Effects of sheep kraal manure on growth, dry matter yield and leaf nutrient composition of a local *Amaranthus* accession in the central region of the Eastern Cape Province, South Africa[#]

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Abstract

Indigenous vegetables that supply abundant amounts of protein, vitamins, calories and minerals could alleviate problems of malnutrition, in developing countries. *Amaranthus* is one such vegetable that could be domesticated and cultivated but information on its fertility requirements is scanty. A dry-land field experiment was therefore conducted to study the effects of sheep kraal manure application rates on growth, fresh and dry matter yields, nutrient uptake and grain yield of one of the *Amaranthus* accessions that grow in the wild in the Eastern Cape. The treatments were sheep kraal manure rates ranging from 0 to 10 t/ha and an NPK {2:3:4(30) + 0.5% Zn} fertiliser as a positive control at 150 kg/ha. Low manure rates (≤2.5 t/ha) resulted in plant heights and fresh matter yields which were comparable to those in the unfertilised control, whereas higher rates (5 and 10 t/ha) and NPK fertiliser gave greater plant heights and higher yields at both 30 and 60 days after transplant (DAT) ($p<0.05$). At 30 DAT, manure application rates of ≥2.5 t/ha and the NPK fertiliser treatment, produced greater shoot dry-matter yields (≥29.35 g/plant) than the unfertilised control (17.11 g/plant). Uptake of N and P in the leaves increased with increase in manure application rate with N uptake reaching a maximum of 308 mg N /plant at a manure rate of 2.5 t/ha which corresponded with the maximum dry matter yield of 45.97 g/plant. There was no effect of manure rate or fertiliser on residual soil N and Ca, whereas P, K, Mg and Zn were increased ($p<0.005$). The findings suggested that ≥2.5 t/ha sheep kraal manure could result in growth, nutrient uptake and yield comparable to 150 kg/ha NPK fertiliser for the *Amaranthus* accession used in this work.

Keywords: *Amaranthus* accession, sheep manure, dry matter yield, nutrient composition, residual nutrients

Introduction

Hunger and malnutrition are mostly experienced in developing countries where they affect growth and development of children (Aphane et al., 2003). Foods of animal origin, which are major sources of vitamins and proteins, are often too expensive for poor households (Aphane et al., 2003; Wehmeyer and Rose, 1983). Vegetables that supply abundant amounts of protein, vitamins, calories and minerals, needed in a diet, could alleviate problems associated with malnutrition (Wehmeyer and Rose, 1983). However, the production of exotic vegetables is made difficult by harsh climatic and resource-poor conditions encountered in most rural areas, where problems of malnutrition occur.

More than 100 different indigenous species, including *Amaranthus* sp., *Corchorus* genera, *Cleome gynandra*, grow well in such areas (Jansen van Rensburg et al., 2004; Aphane et al., 2003). They are popular in communities such as in the former Transkei, South Africa, where their leaves are gathered from plants growing in the wild, chopped and mixed with maize meal to prepare a traditional meal known as '*imifino*' or '*isigwampa*' (Wehmeyer and Rose, 1983). *Amaranthus* could be cultivated in areas of Southern Africa where there is inadequate or unreliable rainfall (Jansen Van Rensburg et al., 2004) but information on its fertilisation requirements is limited (Elbehri et al., 1993). Moreover chemical fertilisers are expensive for the resource-poor farmers who often utilise those vegetables (Jansen Van Rensburg et al., 2004). Hence there is need to investigate cheaper sources of nutrients such as animal manures. According to Schippers (2000), the crop gives good yield when high levels of nitrogen are applied and it responds well to organic matter.

Farmers in the Eastern Cape use kraal manure in their maize-based cropping systems to address problems of declining soil fertility (Van Averbeke and De Lange, 1995). While guidelines exist on the use of kraal manure for crops such as maize (Van Averbeke and Yoganathan, 1997), no information could be found on the use of kraal manure on *Amaranthus* in the Eastern Cape. This article reports on effects of sheep kraal manure application rates on growth, fresh and dry matter yields, nutrient uptake and grain yield of a local *Amaranthus* accession in the central region of the Eastern Cape.

