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Nutrient Availability as Affected by Manure Application to Cowpea (*Vigna unguiculata* L. Walp.) on Calacarious Soils

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ABSTRACT

A greenhouse experiment was carried out to study the effects of cattle manure and poultry litter on the avialability of major and minor nutrients to cowpea [*Vigna unguiculata* (L.) Walp.]. Rates of manure and litter were 20, 40, 60, 80 and 100 metric tones ha^{-1}. Tissue analysis were made for different nutrients. The aviallability and content of macro- and micro-nutients and heavy metals were increased by application of manure, as was determined by plant tissue analysis studies. As a result dry matter yield and yield components were also significantly affected by manure application. In general, nutrient avialability in cowpea was much affected by application of cattle manure and poultry.

Key Words: Nutrient; Manure; Cowpea; Calacarious soil

INTRODUCTION

Poor soil fertility is one of the major problems limiting crop production in dryland areas due to low soil organic matter and light, high temperature and low rainfall. Manure from confined animal feeding lots is important for crop production and soil sustainability, in that it is a source of all essential nutrients. The manure also provides an excellent source of organic matter when added to soils, restoring some of the organic matter depleted by many agricultural practices (Allison, 1973; Eghball & Power, 1994). Cowpea [(*Vigna unguiculata* (L.) Walp.] is a grain legume grown in Savanna of the tropical and subtropical regions. The majority is grown in West and Central African countries. Its value lies in its high protein content and tolerance to drought. In fact, it fixes atmospheric nitrogen which allows it to grow on and improve poor soils. Its grain contains about 25% protein, making it extremely valuable food where many people cannot afford the cost of animal protein. After the cowpea pods have been harvested, the rest of the plant can be used as animal feed. The ability of cowpea crop to tolerate drought and poor soils makes it an important crop in Savanna regions where these constraints restrict growth of other crops. In an estimate 3.3 million tonnes of cowpea dry grains were produced worldwide during the year 2000. The world average yield was 337 kg ha^{-1} (Bressani & Ricardo, 1985; IITA, 2000). This research was conducted in the greenhouse in view of the fact that scanty information is available on the growth, quality and aviallabilty of nutrient to cowpea in calcareous soils ammended with cattle manure and poultry litter.

MATERIALS AND METHODS

A greenhouse study was conducted in CRD factorial with four replicates during summer 2001 on a calcareous silty loam soil at the University of Jordan, Faculty of Agriculture. Dry cattle manure and poultory litter each with five rates (20, 40, 60, 80, and 100 metric tones ha^{-1}), were added and mixed with 12 kg soil pot^{-1}. Soil was collected from the University of Jordan Research Station, located near Muwqare village (45 km South East of Amman), from a site that did not received any manure treatment. Samples were taken from the surface down to 20 cm depth. The soil was classified as fine silty, mixed, thermic, typic calciorthid. The exact quantity of cattle manure and poultry litter of different rates on air dry weight basis was thoroughly mixed with soil in each pot (measuring 20x27 cm) separately before planting. Ten seeds of cowpea variety California Blackeye Beans (determinate type) were sown on 28 June 2001 at the depth of 2.5 cm. After emergence the plants were thinned to five seedlings per pot. Irrigation was scheduled according to the field capacity of the control pots. The soil moisture of all treatments were maintained at 60 to 65% of field capacity by weighing the pots and adding the difference in weight. Application rate of poultry litter (PL) and cattle manure (CM) on a hectar and pot bases are listed below. The following agronomic data were collected from each pot: number of days to 50% emergence, number of days to 50% flowering, dry matter yield at maturity (plant material 3 cm above the soil level), number of main branches per plant, number of leaves per plant, pod length, number of pods per plant and plant height. Samples for chemical analysis were taken from those plants which were used to evaluate the dry matter yield. An soil particles were removed from the samples, washed with detergent (0.01N HCl) followed by distilled water, oven dried at 65-70^{o}C and then ground with Willy Mill. The chemical analysis included: wet digestion was used to digest the plant samples (Jackson, 1958) to determine total N concentration by Kjeldahl method, P concentration by spectrophotometer, K concentration by flame photometer and crude proteins as N % x 6.25. Wet digestion was used to digest the plant samples using concentrated HNO_3 and concentrated $HClO_3$ (Jackson, 1958) to determine concentrations of Fe, Zn, Mn and Cu by atomic absorption spectrophotometer. Data were evaluated using orthogonal contrast, and the mean separation (using LSD methods) was done using MSTAT-C program (Russell, 1989).

