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Effect of Supplemental Nitrogen and Incubation Periods of Animal Manures on Sorghum Growth and Soil Properties

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ABSTRACT. A greenhouse experiment was conducted to evaluate the effects of N amendments, incubation period and manure type on the dry matter production and its content of N, P and K, in sorghum and to detect recent changes in the chemical properties of the soil as influenced by these parameters.

Results revealed that, under all manure types, dry matter yield of sorghum for the first crop was significantly higher than that of the second. Longer incubation periods for chicken and cow manures significantly reduced the dry matter yield compared with the shorter incubation periods. Under all manure types, N and P uptake in contrast to that of K was significantly decreased with prolonging incubation period. Soil organic matter content, C:N ratio and soil N, P and K content, were significantly increased; whereas its pH was reduced; on the application of each of the studied manures. Meanwhile, prolonging the incubation period had negative effects on C:N ratio and on dry matter of the soil and its element contents. Effects on pH, on the other hand were positive. N-amendment showed no significant effects.

Introduction

Numerous studies are available on the application of manures in relation to nutrients distribution throughout the soil profile. The effect of applying high rates of cattle and poultry manures on N balance was intensively investigated (Kimble *et al.* 1972; Jackson *et al.* 1977; Guenzi *et al.* 1978; Mugwira, 1979; Liebhardt *et al.* 1979). Application of cattle and poultry manures resulted in a crop removal of 36% of the inorganic fertilizer added (Cooper *et al.* 1984).

Animal manure contains many essential plant nutrients. It extremely varies in its chemical composition according to animal type, its feed and amount and the type of bedding material. Animal manures contain ample amounts of N that must be mineralized before being available to plants. Because of the slow nature of the mineralization process, the organic manure acts as a slow-release fertilizer, thus insufficient N may become available to rapidly growing or short-season crops (Tiessen 1982; Cooper *et al.* 1984).

Animal manures seem to be an important source of P on P-deficient soils where it contributes to the accumulation of residual P in some soils (Abbott and Tuckers, 1973; Meek *et al.* 1979). Manure application increased the availability, persistence and movement of P (Hannapel *et al.* 1964; Miller, 1973), and also increased K levels (Pratt, 1984). Manure was found to substantially increase soil organic matter content in the surface layer (Sommerfeldt and Chang, 1985). Manure addition markedly results in a reduction in soil pH (Kwakye, 1988).

The objectives of this study were to (i) evaluate the effect of supplemental N addition to some selected types of animal manures incubated for different periods on dry matter and its mineral composition in sorghum and (ii) detect the recent changes in the soil chemical properties relevant to its elemental content of N, P and K as well as the changes in soil pH and organic matter accumulation.

Materials and Methods

Three manure types were used (chicken, cow and sheep). Each manure was treated with three levels of nitrogen (0.0, 0.1 and 0.5%) and incubated for 0, 2, 4, 6 and 8 weeks before being mixed with the soil. The soil was brought from Hada Al-Sham Experimental Station, King Abdulaziz University, Jeddah, Saudi Arabia. The main characteristics of the soil at Hada Al-Sham are shown in Tables 1 and 2.

TABLE 1. Soil analysis for the experimental site at Hada Al-Sham open field soil samples.

Composition %			Texture
Sandy	Silt	Clay	
76	12	12	Sandy loam

TABLE 2. Initial analysis for open field soil at Hada Al-Sham.

Soil pH	Soil EC ds^{-1}	Organic matter %	N	P	K	C:N
			g/kg			
8.36	0.415	0.484	0.3	0.115	2.1	8.96

One hundred and thirty five PVC tubes, 18 cm diameter × 40 cm length, were lined up with plastic sheets to contain the soil and to prevent contact of plant roots with the surface. Three kg of soil were placed in the bottom of each tube before adding another 3 kg of soil mixed with manure at the rate of 44 t/ha. Five seeds of grain sorghum (*Sorghum bicolor* Moench) were planted in each tube. The emerging seedlings were later thinned to three plants per tube. Two sorghum crops were sequentially planted in the same tube. The first crop was planted on the 23rd of July 1989 and harvested after six weeks. The second was sown on the 3rd of September 1989 and harvested after five weeks. All tubes were arranged in a randomized complete block design with three replications in a 3 × 3 × 5 factorial arrangement and both experiments were conducted under greenhouse conditions.