Experimental

The experiment was conducted between November 2002 and May 2003 in Gqumahashe village (32° 45' S; 26° 52' E), five km north of Alice town. The soil contained 0.026% K, 0.35% Ca, 0.044% Mg, 2.5 mg P/ℓ and 1.4 mg Zn/ℓ, with pH 5.3 (in KCl). Sheep kraal manure used in this study was collected from kraals in the village and contained 1.8% N, 3.7% Ca, 1.4% Mg, 0.37% P, 16 000 mg/kg Fe and 872 mg/kg Zn. It was applied to the soil at different rates (0, 0.3, 0.6, 1.2, 2.5, 5.0 and 10 t/ha). Inorganic NPK fertiliser {2:3:4(30) + 0.5% Zn} was applied at a rate of 150 kg/ha, the rate recommended for spinach by Makus (1984), as a positive control. The experiment

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was arranged in a randomised complete block design (RCBD) with four replications. Sheep kraal manure was broadcast in the designated plots after land preparation and incorporated into the soil, using a rotavator, two weeks before transplanting. Inorganic fertiliser was also applied by broadcasting and incorporated a day before planting.

One-month-old seedlings of an unclassified *Amaranthus* accession that grows in the wild in the Eastern Cape were transplanted on 17 December 2002, in 6 m rows (6 rows /plot) with an inter-row spacing of 1 m and intra-row spacing of 30 cm. The seedlings were then irrigated for the first week to aid establishment, whereafter they solely depended on rain. Other management practices, like weeding, were the same across the treatments. No pesticides were applied. Data collection and sampling for growth, fresh and dry matter yields, were done at 30 and 60 d after transplanting (DAT). Two plants were randomly selected from the two middle rows in each plot and uprooted. Stem girth, plant height, number of leaves and fresh mass (stems and leaves) were determined, before dry matter (leaves and stems) was determined after drying in an oven at 60°C to constant mass. All oven-dried leaf samples were ground, digested and analysed for total N, P, K, Ca, Mg, Fe and Zn as described by Okalebo et al. (2002). Nutrient uptake (N, P, K, Ca, Mg, Fe and Zn) was then calculated from the leaf dry matter and the composition of the nutrients in the leaves. Grain mass and residual soil nutrient composition were determined at 90 DAT. Analysis of variance (ANOVA) was done using the MStat C statistical software and least significant differences (LSD) at 5% significant level were used to separate the means.

Results and discussion

Effects of sheep manure application rate on growth of *Amaranthus*

Plant height, number of leaves and stem girth, increased significantly ($p<0.05$) with an increase in sheep kraal manure application rate (Table 1). At low manure rates (≤2.5 t/ha), the plants had comparable height to those in the unfertilised control, whereas higher rates (5 and 10 t/ha) and NPK fertiliser resulted in greater plant heights both at 30 and 60 DAT. Similar results were observed by Elbehri et al. (1993), who reported increased *Amaranthus* plant height at higher nitrogen application rate. At low manure rates (≤1.3 t/ha) the number of leaves were comparable to the unfertilised control, whereas higher rates (2.5 to 10 t/ha) and the NPK fertiliser treatments produced larger numbers of leaves both at 30 and 60 DAT. These responses could be ascribed to increased uptake of nutrients as a result of the availability of larger amounts of nutrients in the soil as the amount of manure increased.

Manure application resulted in larger stem girth when compared to the unfertilised control but there was no additional response to increased application from 0.3 to 10 t/ha, giving values similar to that obtained with the NPK fertiliser. These results appear to indicate that addition of manure at 0.3 t/ha provided sufficient nutrients for maximum stem girth at growth stages up to 60 DAT and the rest of the nutrients were partitioned towards stem elongation and leaf production.