RESULTS AND DISCUSSION

The total soil nitrogen was 0.084%, that is within the range of surface layers of most cultivated soils (0.06 - 0.5%) (Table I). However, the concentration of P and K were sufficient according to Ryan *et al.* (1996). The soil Zn, Mn and Cu concentrations were more than adequate for cowpea growth, however, concentration of Fe was very low since it was less than 4.5 ppm (Ryan *et al.*, 1996). Soil organic matter content was marginal since it was within the range of 0.86-1.29%. On the other hand, P and trace elements were higher for poultry litter than cattle manure. Heavy metals concentrations were almost equal in both the soils (Table II). Consequently poultry litter was likely to provide more P and trace elements than cattle manure. Cattle manure is mineralized faster due to low C:N ratio content.

Performance of Cowpea. Manure treated soils didn't show significant difference from the control (non manured) treatment in number of days to seedling emergence (Table III). No significant difference existed between the poultry litter and cattle manure, as well as between the different

Table I. Some chemical and physical characteristics of the soil used

Characteristics	Value
pH (1:1)	8.100
EC (dS/m)	1.300
O.M (%)	0.084
$CaCO_3$(%)	14.800
N (%)	0.200
NO_3 (ppm)	106.000
P (ppm)	12.000
K (ppm)	900.000
Fe (ppm)	2.010
Zn (ppm)	2.890
Mn (ppm)	3.490
Cu (ppm)	1.260
Pb(ppm)	0.420
Cd(ppm)	0.034
Soil Texture	Silt loam
Bulk Density (g/cm ^{3})	1.300

Table II. The chemical characteristics of poultry litter and cattle manure

Characterstics	Values	
	Poultry litter	Cattle manure
pH	7.60	8.30
EC (dS/m)	6.50	14.40
O.M(%)	42.40	40.20
N(%)	0.84	0.94
P (%)	1.00	0.80
K (%)	1.80	4.30
NO_3(ppm)	6732.00	8420.00
Fe (ppm)	1345.00	2524.00
Zn (ppm)	391.90	266.50
Mn (ppm)	269.20	160.80
Cu (ppm)	46.40	30.40
Pb(ppm)	29.60	30.40
Cd(ppm)	2.96	2.96
C/N ratio	29.27	24.8

Table III. Mean values and orthogonal contrast of dry matter yield and yield components at different rate of poultry litter and cattle manure