Sampling Procedure and Analysis

Three plants from each treatment in each replication were taken at the final harvest of each crop, oven dried, grinded and used for the determination of N, P and K contents. Total N was determined according to Bremner (1965). N content was measured using a KJELTEC AUTO 1030 analyzer (tecator). Total P and K were determined after being extracted by the perchloric-nitric acid digestion procedure of Shelton and Harper (1941). P-content was quantified at 640 nu using a Turner spectrophotometer (Model 2000). Total K was measured by a flame photometer (Corning 400).

Soil samples were collected after the second harvest from each tube and were analyzed for EC, pH and organic matter (Jackson, 1973). Total N, P and K were analyzed in soil samples. Methods of analysis were exactly the same as those used for the plant material.

Results and Discussion

Effect on Plant

1. Dry matter production

Analysis of variance for the successive sorghum crops revealed that the dry matter production was significantly affected by season (crop 1 vs. crop 2), manure type, and incubation period ($P \leq 0.01$), (Table 3).

TABLE 3. Summary of analysis of variance for the two successive crops of sorghum experiment.

Variable		N	P	K	Dry weight
A	OSL	0.000**	0.000**	0.000**	0.000**
B	OSL	0.000**	0.000**	0.000**	0.000**
AB	OSL	0.000**	0.000**	0.000**	0.000**
C	OSL	0.363	0.018*	N.S.	0.080
AC	OSL	N.S.	N.S.	N.S.	N.S.
BC	OSL	0.023*	N.S.	0.037*	0.030*
ABC	OSL	N.S.	0.077	0.004**	0.040*

TABLE 3. Contd.

Variable		N	P	K	Dry weight
D	OSL	0.000**	0.000**	0.000**	0.000**
AD	OSL	0.000**	0.006**	0.000**	0.000**
BD	OSL	0.000**	0.000**	0.000**	0.000**
ABD	OSL	0.000**	0.000**	0.000**	0.000**
CD	OSL	N.S.	0.101	0.305	0.026*
ACD	OSL	0.294	0.137	N.S.	0.023*
BCD	OSL	N.S.	0.273	0.432	0.000**
ABCD	OSL	0.105	0.041*	N.S.	0.012
EMS		0.002	0.000	0.023	0.403
DF		178	178	178	178

* Significant at 0.05 level **Significant at 0.01 level

EMS = Error mean square
DF = Degree of freedom

A = Two successive crops B = Manure type
C = Manure applied N D = Incubation time

Sorghum plants grew well and showed no symptoms of N deficiency owing to the application of N amendment. However, average values of the dry matter for the second crop were lower than those for the first ($P \leq 0.05$), (Table 4). Differences in total dry matter may be related to differences in the availability of N, P and K for the two successive crops. Apparently, availability of the three elements was higher for the first than for the second crop. Similar results were obtained by Hinsely *et al.* (1979). Also, the difference in the dry matter production for the two crops may have been related to climatic effects particularly temperature and light.

TABLE 4. Average N, P, K, D.M. and their tests of significance* for experiments in the greenhouse.

Factors Means				N	P	K	D.M.
A	B	C	D		g/Kg		g/pot
Season (A)							
1				6.38 A	0.49 A	33.94 A	10.154 A
2				5.67 B	0.34 B	17.26 B	4.954 B
L.S.D.**				0.0107	0.00024	0.0362	0.1514

TABLE 4. Contd.

