The effects of green manuring and chemical fertiliser application on maize yield, quality and soil composition

Y. SHEHU[1,2], W.S. ALHASSAN[1], G.W.K. MENSAH[1], A. ALIYU[1] AND C.J.C. PHILLIPS[2]
[1]*School of Agriculture, Abubakar Tafawa Balewa University, Bauchi, Nigeria*
[2]*School of Agricultural and Forest Sciences, University of Wales, Bangor, UK*

Abstract

The demand for home-grown cereals and fodder residues in Nigeria is increasing, but continuous cereal growing depletes soil fertility and artificial fertilisers are frequently uneconomic or unobtainable. An alternative is the use of leguminous crops that can be partly grazed and then ploughed into the soil to add nitrogen, organic matter and other minerals (green manuring). The effect of green manuring with pigeon pea (*Cajanus cajan*) on the growth and chemical composition of maize (*Zea mays*) was compared with that of high or low rates of N, P and K artificial fertiliser.

Green manuring increased soil organic carbon and total N content. One year of pigeon pea growth increased the maize leaf yield by a similar amount as the high level of fertiliser (125 kg N, 30 kg P and 30 kg K/ha) and produced a similar increase in leaf crude protein (CP) concentration.

It is concluded that green manuring with pigeon pea can provide crop nutrients equivalent to a high level of fertiliser application.

Introduction

The maintenance of grain yields by traditional shifting cultivation is becoming increasingly difficult in Nigeria due to the increasing demand for land. Continuous cereal growing depletes soil fertility unless nutrients are returned to the soil. The use of chemical fertiliser is one alternative that may be economical in the short term, but the cost is too high for subsistence farmers, if fertiliser can be obtained at all. Green manuring is another alternative, which utilises a legume to fertilise the soil with N fixed from the atmosphere and, when ploughed in, with organic matter from the plant material itself (Tothill 1986). This technique is especially applicable in the humid tropics where rainfall and temperature are sufficient to ensure rapid decomposition of plant material. In the long term, green manuring improves both the physical properties of the soil and soil nutrient levels (Nagar 1979).

Pigeon pea *(Cajanus cajan)* is an adapted legume which has a useful fertiliser value and also provides a valuable dry season feed for cattle (Gooding 1962) and seeds for human consumption. In comparative trials, pigeon pea had a greater fertiliser value than natural regeneration (Dennison 1959), bush fallow, sudan grass, common star grass *(Cynodon dactylon)* and bulrush millet *(Pennisetum typhoides)* but less value than velvet beans (*Stozolobium deeringianum*) (Gooding 1962). However, it is not known how the effects of pigeon pea as a green manure compare with using artificial fertiliser.

In this experiment, the effect on soil composition and maize yield and quality, of 1 year of green manuring with pigeon pea, is compared with that from the application of artificial fertiliser.

Materials and methods

The study was carried out in Bauchi (10° 17′N, 9° 49′E) in the Northern Guinea Savanna Zone of Nigeria over 2 growing seasons (1988–1989). The climate of the area, as described by Blair-Rains (1963), is characterised by 2 well defined seasons, rainy and dry. Rainfall average is 898 mm per year (1980–1991), nearly all of which falls between May and October. Mean daily rainfall was less than normal in the pre-trial

Correspondence: Dr C.J.C. Phillips, Department of Clinical Veterinary Medicine, University of Cambridge, Madingley Road, Cambridge CB30ES, UK. e-mail: cjcp2@cam.ac.uk

year but similar to the 12-year average in the 2 trial years (Table 1). Mean annual maximum and minimum temperatures are 33°C and 19°C, respectively, and mean annual relative humidity is 42%. Mean daily temperature during the period of maize growth was 24°C and relative humidity, 73%. Physical and chemical properties of soils of the study area are presented in Table 2.

Table 1. Pattern of rainfall between April and October, 1987–1989.

	Rainfall			Days with rain		
Month	1987	1988	1989	1987	1988	1989
	(mm)					
April	0	68	27	0	3	2
May	56	91	100	4	6	8
June	219	143	77	11	9	7
July	151	173	182	10	11	12
August	240	276	325	15	16	18
September	31	159	141	5	7	7
October	46	9	82	3	2	4
Total	743	919	934	48	54	58

Table 2. Soil properties before the experiment and after 1 and 2 years of green manuring.