Sources	Rate (mt/ha)	Dry matter yield (gm/plant)	No.of Leaves/ Plant	No. of Branches / plant	No. of Pods / plant	Pod length (cm)	plant height (cm)	No. of days to 50% emergence	No. of days to 50% flowering
Control	0	17.500	12.075	4.200	2.000	12.000	33.700	6.5	35.200
Poultry litter	20	21.250	14.000	5.100	2.750	13.800	40.250	6.5	41.250
	40	26.500	15.400	5.650	3.750	14.850	50.950	6.7	48.950
	60	30.750	16.900	6.150	4.000	15.475	56.800	6.5	55.300
	80	34.750	18.550	6.800	4.250	16.375	60.450	6.5	59.450
	100	34.250	21.575	8.125	4.250	17.325	68.530	6.3	63.025
Cattle manure	20	27.500	15.250	5.050	2.750	12.425	35.750	6.8	35.750
	40	33.000	19.575	7.025	3.250	14.125	43.950	6.5	42.200
	60	36.500	20.950	7.800	4.000	16.225	57.430	6.5	52.175
	80	37.750	23.100	8.000	4.000	16.225	64.150	6.5	58.400
	100	40.000	26.350	8.700	4.500	16.875	73.600	6.8	63.850
LSD (0.05)		4.467	3.479	1.193	0.6228	1.823	9.474	NS	6.308
CV, %		10.000	13.010	12.510	12.020	8.380	12.320	8.38	8.650
Contrast									
Control vs others		***	***	***	***	***	***	NS	***
Poultry litter vs cattle manure		***	***	***	NS	NS	NS	NS	***
Poultry litter rate									
Linear		***	***	***	NS	***	***	NS	***
Quadratic		NS	NS	NS	***	NS	NS	NS	NS
Cattle manure rate									
Linear		NS	***	***	***	***	**	NS	***
Quadratic		***	NS	NS	NS	NS	NS	NS	NS

*, **, ***: Significant F-tests at the 5, 1, and 0.1 % levels, respectively. NS: not significant

rates for the same parameter. This was probably due to the shallow planting depth used that masked the effect of manure even at higher rates. Which was in contrast to Ahmed (1997) who found an increase in emergence of common vetch by addition of 10 tons ha^{-1} manure. Contrary of the emergence data, there was significant difference for manure treated soils (52.04) over the control (35.2) in number days to 50% flowering. Poultry litter treatment (53.6) was also significantly superior to cattle manure (50.48). As the level of manure increased the number days to 50% flowering was also prolonged showing a positive relashnship (Table III). This can be assignable to the supply of nutrients by manure and the higher ability of the ammended soil to retain moisture that extended the vegtative stage and thereby longer period of the plants to flower for higher rate manure treated pots. Cowpea total dry matter yield was significantly superior for manure treated soils (32.23 gm plant^{-1}) over the control (17.5 gm plant^{-1}) (Table III). In other words, manure has increased dry matter yield of cowpea by 84% over the control. Cattle manure ammended soil (34.95 gm plant^{-1}) was significantly higher than poultry litter treated soil (29.5 gm plant^{-1}) in dry matter yield., indicating 18.5% increase in dry matter for cattle manure over poultry litter. The increase in cattle manure and poultry litter applications rates also resulted in significant increase in dry matter yield with cofficient of determination (R^2 = 0.94). The highest dry matter yield (40 gm plant^{-1}) was recorded at the rate of 100 metric ton ha^{-1} cattle manure treated pots. An increase in nutrient content of the soil due to manure application led to the increase in nutrient content of the plant that ultimately resulted in higher rate of synthesis and assimilation of photosynthates and finally the higher dry matter yield. Similarly, dry matter yield increase was also reported by others on corn (Zhang *et al*., 1998; Ferguson & Nienaber, 1995; Jokela, 1992; Zebarth *et al*., 1996) and sorghum (Thomas & Mathers, 1978). Ahmed (1997) reported a substantial increase in herbage yield of common vetch after manure application. An increase in markatable tomato yields also reported after poultry litter application (Suwwan & Hattar, 1987). Plant height was significantly greater for manure treated soils (55.2 cm) over the control (33.7 cm). This represents, 63.8% increase in plant height due to manure treatment. However, there was no significant difference between poultry litter and cattle manure treated soils for plant height (Table III). Significant difference within the different levels of poultry litter was observed with cofficient of determination of R^2 = 0.98. The different levels of cattle manure were significantly different and with R^2 = 0.97. The highest plant height (73.6 cm) was recorded at the rate of 100 mt ha^{-1} cattle manure treated pots. Since both manure supplied a better soil condition for including high soil moisture and essential nutrient taller plant growth was manifested. The results were consistant with those obtained by Ahmed (1997) indicating that plant that received higher rate of manure resulted in taller common vetch plant. Number of leaves per branch was significantly different for manure treated soils (19.65) over the control (12.08) i.e, 62.7% higher for manure treated soils over the control for this parameter. Result obtained from cattle manure treated soils (21.05) was significantly higher than that of poultry litter treated soils (17.29), showing 21.7% higher for cattle manure treatment over poultry litter in number of leaves/ branch. Different levels of cattle manure and poultry litter were significantly different for R^2 = 0.98. As the rate of manuring increased, leaves per branch also increased (Table V). The highest number of leaves per branch (26.35) was recorded at the rate of 100 mt ha^{-1} cattle manure treated pots, that was due to the improvement of soil properies under cattlele manure treatment. Contrarily, Ahmed (1997) found no significant difference between manure treated and nonmanured treatment on leaves /branch in commom vetch plant. Significant difference was obtained for number of branches/plant for manure treated soils (6.84) over the control (4.2), that was about 62.9% higher for manure treated pots over the control. Cattle manure treated soils (7.32) was significantly superior over poultry litter treated soils (6.37) for this parameter. Increasing the level of cattle manure resulted an increase in number of branches/plant. The higher rate of poultry litter also gave greater no. of branches/plant (Table III). The highest number of branches/plant (8.7) was recorded at the rate of 100 mt/ha cattle manure treated pots. Similar result was obtained by Ahmed (1997) that all manure rates resulted in plant with higher branches than those obtained from nonmanured treatment. Number of pods per plant in manure treated soils was significantly higher (3.75) than those of the control (2.0), which means a 46.75% increase. However, there was no significant difference in this parameter between cattle manure and poultry litter treated soils (Table III). Different rates of cattle manure showed significant differences; a significant positive response was shown with a cofficient of determination of R^2 = 0.94 for cattle manure and R^2 = 0.98 for poultry litter. The highest number of pods per plant (4.5) was recorded at the rate of 100 metric tone ha^{-1} cattle manure treated pots. Manure treatments also resulted in significant increase in the pod length (15.37 cm) over that of the control (12 cm), equalling 28.1% increase. However, addition of different sources of manure was not significantly different. There were significant differences for pod length at different levels of poultry litter and cattle manure, as their rate increased pod length also increased (Table III). The highest pod length (17.32 cm) was recorded at the rate of 100 metric tonne ha^{-1} poultry litter treated pots.