Factors Means	N	P	K	D.M.
A B C D		g/Kg		g/pot
Manure Type (B)				
1	6.61 A	0.46 A	26.39 A	10.145 A
2	5.24 C	0.36 B	25.26 B	6.337 B
3	6.21 B	0.42 A	25.15 B	6.180 B
L.S.D.	0.13	0.0088	0.0635	1.87
Nitrogen Amendment (C)				
1	5.97 A	0.41 A	25.57 A	7.607 A
2	6.08 A	0.42 A	25.59 A	7.624 A
3	6.02 A	0.42 A	25.64 A	7.431 B
L.S.D.	0.13	0.0088	0.0635	1.87
Incubation Period (D)				
1	6.62 A	0.49 A	23.32 C	8.49 A
2	6.08 B	0.41 AB	23.35 C	7.69 B
3	5.60 D	0.41 AB	26.57 B	7.07 C
4	5.98 BC	0.39 AB	26.64 B	7.84 B
5	5.83 C	0.37 B	28.13 A	6.68 D
L.S.D.	0.17	0.0139	0.0820	0.24

*Every two means having at least one liter in common do not different significantly, otherwise they do.
**L.S.D. = Least Significant Difference at 0.05.

A – Season	B – Manure type	C – Incubation period	D – Nitrogen amendment
1 – Crop 1 2 – Crop 2	1 – Chicken manure 2 – Cow manure 3 – Sheep manure	1 – 0 week 2 – 2 weeks 3 – 4 weeks 4 – 6 weeks 5 – 8 weeks	1 – 0.0 % N 2 – 0.1 % N 3 – 0.5 % N

Dry matter yield was significantly influenced by manure type ($P \leq 0.01$), Table 3. This was mostly attributed to the differences in the nutrient content of the various manure types. In this respect, highest dry matter yield was produced from soil treated with chicken manure (Table 4). The N-amended manure showed significant effect on dry matter production (Table 4).

Increasing the incubation period from 0-week to 8-weeks significantly decreased dry matter production particularly in soils treated with chicken and cow manures (Table 4). This is probably attributed to the reduction in the soil elemental content as the incubation period was prolonged. These results were verified from the final soil analysis and also from the findings of Meek *et al.* (1982). On the other hand, as incubation period was extended to 8 weeks, a gradual increase in the dry matter production was observed in soils treated with sheep manure (Fig. 1). The low dry matter produced in soils untreated with sheep manure was mostly due to the utilization of the available N by microorganisms in the mineralization process of high organic carbon (Gilmour *et al.* 1985).

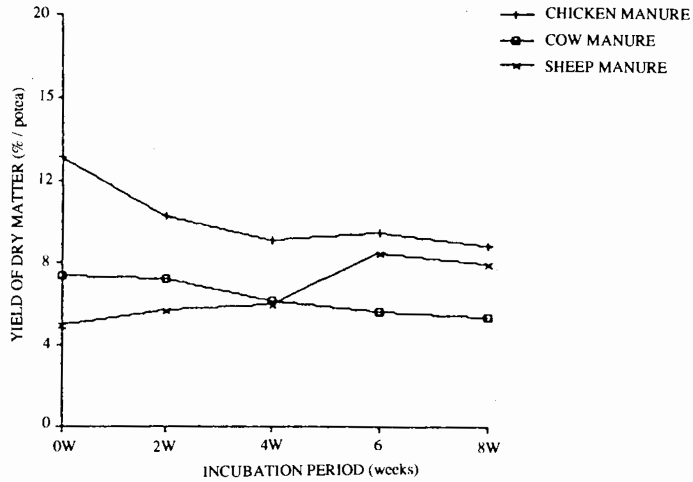

FIG. 1. Effect of incubation period on sorghum yield under different manure types.

2. N and P uptake

N and P uptake in sorghum was significantly affected by season, manure type and incubation period ($P \leq 0.01$). Interactions among these parameters were also significant (Table 3).

The average values of N and P uptake were highest in the first crop and were lowest in the second (Table 4). This trend was observed by Keeney *et al.* (1975) and Pratt *et al.* (1976). Regarding manure type, the average N and P uptake was significantly highest in chicken followed by sheep and cow manures, respectively (Table 4). The N-amendment showed insignificant effect on both N and P uptake (Table 4).