Soil property	Period of green manuring (years)			LSD ($P < 0.05$)
	0	1	2	
pH	6.50	6.50	6.26	0.23
Organic C (%)	0.35	0.39	0.56	0.12
Total N (%)	0.037	0.048	0.080	0.001
CEC (m eq/100 g soil)	12.0	7.5	10.0	1.13
Available P (ppm)	20.2	11.0	15.2	1.04

A 2 ha field was divided into 2 equal areas for a 2-factor (growth of pigeon pea and fertiliser level) experiment. Both areas were drilled on July 5, 1986 with the perennial legume pigeon pea *(Cajanus cajan)* at 35 cm interrow and 10 cm within-row spacing and 2 seeds per hole. One area was grown for 1 year and cattle grazed the pigeon pea from October to March before it was ploughed into the soil and a maize crop was planted in Year 1 of the trial (Treatment 1). The other area was grown with pigeon pea for the pre-trial year and Year 1 and was grazed by cattle during both winters from October–March in the pre-trial year and December–March in Year 1 of the trial before the maize crop evaluation commenced after ploughing the residue into the soil (Treatment 2). Both areas were ploughed and harrowed 3 weeks before the start of the maize crop evaluation in Year 2 of the trial. Spatial replication of these treatments was not possible due to the need to graze cattle on the areas in line with local practice.

Both Treatments 1 and 2 were planted with maize on July 10, 1988 (Year 2) and the trials were repeated the following year with the sowings done on July 17, 1989 (Year 3). Before sowing in both years, both areas were raked and levelled to obtain a good seedbed and 18 plots (5 × 5 m each) laid out on each of the 2 areas with the 2 sets of plots located adjacent to each other. A randomised complete block design consisting of 3 sub-treatments (High, Low and Nil levels of fertiliser) replicated 6 times was used. In each plot, maize (*Zea mays* cv. TZE) was drilled into the seedbed at 2 seeds per hole and 50 cm interrow and 35 cm within-row spacing. The high and low levels of chemical fertiliser provided 125 and 62.5 kg N, 30 and 15 kg P and 30 and 15 kg K/ha, respectively. This was applied as 300 or 150 kg/ha of mixed fertiliser (20N:10P:10K) at sowing and 140 or 70 kg/ha urea (46%N) as a side dressing 3 weeks later, when the seeds had germinated and emerged.

The maize was harvested on November 6, 1988 and November 13, 1989 by cutting plants by hand at 15 cm above ground level. After removing the cobs, the stover was then separated by hand into leaf and stem and samples oven-dried at 80°C for 48 h, before analysing for crude protein (CP) and ash concentration using the procedures of the AOAC (1970). After natural dehydration, the maize seeds were removed from the cobs by hand and weighed.

Soil samples were taken to a depth of 15 cm from 5 locations within each of the 2 experimental areas, 3 weeks before planting with the pigeon pea, and again at the time of maize sowing each year. After analysing for pH, air-dried samples of soil were analysed for clay, silt and sand proportions, organic carbon, total nitrogen, cation exchange capacity and available P (AOAC 1970). Before the experiment commenced, no significant difference was observed between the 2 experimental areas in any of the soil characteristics ($P > 0.05$). Mean clay, silt and sand percentages for the two years were 11.5, 5.0 and 83.5%, respectively.

Analysis of variance was carried out on the maize yields and soil characteristics using the Minitab statistical package (Ryan *et al.* 1985). For maize yields, the green manuring and fertiliser treatments were included as factors. For soil characteristics, the use of the pre-experimental samples as a covariate did not alter the results of analysis of variance of the experimental samples, and the covariate was therefore excluded from the analysis.

Results

The effect of green manuring on soil characteristics is shown in Table 2. Soil organic carbon, total N, cation exchange capacity and available P all increased with green manuring. The organic C and total N proportions after 2 years of green manuring were greater than after 1 year.

There were no significant interactions ($P > 0.25$) between green manuring and fertiliser application, so results are presented separately for the 2 factors. Cropping with pigeon pea rather than maize in Year 1 increased leaf yield and slightly improved grain yield in the subsequent maize crop (Table 3). Pigeon pea also increased the CP concentration of the leaves and reduced the ash concentration of the stems.

The high level of fertiliser tended to increase grain yield compared with no fertiliser but this difference was not statistically significant (Table 4). However, the high fertiliser level did increase the yield of maize leaves and tended to increase the yield of stems and the combined weight of leaves plus stems. Yields of maize receiving the low fertiliser level were intermediate between the high and nil levels. The CP concentration in the leaves was increased with the high level of fertiliser.

Table 3. The effect of green manuring or maize in Year 1 on maize yields and chemical composition in Years 2 and 3.

	Treatment		LSD ($P < 0.05$)
	Maize	Green manure	
DM yields (t/ha)			
Grain	4.56	5.50	1.16
Leaves	1.35	1.63	0.17
Stems	2.79	3.00	0.61
Leaves + Stems	4.14	4.63	0.75
Crude protein (g/kg DM)			
Leaves	57.8	66.2	4.32
Stems	35.8	36.2	6.15
Ash (g/kg DM)			
Leaves	102.1	103.1	5.74
Stems	64.2	52.3	7.19

Table 4. The effect of green manuring and level of chemical fertiliser on maize grain, leaf and stem yields and quality.