The increases in dry matter yield and yield components resulted due to the ability of manure to increase the nutrient content of the soil, increase the soil moisture holding capacity, reduction in soil pH and improvement in other physico-chemical properties of the soil. Increase in plant growth and dry matter accumulation due to organic manure application was been reported for corn (Klausner & Guest, 1981). As shown in Table I, the nutrient content of cattle manure was higher than that of poultry litter. The decomposition rate of cattle manure could be higher resulting in faster release of essential nutrients, thereby increasing the yield of cowpea.

Plant chemical composition. Nitrogen concentration in cowpea tissues were significantly greater for manure treated pots (3.8%) over the control (2.15%), which was 76.7% higher for manure treatment. Cattle manure treated pots resulted in higher tissue N concentration (4.23%) than poultry litter treated pots (3.36%) indicating that cattle manure treatment supplied cowpea plants more amount of N than did poultry litter treatment. As the rates of cattle manure and poultry litter increased, an increasing in tissue N was observed (Table IV; Fig. 1). Similarly high recovery of N by corn after manure application was recorded (Beauchamp, 1983; Saftley *et al.*, 1986; Xie & MacKenzie, 1986; Paul *et al.*, 1990) .The concentration of tissue P was also superior for manure treated pots (0.16%) over control (0.10%). These values could be considered low, since all tissue P values were near or below 0.16% (Benton *et al.*, 1991). Lower tissue P concentration could be due to P-fixing ability of calcareous soils resulting in non-availability of P. Cattle manure treated pots showed higher tissue P (0.16%) than poultry litter treated pots (0.15%). An increase in the rate of poultry litter and cattle manure also resulted in increasing tissue P concentration (Table IV).