Average N and P uptake was highest in plants that received the unincubated manure (0-week incubation) followed by those treated with manures incubated for 2, 6, and 4 or 8 weeks, respectively (Fig. 2). Such trends were mostly attributed to the increase in available N and P with the reduction of incubation period. Similar results were observed by Miller (1973), Saber *et al.* (1977), Pratt and Laag (1981) and Meek *et al.* (1982).

3. K uptake

K uptake was also significantly influenced by season, manure type and incubation period ($P \leq 0.01$). Interactions among these parameters were significant (Table 3).

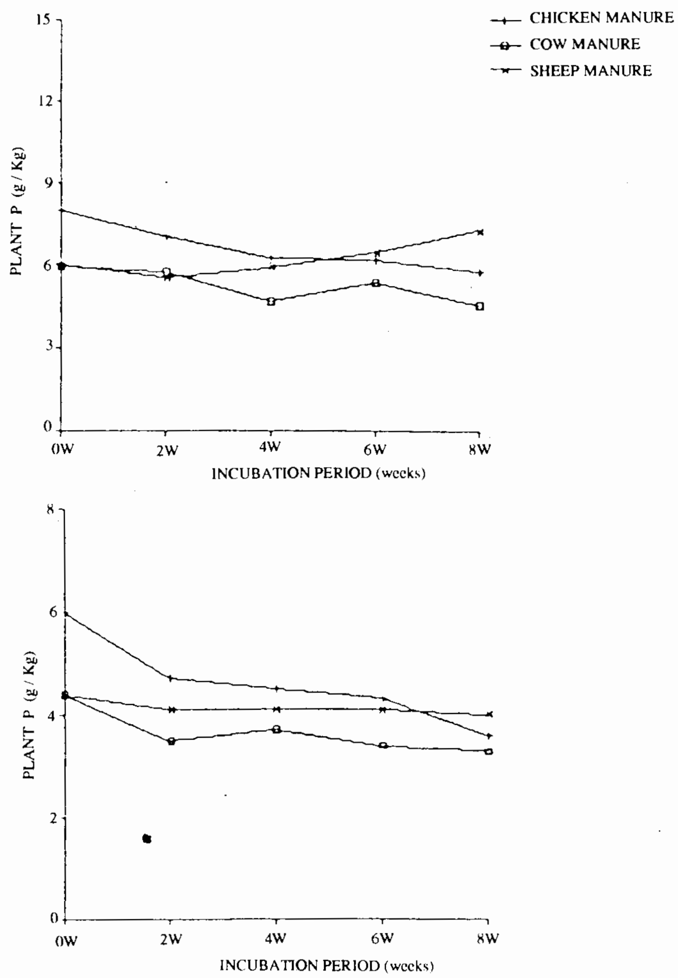

FIG. 2. Effect of incubation period on N and P uptake at different manure types.

K-uptake in the first crop, similar to that of N and P, was also higher than that in the second (Table 4). K-uptake was significantly highest in chicken manure than cow and sheep manures (Table 4). However, K-uptake was not significantly influenced by N-amendment (Table 4). The effect of incubation period of K-uptake was significantly highest when the crop was fertilized with 8-weeks incubated manure followed by those incubated for 6 or 4 weeks, then for 2 weeks in a decreasing order (Table 4).

In conclusion, highest dry matter yield of sorghum was produced from soil treated with chicken manure. While increasing the chicken or cow manure incubation period from 0 to 8 weeks resulted in a decrease in the dry matter production, an opposite trend was exhibited by sheep manure. Thus, chicken and cow manures can be directly mixed with the soil and used in crop production without incubation; whereas sheep manure needs to be incubated for a period of one month before its utilization, as it contains a high proportion of plant debris.