Sheep manure application effects on fresh yield of *Amaranthus*

Fresh matter yield (leaf, stem and shoot) increased significantly ($p<0.05$) with an increase in sheep kraal manure application rate (Table 2). Where low rates of kraal manure (≤2.5 t/ha) were applied, leaf stem and shoot fresh matter yields were comparable to unfertilised control both at 30 and 60 DAT. Higher rates of sheep kraal manure (5 and 10 t/ha) produced higher fresh matter yields than the unfertilised control, giving values similar to that obtained with the NPK fertiliser. At the higher sheep kraal manure application rates, the results compared well with those reported by Makus (1984) for different accessions of *Amaranthus*, fertilised with mineral fertiliser at recommended rates for spinach. The values obtained in the present study were lower than those reported by Allemann et al. (1996) for different varieties of *Amaranthus* at ARC-Roodeplaat, the research station of the Vegetable and Ornamental Plant Institute, near Pretoria. This is logical, since in the latter experiment the crop was grown under irrigation, while in the present study it was grown under rain-fed conditions in an abnormally dry season. In the irrigated experiment of Allemann et al. (1996) fertiliser applications were also much higher than in the present experiment, as is normal for irrigated conditions. In the present study the highest leaf fresh matter yield at 30 DAT was obtained with an application of 5 t/ha sheep kraal manure, while at 60 DAT it was obtained with the inorganic NPK fertiliser treatment. These results indicate that a sheep kraal manure application rate of at least 5 t/ha is critical to maximise *Amaranthus* fresh matter yield if the crop is to be cultivated and used as a vegetable.

TABLE 1
Effects of sheep kraal manure application on growth of *Amaranthus*

Manure rates (t/ha)	Plant height (cm)		Stem girth (cm)		Number of leaves	
	30 DAT*	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
0	30.50c**	37.00d	0.75c	1.40b	67b	92c
0.3	34.00bc	42.25cd	1.00bc	1.68ab	86ab	111bc
0.6	33.75bc	41.50d	1.10ab	1.70ab	86ab	112bc
1.3	38.75abc	48.25bcd	1.18ab	1.73a	99ab	122bc
2.5	40.50abc	47.75bcd	1.25ab	1.90a	117a	140abc
5.0	45.00ab	54.25abc	1.35a	1.95a	118a	150ab
10.0	47.25a	61.00a	1.30a	2.03a	126a	153ab
NPK fertiliser	46.50a	57.50ab	1.23ab	2.03a	114ab	181a
CV (%)	21	17	17	16	32	27

** DAT = Days after transplanting*
***Means in each column followed by the same letter or none at all are not significantly different at p < 0.05.*

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TABLE 2 Effects of sheep kraal manure application on fresh matter yield of *Amaranthus*						
Manure rate (t/ha)	Leaves (g/plant)		Stems (g/plant)		Shoots (g/plant)	
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
0	18.88d*	28.50c	21.73d	45.76d	45.66c	97.16d
0.3	25.85cd	51.82bc	31.39cd	66.08cd	67.47bc	132.66cd
0.6	31.08abcd	56.05bc	43.33bcd	66.43cd	96.14abc	143.53cd
1.3	28.48bcd	54.06bc	43.93bcd	96.90bcd	103.27abc	154.70bcd
2.5	38.90abcd	68.21abc	51.55abcd	113.15abcd	106.54abc	194.85abc
5.0	50.45a	77.25ab	78.00ab	129.40abc	149.17a	239.05ab
10.0	48.88ab	78.73ab	90.28a	156.60ab	149.72a	262.45a
NPK fertiliser	41.95abc	104.10a	70.28abc	181.38a	127.94ab	258.80a
CV (%)	39	46	53	49	50	35