Similarly, the concentration of tissue K^+ for manure treated pots (3.97%) was superior over the control (2.47%), which was 60% higher for manure treatment than the control. This tissue K^+ value was sufficient for control and manure treatments. However, cattle manure and poultry litter concentartion of tissue K^+ was no significantly different. But, increased rate of cattle manure and poultry litter resulted in an increase in tissue K concentration (Table IV), as the manure is a rich source of K^+ (Mathers *et al.*, 1980). Suwwan and Hattar (1987) observed an increase in plant uptake of macro- and micro-nutrient nutrient above 25 tonnes ha^{-1} poultry litter application. Tissue trace elements (Cu, Mn, and Zn) were significantly higher in the plant grown on manure treated pots than those of the control treatment, whereas, tissue Fe concentration was not significant. Concentration of tissue Cu, Mn and Zn were significantly greater for plants grown using poultry litter than cattle manure treated. However, tissue Fe was higher in cattle manure treated pots than poultry litter treated pots. As the rate of poultry litter increased, the concentration of tissue Fe, Mn and Cu increased. Tissue Mn concentarion was not

Table IV. Mean values and orthogonal contrast of tissue N, P, K, NO_3 and protein concentration at different rates of poultry litter and cattle manure

Sources	Rate (mt/ha)	N (%)	P (%)	K (%)	NO_3 (g kg^{-1})	Proteins (%)
Control	0	2.15	0.10	2.47	1.88	13.4
Poultry litter	20	2.62	0.12	2.97	2.27	16.4
	40	2.92	0.15	3.52	2.63	18.3
	60	3.22	0.16	4.07	2.86	20.1
	80	4.05	0.17	4.50	3.06	25.3
	100	4.00	0.18	4.65	3.19	25.0
Cattle manure	20	2.45	0.13	3.20	2.03	15.3
	40	3.60	0.15	3.62	3.56	22.5
	60	4.75	0.16	4.05	4.04	29.7
	80	4.97	0.18	4.50	4.53	31.1
	100	5.40	0.18	4.60	4.81	33.8
LSD (0.05)		0.97	0.08	0.25	4.10	6.08
CV, %		5..25	3.88	4.63	0.89	8.48
Contrast						
Control vs others		***	***	***	***	***
Poultry litter vs cattle manure		***	***	NS	***	***
Poultry litter rate						
Linear		***	***	***	**	**
Quadratic		NS	NS	NS	NS	NS
Cattle manure rate						
Linear		***	NS	NS	***	**
Quadratic		NS	***	***	NS	NS

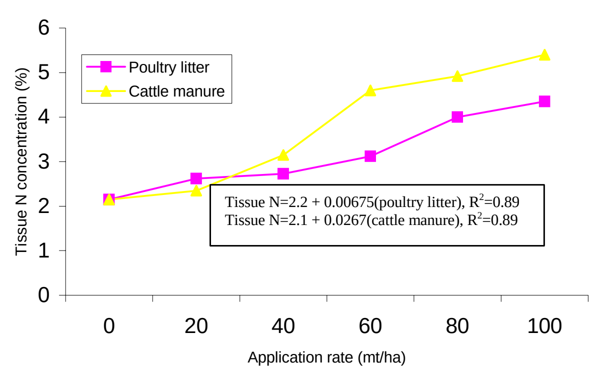
*, **, ***: Significant F-tests at the 5, 1, and 0.1 % levels, respectively. NS: not significant

Table V. Mean values and orthogonal contrast of tissue Fe, Cu, Zn, Mn, Pb and Cd concentration at different rates of poultry litter and cattle manure.