Effects on Soil Characteristics

1. Initial and final soil analysis

Initial analyses of the soil prior to manure addition showed that Hada Al-Sham soils are sandy loam, alkaline and contain low amounts of soluble salts and organic matter. N, P and K amounts are respectively 0.3, 0.115 and 2.1 g/kg (Tables 1 and 2). Application of animal manure at rate of 44 t/ha significantly increased soil organic matter, C:N ratio and soil N, P and K contents but decreased soil pH (Table 6).

2. Soil pH

Soil pH was significantly affected by manure type ($P \leq 0.05$) and incubation period ($P \leq 0.01$), (Table 5). Soil pH was higher in soils treated with cow manure than those treated with sheep and chicken manures (Table 6). This may be attributed to the decomposition of organic matter by microorganisms which could have been more active in chicken and sheep than in cow manure due to the high N-content that might have caused a drop in soil pH due to the nitrification process (Larry and Morris, 1972; Sims, 1986). N-amendment showed no significant effect on soil pH (Table 6). Application of unincubated manure reduced soil pH (Table 6). This drop was probably due to the high organic carbon and N-content mineralized by the soil microorganisms (Larry and Morris, 1972; Sims, 1986).

TABLE 5. Summary of analysis of variance for final soil analysis.

Variable		pH	OM	N	P	K	C:N
A	OSL	0.042*	0.033*	0.002**	0.000**	N.S.	0.074
B	OSL	0.185	N.S.	N.S.	0.080	N.S.	N.S.
AB	OSL	N.S.	0.147	0.374	0.143	0.351	0.295
C	OSL	0.000**	0.000**	0.000**	0.000**	0.283**	0.000**
AC	OSL	0.283	0.348	0.128	0.315	0.377	0.361
BC	OSL	0.282	0.172	N.S.	0.020*	N.S.	0.209
ABC	OSL	0.113	N.S.	N.S.	N.S.	0.300	0.448
	EMS	0.006	0.064	0.00001	0.00001	0.001	11.164
	DF	88	88	88	88	88	88

A – Manure type
1 – Chicken manure
2 – Cow manure
3 – Sheep manure

B – Incubation period
1 – 0 week
2 – 2 weeks
3 – 4 weeks
4 – 6 weeks
5 – 8 weeks

C – Nitrogen amendment
1 – 0.0 % N
2 – 0.1 % N
3 – 0.5 % N

OSL = Observed Statistical Level EMS = Error Mean Square DF = Degree of freedom

3. *Organic matter*

Soil organic matter was significantly influenced by manured type ($P \leq 0.05$) and incubation period ($P \leq 0.01$), (Table 5). Average O.M. content was significantly higher ($P \leq 0.05$) in soil treated with sheep manure than those treated with chicken and cow manures (Table 6). This was most probably due to the high content of organic carbon in such soils (Sommerfeldt and Chang, 1985). Soil organic matter content was not influenced by N treatments (Table 6). Average organic matter (%) in the soil treated with unincubated manure was significantly higher ($P \leq 0.05$) than that in those treated with incubated manures (Table 6). This could be attributed to the shortened period of the mineralization process.

TABLE 6. Average pH, OM, N, P, K, and C:N and their tests of significance* for final soil analysis.

Factors means (A B C)	pH	OM %	N g/Kg	P g/Kg	K g/Kg	C:N
Manure Type (A)						
1	8.090 B	0.847 AB	0.45 A	0.23 A	2.26 A	10.321 A
2	8.131 A	0.748 B	0.41 B	0.20 B	2.30 A	10.057 AB
3	8.105 AB	0.884 A	0.43 AB	0.21 B	2.24 A	11.580 B
L.S.D.**	0.0325	0.105	0.00397	0.00132	0.013	1.3998
Nitrogen Amendment (B)						
	8.098 A	0.809 A	0.44 A	0.22 A	2.25 A	10.286 A
1	8.103 A	0.821 A	0.43 A	0.22 A	2.28 A	10.659 A
	8.126 A	0.849 A	0.43 A	0.21 A	2.26	11.013 A
L.S.D.	0.0325	0.105	0.00397	0.00132	0.013	1.3998
Incubation Period (C)						
1	8.046 C	1.143 A	0.49 A	0.23 A	2.219 A	13.219 A
2	8.101 B	0.833 B	0.44 AB	0.22 AB	0.225 A	10.389 B
3	8.105 B	0.747 BC	0.42 A	0.21 BC	2.227 A	9.820 B
4	8.136 AB	0.724 BC	0.41 B	0.20 C	2.33 A	9.862 B
5	8.155 A	0.684 C	0.39 B	0.21 BC	2.228 A	9.972 B
L.S.D.	0.0429	0.1368	0.00513	0.00171	0.0171	1.8072