** Means in each column followed by the same letter or none at all are not significantly different at $p < 0.05$.*

TABLE 3 Effects of sheep kraal manure application rates on dry matter yield of *Amaranthus*							
Manure rate (t/ha)	Leaves (g/plant)		Stems (g/plant)		Shoots (g/plant)		Grain yield (g/plot)
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	
0	6.17c*	10.26f	4.11d	5.69d	17.11c	19.35c	362
0.3	8.44bc	14.62ef	6.15cd	10.09cd	21.88bc	28.74b	402
0.6	9.79abc	16.63de	7.55bcd	12.65bcd	26.67abc	31.27b	405
1.3	9.75abc	18.32cde	7.71bcd	15.49bcd	27.03abc	36.69b	412
2.5	11.84ab	21.96bcd	9.30abc	18.28abc	29.35ab	45.97a	428
5.0	12.49ab	23.52abc	9.86abc	22.28ab	30.74ab	46.97a	443
10.0	13.44a	24.68ab	14.03a	25.35a	37.68a	49.77a	488
NPK fertiliser	12.16ab	27.72a	12.07ab	26.49a	38.09a	52.78a	532
CV (%)	30	19	38	39	27	16	33

** Means in each column followed by the same letter or none at all are not significantly different at $p < 0.05$*

Effects of sheep manure rate on dry matter and grain yield of *Amaranthus*

Dry matter (leaf, stem and shoot) yields increased with increasing manure application rate (Table 3). At 30 DAT, manure application rates of ≥2.5 t/ha and the NPK fertilised treatment, produced greater shoot dry-matter yields than the unfertilised control. The yields obtained in the present study were lower than those reported for the irrigated experiment by Allemann et al. (1996), which is logical. The unfertilised control produced yields which were comparable to those from manure rates ranging from 0.3 to 1.27 t/ha. Elbehri et al. (1993) reported improved forage yield of *Amaranthus* as a result of nitrogen addition. The findings suggested that 2.5 t/ha of sheep kraal manure would supply sufficient nutrients (compared to the recommended fertiliser application) for dried vegetable *Amaranthus,* especially when the leaves are to be harvested at a young age (30 DAT). This is recommended and is practised in the Eastern Cape (Wehmeyer and Rose, 1983; Bhat and Rubuluza, 2002). This critical manure rate is lower than the one based on fresh matter yield. This could be a result of differences in water uptake by the plants at the time of sampling. From the differences in fresh and dry matter responses to the two different kraal manure rates, the results indicated that the plants in the 5 t/ha manure treatment took up more water than in the 2.5 t/ha treatment. Since fresh material is normally consumed, a kraal manure application of 5 t/ha would seem the more logical rate at which to apply it. It is important to note that at the young growth stage at which the leaves are normally harvested (30 DAT) fairly moderate sheep kraal manure applications gave better results than inorganic NPK fertilisers. Grain yield did not respond to sheep kraal manure or fertiliser application when compared to the control (Table 3).

Sheep manure effects on nutrient concentrations and amounts in *Amaranthus* leaves

The concentrations of Ca, Mg, P, N and K in the *Amaranthus* leaves agreed very well with those reported for different accessions of the crop by Makus (1984) while Fe and Zn were much lower. There were no effects of rate of manure application on N, P, K, Ca, Mg, and Zn concentrations in *Amaranthus* leaves at 30 DAT (Table 4). These results agree with those of Ore-Oluwa et al. (1981) who reported no effects of nitrogen on accumulation of Ca, K, Na, Cu and Zn in *Amaranthus* leaves. However, uptake of N and P in the leaves increased with increase in manure application rate, with N uptake reaching a maximum at a manure rate of 2.5 t/ha, which corresponded with maximum dry matter yield (Table 5). Due to the close relation between N and protein, the same trend was observed for crude protein. Crude protein contents compared favourably with other indigenous vegetables used in the Eastern Cape, and thus could supplement the maize-based diets with protein (Wehmeyer and Rose, 1983). The findings indicate that 2.5 t/ha or higher rates of sheep kraal manure supplied adequate amounts of nutrients (especially N and P) for optimum yields.

