5
Net Benefit/ ZAR VC	-0.19	1.19	0.07	1.53	
Marginal Net Benefit (ZAR)	NA	1878.09	-1515.32	2050.90	-1
Marginal Variable Cost (ZAR)	NA	11.91	35.72	11.90	-
Marginal Rate of Return (ZAR)	NA	1576%	-4242%	17234%	6

References

DE VELLIERS JF, LETTY B.A, VAN RENSBURG JAJ, & MADIBA S (1999). *Summarized report on questionnaire survey conducted in the Obonjaneni community during March 1998*. CEDARA Report No N/A/99/7. Dept of Agric, KZN

FEY MV (1981). Aluminium toxicity. Arena Agricultural Region, *Natal: Soils*. **4 (1),** 15.

GITTINGER J, PRICE (1995). *Economic Analysis of Agricultural Projects*, Baltimore, Maryland 21218, U.S.A, The John Hopkins University Press.

GRANT PM (1981). The fertility of sandy soil in peasant agriculture, *Zimbabwe Agricultural Journal* **78**, 169-175.

HILL B (1990). *An introduction to economics for students of Agriculture*, Headington Hill Hall, Oxford, England, Pergamon Press plc.

MAKEHAM JP, & MALCOLM LR (1986). *The Economics of Tropical Farm Management,* Cambridge University Press. United Kingdom.

KIRCHMANN H (1985). Losses, plant uptake and utilisation of manure nitrogen during a production cycle, *Acta Agriculturae Scandinavica Supplementum* **24:** 77.

METHO L (2002). *Small-scale maize inter-cropping production*. Ezolimo neZemvelo News, First Edition, April-June, KwaZulu-Natal Department of Agriculture and Environmental Affairs Publication, pp. 15-16.

MKHABELA TS (2002a). Determinants of manure use by small-scale crop farmers in the KwaZulu-Natal Province: A logit analysis, *Agrekon* **41(1)**, 24-42.

MKHABELA TS (2002b). The use of manure by small-scale farmers under dryland farming in KwaZulu-Natal. *Proceedings of the Incentives and mechanisms for conservation in the Arid Zone. Arid Zone Ecology Forum, 27-30 August 2002*, Grootfontein Agricultural Development Institute, Middelburg, Eastern Cape Province, South Africa.

MKHABELA TS (2003). The economic feasibility of using composted feedlot maize on dryland maize. *Agrekon* **42(1)**, 61-71.

MKHABELA TS & SMEDA Z (2003). The use of manure by small-scale farmers under dryland farming in KwaZulu-Natal, *South African Journal of Plant and Soil* (IN PRESS).

MURWIRA HK & KIRCHMANN H (1993). Nitrogen dynamics and maize growth in a Zimbabwean sandy loam under manure fertilization, *Communications in Soil Science and Plant Analysis* **24:** 2343-2359.

MURWIRA HK, SWIFT MJ & FROST PGH (1993). Manure as a key resource in sustainable agriculture. In: Powell MS, Fernandez-Rivera S, Williams TO and

Renard C (eds) Livestock and Sustainable Nutrient Cycling in Mixed Framing Systems of Sub-Saharan Africa Vol. II, pp 131-148. Addis Ababa, Ethiopia: International Livestock Centre for Africa (ILCA).

SIMS JT & WOLF DC (1994). Poultry waste management: Agricultural and Environment issues. *Advances in Agronomy*, **52:** 1-72.