	Fertiliser rate			LSD ($P < 0.05$)
	High	Low	Nil	
DM yields (t/ha)				
Grain	5.26	5.18	4.65	1.45
Leaves	1.65	1.49	1.33	0.23
Stems	3.22	3.01	2.45	0.78
Leaves + Stems	4.87	4.50	3.78	1.12
Crude protein (g/kg DM)				
Leaves	65.9	62.5	57.6	5.34
Stems	39.2	34.7	34.0	7.60
Ash (g/kg DM)				
Leaves	104.6	103.5	99.8	7.19
Stems	53.7	63.3	57.7	9.82

Discussion

The results indicate that the effect of green manuring is similar to that from applying the higher level of fertiliser (125 kg N, 30 kg P and 30 kg K/ha) in the magnitude of the increase in maize leaf yield and CP concentration. This is greater than the 45–60 kg/ha N which Mohamed-Saleem (1985) estimated a fodder bank supplied for a subsequent crop. However, Haque and Jutzi (1984) estimated that forage legume cropping normally produced about 100–140 kg/ha N for the subsequent crop, which is similar to the high level used in this experiment.

The tendency for green manuring to increase maize grain yields was not achieved with artificial fertiliser and may reflect improved soil organic C concentration and greater long-term benefits to crop growth with green manuring. Apart from this, the similarity in response to chemical and manurial fertilisers demonstrates the potential of the maize crop to respond to both forms of fertiliser equally and additively. The maximum yields of grain, stem and leaf achieved with both the 2-years green manuring and the

high level of fertiliser are similar to yields normally achieved under temperate conditions (Wilkinson 1985), but less than the maximum yields recorded under trial conditions of about 17 t/ha DM (Cambridge Plant Breeders, personal communication). However, Gooding (1962) reported that the beneficial effect of pigeon pea green manuring on maize yield was negated by the application of 45 kg/ha of ammonium sulphate. Maize grain yields of 4.5–5.5 t/ha DM in this experiment were considerably greater than the 1.8 t/ha DM, which is the normal yield with the recommended application of 120 kg N, 60 kg P and 60 kg K/ha in the Sudan Savanna zone (Powell 1984). However, the yield is similar to the 5.5 t/ha reported previously from the same site by Shehu and Alhassan (1988) with the application of 90 kg/ha N.

References

AOAC (1970) *Official Methods of Analysis of the Association of Official Analytical Chemists.* 11th Edn. (AOAC: Washington, DC).

BLAIR-RAINS, A. (1963) Grassland Research in Northern Nigeria, 1952–1962. *Samaru Miscellaneous Paper No. 1.* 69pp. (Ahmadu Bello University: Zaria, Nigeria).

DENNISON, E.B. (1959) The maintenance of soil fertility in the Southern Guinea Savannah zone of Northern Nigeria (Tiv Country). *Tropical Agriculture (Trinidad),* **36**, 171–176.

GOODING, H.J. (1962) Review article: The agronomic aspects of pigeon pea. *Field Crop Abstracts,* **15**, 1–5.

HAQUE, I. and JUTZI, S. (1984) Nitrogen fixation by forage legumes in Sub-Saharan Africa: Potential and limitations. *International Livestock Centre for Africa Bulletin,* **20**, 2–18.

MOHAMED-SALEEM, M.A. (1985) Effect of sowing time on grain yield and fodder potential of sorghum under-sown with stylo in the sub-humid zone of Nigeria. *Tropical Agriculture (Trinidad),* **62**, 151–153.

NAGAR, B.R. (1979) Alternative to energy-intensive fertilizers. In: Lockertz, W. (ed.) *Agriculture and Energy.* pp. 657–667. (Academy Press: New York).

POWELL, J.M. (1984) Assessment of dry matter yield from grain yield in the West African Savanna Zone. A short note. *Journal of Agricultural Science (Cambridge),* **103**, 695–696.

RYAN, B.F., JOINER, B.L. and RYAN, T.A. (1985) *Minitab Handbook.* 2nd Edn. (Duxbury Press: Boston, Massachusetts).

SHEHU, Y. and ALHASSAN, W.S. (1988) Cereal-forage legume intercropping studies in the Sudan Savanna zone of Nigeria. *Paper presented at the 13th Annual Conference of the Nigerian Society of Animal Production held at the University of Calabar, Calabar, March 20–24, 1988.*

TOTHILL, J.C. (1986) The role of legumes in farming systems of Sub-Saharan Africa. In: *Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, September 16–19, 1985.* pp. 162–185.

WILKINSON, J.M. (1985) *Beef Production from Silage and other Conserved Forages.* 31pp. (Longmans: London).

(Received for publication December 8, 1995; accepted February 20, 1997)