Leaf Fe concentration results agreed with those reported by Jansen Van Rensburg et al. (2004). It varied with different

TABLE 4 **Effects of sheep kraal manure application on nutrient concentrations in *Amaranthus* leaves at 30 DAT**							
Manure rate (t/ha)	**Nutrient concentrations in *Amaranthus* leaves**						
	N	**P**	**K**	**Mg**	**Ca**	**Fe**	**Zn**
	(%)					**(mg/kg)**	
0	2.17*	0.09	3.3	1.4	3.9	60.0bc	2.9
0.3	2.19	0.12	3.5	1.4	3.9	46.9c	3.2
0.6	2.57	0.09	3.8	1.3	3.6	132.3a	2.4
1.3	2.34	0.12	3.4	1.3	3.8	90.9abc	2.2
2.5	2.53	0.12	3.6	1.5	3.7	100.6abc	2.3
5.0	2.13	0.11	3.7	1.3	3.5	81.1abc	2.5
10.0	2.25	0.13	4.3	1.5	3.7	97.8abc	3.8
NPK fertiliser	2.47	0.14	4.7	1.3	3.7	116.5ab	2.3
CV (%)	17	14	16	13	12	43	49

**Means in each column followed by the same letter or none at all are not significantly different at p < 0.05.*

TABLE 5 **Effects of sheep kraal manure rate on nutrient amounts in *Amaranthus* leaves at 30 DAT**						
Manure rate (t/ha)	**Nutrient uptake (mg/plant)**					**Crude protein (g/plant)**
	N	**P**	**K**	**Mg**	**Ca**	
0	134c	6.03d	207	82	240	0.84c
0.3	178bc	9.05cd	288	116	324	1.11bc
0.6	264ab	9.88bcd	360	138	352	1.65ab
1.3	262ab	11.88abcd	310	130	369	1.64ab
2.5	308a	13.10abc	482	176	436	1.93a
5.0	273ab	13.38abc	506	158	443	1.71ab
10.0	267ab	17.83a	520	182	503	1.67ab
NPK fertiliser	315a	16.80ab	565	154	452	1.97a
CV (%)	35	35	34	34	34	21

**Means in each column followed by the same letter or none at all are not significantly different at p < 0.05.*

manure and fertiliser applications, though no specific trend was observed (Table 4). Rates of manure application greater than 0.6 t/ha, however, generally resulted in levels of Fe that were higher than in the control treatment. Since Fe is an important element in human nutrition, these results suggest that in addition to improving yields, fertilisation of *Amaranthus* with sheep manure will have the added benefit of improving its nutritional value, including Fe.

Effects of sheep manure application rates on residual soil nutrient composition

Post cropping soil pH increased from 5.4 to 5.8 in response to increasing manure rate from 0 to 10 t/ha, whereas the NPK fertiliser depressed it (Table 6). Manure rates <2.5 t/ha had post-cropping pH values which were comparable to the unfertilised control, whereas higher rates had significantly higher pH values ($p<0.05$). The liming effect of manure could be of great significance in the Eastern Cape where manure is readily available and pH of most of the soils has been reported to be critically low (Mandiringana et al., 2005).

There was no effect of manure rate or fertiliser on residual soil N, suggesting that the crop had exhausted the soil N from manure or fertiliser. Lower manure rates (≤1.3 t/ha) resulted in lower residual soil P than the higher rates (2.5-10 t/ha). Although the latter gave lower plant-available soil P levels than the NPK fertiliser (Table 6), the increases were substantial, which agrees with the findings of Eghball and Power (1999), who reported an accumulation of soil P as a result of manure application. This could probably benefit the next crop grown on this soil but could over several seasons of application of high manure rates lead to the build-up of excessive soil P levels. This could eventually result in P/Zn imbalance, which could result in reduced Zn uptake if manure is applied at high levels over long periods (Brady and Weil, 1999).