Sources	Rate (mt/ha)	Tissue trace element and heavy metals concentration (ppm)					
		Fe	Cu	Zn	Mn	Pb	Cd
Control	0	572.050	12.550	46.600	23.1	27.4	2.5
Poultry litter	20	668.750	14.350	54.600	50.9	29.6	2.6
	40	702.225	15.925	65.875	57.5	29.9	2.7
	60	712.575	17.800	83.500	62.3	30.3	2.8
	80	737.700	18.475	89.975	50.8	30.6	2.8
	100	751.150	19.500	95.800	58.2	30.8	2.9
Cattle manure	20	473.850	12.925	52.850	21.4	27.1	2.5
	40	508.575	13.250	55.300	33.1	27.6	2.6
	60	529.750	13.350	58.150	50.3	28.0	2.6
	80	561.500	13.550	78.000	77.5	29.1	2.7
	100	656.500	13.775	93.475	82.9	29.6	2.8
LSD (0.05)		96.31	1.099	15.34	23.4	1.1	0.09
CV, %		10.67	5.06	5..09	3..3	2.49	2.48
Contrast							
Control vs others		NS	***	***	***	***	***
Poultry litter vs cattle manure		***	***	***	***	***	***
Poultry litter rate							
Linear		***	***	**	NS	***	***
Quadratic		NS	NS	NS	NS	NS	NS
Cattle manure rate							
Linear		***	***	**	***	***	***
Quadratic		NS	NS	NS	NS	NS	NS

*, **, ***: Significant F-tests at the 5, 1, and 0.1 % levels, respectively. NS: not significant

Fig. 1. Effect of application rate (mt/ha) of poultry litter and cattle manure on tissue N concentration



significant at different levels of poultry litter. On the other hand the concentrations of Fe, Cu, Zn and Mn were significantly increased as the rate of cattle manure increased (Table V). In line with Benton *et al.* (1991), it can be concluded that the tissue Fe concentrations were generally higher in all the treatments including the control since all values were greater than 500 ppm, the concentrations of tissue Cu were sufficient since the value were between 10-30 ppm, the tissue Zn concentrations were sufficient for all the treatments except control. Tissue Mn concentrations for all the treatments were in sufficient range since all values were between 21-100 ppm. The concentrations of tissue heavy metals (Cd, Pb) were higher for manure treated pots than the control (Table V). The concentration of Cd in plants was higher for poultry litter treated pots (2.79 ppm) than cattle manure treated pots (2.70 ppm). In contrast, the concentration of Pb was higher for cattle manure treated pots than poltry litter treared pots. All tissue Cd and Pb levels were below the phytotoxicity level since the values were <5 ppm for Cd and <30 ppm for Pb (Chaney, 1973). The different levels of cattle manure were significantly different for plant Cd and Pb and increased as the rate increased. Simillarly, tissue Cd and Pb were increased with increasing poultry litter rate (Table V).