*Every two means having at least one liter in common do not different significantly, otherwise they do.
**L.S.D. = Least Significant Difference at 0.05

A – Manure type	B – Nitrogen amendment	C – Incubation period
1 – Chicken manure	1 – 0.0 % N	1 – 0 weeks
2 – Cow manure	2 – 0.1 % N	2 – 2 weeks
3 – Sheep manure	3 – 0.5 % N	3 – 4 weeks
		4 – 6 weeks
		5 – 8 weeks

4. *Total N and P*

The soil total N and P contents were significantly affected by manure type and incubation period ($P \leq 0.01$), (Table 5). The highest average N and P contents were in soils treated with chicken manure followed by that in sheep and cow manures, respectively (Table 6). There were no significant differences in total N and P due to N-amendment (Table 6). Total N and P were significantly highest ($P \leq 0.05$) in soils treated with unincubated manure (Table 6). This might be due to the high N and P contents in the unincubated manure as observed by Meek *et al.* (1982).

5. Total K

Total K in the soil was not influenced by manure type, N-amendment and incubation period (Table 6). This might be related to the high K uptake by the growing plants.

6. C:N ratio

The C:N ratio was significantly affected by manure type and incubation period ($P \leq 0.05$), (Table 5), highest C:N ratio was observed in the soil treated with sheep manure (Table 6). Apparently, sheep manure had the highest organic carbon content and consequently the highest C:N ratio. N-amendment showed no significant effect on C:N ratio. Meanwhile, there was a gradual decrease in the C:N ratio with the increase in incubation period (Table 6). This might be attributed to the high activity of microorganisms which might have increased the decomposition process of organic matter with time.

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تأثير النيتروجين والتحضين للمخلفات الحيوانية على نمو الذرة الرفيعة وخواص التربة

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المستخلص . أجريت هذه التجربة تحت ظروف البيوت المحمية لتقييم أثر إضافة النيتروجين وفترات التحضين والمخلفات الحيوانية المختلفة (دواجن – أبقار – أغنام) على إنتاجية المادة الجافة للذرة الرفيعة ومحتواها من النيتروجين (N) والفوسفور (P) والبوتاسيوم (K) وكذلك تأثير العوامل السابقة على التغيرات الحديثة للخواص الكيميائية للتربة .

أظهرت النتائج أن إنتاجية المادة الجافة من محصول الذرة الأول أعلى مما هي عليه للمحصول الثاني لجميع المخلفات الحيوانية المضافة للتربة . كما قلت كمية المادة الجافة مع زيادة فترات التحضين لمخلفات الدواجن والأبقار وقلة فترات التحضين لمخلفات الأغنام . كذلك فإن زيادة فترة التحضين قللت من امتصاص نبات الذرة الرفيعة لعنصر النيتروجين (N) والفوسفور (P) بينما زاد امتصاصها لعنصر البوتاسيوم (K) مع زيادة فترة التحضين . كذلك أوضحت النتائج أن إضافة المخلفات الحيوانية الثلاث للتربة زاد معنويا من كمية المادة العضوية وكذلك نسبة الكربون إلى النيتروجين (C: N ratio) وكمية النيتروجين (N) والفوسفور (P) والبوتاسيوم (K) ولكنه قلل معنويا من رقم الحموضة (pH) كما أن زيادة فترة التحضين قللت من معدلات خواص التربة السابق ذكرها إلا أن إضافة النيتروجين لم يكن لها أي تأثير معنوي .