Residual soil K from plots fertilised with NPK fertiliser, and low manure rates (0.3 to 1.3 t/ha), did not differ statistically significantly from that in the unfertilised control. At higher kraal manure rates (2.5 to 10 t/ha) sharp increases in soil K levels were observed. Soil K levels in all the treatments, even the unfertilised control, exceeded 200 mg K/kg. This is above the critical level of 80 to 120 mg K/kh (Bornman et al., 1989), which explains the lack of K uptake response to manure or fertiliser application. The results are in agreement with Laker (1976), who reported that, in general, South African soils do not have K deficiency problems. Although the uptake of Mg did not respond to manure and fertiliser application, its residual levels increased at manure rates of 5 and 10 t/ha (Table 6). Calcium ranged between 3 914 and 4 690 mg Ca/kg. The manure rate of 10 t/ha gave a significantly higher calcium level than all the other treatments (Table 6). Low manure rates (0.3 to 1.3 t/ha) did not increase residual Zn levels significantly above the unfertilised control, while higher manure applica-

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TABLE 6 Effects of sheep kraal manure application rates on residual soil nutrient composition								
Manure rate (t/ha)	pH (KCl)	Total N (%)	OC (%)	Selected nutrients (mg/kg)				
				P	K	Mg	Ca	Zn
0	5.40c	0.07	1.70b	4.00d	212.00d	309.70c	3914b	1.61e
0.3	5.50c	0.09	1.93a	4.50d	203.28d	325.63bc	3943b	2.13cde
0.6	5.45c	0.09	1.74ab	4.87d	237.55d	344.83bc	3900b	1.88de
1.3	5.50c	0.10	1.88ab	6.21d	268.75d	359.75bc	3822b	2.02cde
2.5	5.55bc	0.10	1.89ab	15.28c	351.75c	350.50bc	4038 b	2.28bcd
5.0	5.70ab	0.09	1.92a	19.50c	433.61b	376.00b	4019 b	2.43bc
10.0	5.80a	0.09	1.87ab	28.00b	533.75a	456.50a	4690a	2.78b
NPK fertiliser	5.20d	0.09	1.78ab	36.23a	267.25d	362.63bc	3968b	6.04a
CV (%)	2.02	17.50	7.01	29.21	14.36	10.71	9.32	13.12

**Means in each column followed by the same letter or none at all are not significantly different at $p < 0.05$.*

tions (≥2.5 t/ha) significantly increased soil Zn levels. This indicates that the application of sheep manure can increase the zinc fertility of Zn deficient soils. In the present study, however, Zn was not a problem as levels in all treatments, including the control were within or above the critical range of 1.5 to 2 mg Zn/kg (Bornman et al., 1989). The inorganic NPK {2:3:4(30) + 0.5% Zn} fertiliser treatment gave the highest level of residual Zn (Table 6), because the fertiliser contained Zn in its formulation.

Conclusions

The findings of this study suggest that sheep kraal manure rates of 2.5 t/ha or higher could result in *Amaranthus* growth, yield and nutrient uptake, similar to those of the recommended NPK {2:3:4(30) + 0.5% Zn} fertiliser at 150 kg/ha under dry-land conditions of the Central Region of the Eastern Cape. In fact, at the young growth stage at which *Amaranthus* is normally harvested, fairly moderate sheep kraal manure applications gave better results than commercial inorganic NPK fertiliser. In addition to improved growth, the crop was enriched with iron and crude protein, which are very important in human nutrition. Sheep manure, at rates ≥2.5 t/ha, raised soil pH (liming effect) and had high residual fertility, as indicated by high levels of P, K, Mg and Zn at harvest time. Therefore, *Amaranthus* needs not be fertilised with mineral fertilisers where sheep kraal manure or other forms of manure are available. Organoleptic tests and other proximate analyses are needed to establish whether or not the yield increase observed with manure addition was at the expense of the good taste and high crop quality of the vegetable. Further research replicated over many sites and incorporating a comparative cost analysis is needed to establish the cost effectiveness of using kraal manure as a source of nutrients for *Amaranthus.*

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