Some quality parameters of cowpea. Plants grown on manure treated soils showed higher content of protein (23.8%) than no manure treatment (13.4%), which shows 76.7% higher protein content as a result of manure treatments (Table III; Fig. 2). Plants grown on cattle manure treated soil were higher in plant protein content (26.5%) than those grown on poultry litter treated pots (21.0%). In addition, plants grown at different levels of poultry litter and cattle manure were significantly different for their protein content; increasing the rate, increased the cowpea tissue protein content. The highest protein content (33.8%) was recorded at the rate of 100 metric tonnes ha^{-1} of cattle manure. The higher content of protein was due to high nitrogen supplied as a result manure treatment. Plants grown on manure treated soils contained significantly higher NO_3^- (3.30 g kg^{-1}) than those grown on nonmanured pots (1.88 g kg^{-1}) that shows 75.5% higher NO_3 for manure treated pots than the control. Moreover, plants grown on cattle manure treated pots exbhited higher content of NO_3 (3.79 g kg^{-1}) than poultry litter treated pots (2.80 g kg^{-1}). Also increasing the rate of both poultry litter and cattle manure resulted in an increase in tissue NO_3 concentration. The highest tissue NO_3 (4.81 g kg^{-1}) was recorded at the rate of 100 metric tonnes ha^{-1} cattle manure treated pots (Table III; Fig. 3). The values of plant nitrate content obtained after manure treatment in this study can be considered as sufficient but not toxic since all the value were near to 3 g kg^{-1} (Benton, 1991). In general, dry manure treatments increased the essential nutrient content of the soil, lowered bulk density, increased soil organic matter, increased soil moisture content, and decreased pH of the soil. This ultimately resulted in increasing dry matter yield, yield components and tissue nutrient concentration of cowpea. The release of essential nutrients upon decomposition of air dried manure soil microbes mainly contributed for nutrients availability in soils and plants and improvement in the protein content of cowpea. However, high content of NO_3^- and heavy metals in the tissue could result in health hazard. Cattle manure was better in supplying N than poultry litter, this could be due to the low C:N ratio that led to faster organic matter decomposition in cattle manure than in poultry litter. However, P and trace elemets were higher in soil treated with poultry litter than in those of cattle manure, that could be as a result to the lower pH condition created by poultry litter treatment leading to higher availability of P and trace elements. Increased application of both sources resulted in a similar increase in the above parameters. This could be the positive effect of both manures on improving the nutrient status of the soil and of the improvement recorded on physical and chemical properties of soil due to higher rates. In general, the results of the current study clearly showed that application of manure (both cattle and poultry) was advantageous in improving the quality of degraded soils, thereby, increasing the productivity. However, a better

Fig. 2. Effect of application rate (mt/ha) of poultry litter and cattle manure on cowpea protein percentage

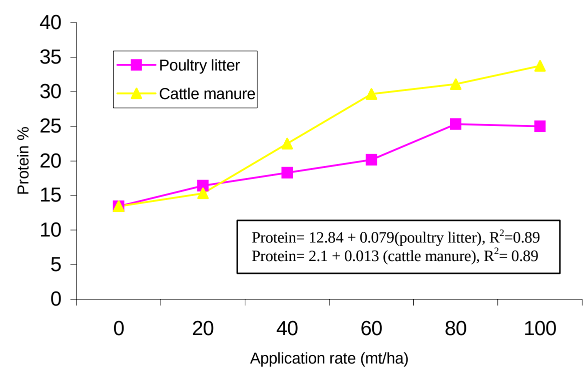
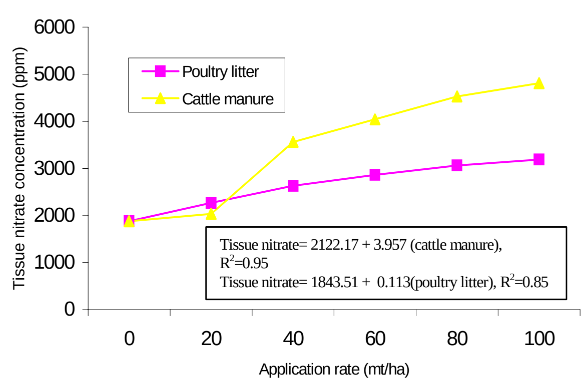


Fig. 3. Effect of application rate (mt/ha) of poultry litter and cattle manure on tissue nitrate concentration



understanding of the effect of high rates of manure application on the environment and its long-term effect in this specific soil should be studied further. Generally, dry matter yield and yield components of cowpea were increased as the rate of manure increased. Cattle manure was better than poultry litter treatments in improving dry matter yield and yield components of cowpea. Nutrient aviallability of cowpea was improved by application of manure. Both cattle manure and poultry litter should be chemically analysed before applying to the soil. Cattle manure with 100 metric tonnes ha^{-1} could be used to ammend degraded soils such as Muwaquar soil and to increase crop production. However economic viability and environmental impact of such higher rates should be further studied. Additional research is required to study the residual effect of both poultry litter and cattle manure at different rates on Muwaquar soils.

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