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Effect of cattle manure application on pod yield and yield indices of okra (*Abelmoschus esculentus* L. Moench) in a semi-arid sub-tropical environment

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Abstract

The effects of cattle manure rate and time of application on okra yield and yield indices were studied at Harare, Zimbabwe during two cropping seasons (2000-2002). The treatments were factorial combinations of four cattle manure rates (0, 6, 12 and 18 t ha^{-1}) and two application timings (4 and 8 weeks after planting). The experiment was a randomized complete block design with four replications. Both cumulative green pod count and yield were increased by manure application up to 12 t ha^{-1} in 2000 and 6 t ha^{-1} in 2001. Yield values for the best manure rates were 131 and 123% of those for the control in 2000 and 2001 respectively. Average green pod weight and length were increased by manure application in one year only (2000). Application of manure 6 t ha^{-1} gave the highest dry pod weight while 12 t ha^{-1} produced the highest weight of seeds pod^{-1}. Parameters were generally not influenced by time of manure application or rate x timing interaction. Leaf Ca was slightly higher for earlier applied manure and for 6 and 12 t ha^{-1} than for no manure or 18 t ha^{-1}. Pod N was also slightly higher for earlier manure application than for the later application. The best manure rate would vary with manure quality. However, application of manure 6 t ha^{-1} as early as possible in the cropping season appears to be best for okra production in semi-arid Zimbabwe.

Key words: Manure, okra, *Abelmoschus esculentus*, yield, sub-tropics.

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is an important local vegetable cultivated in the tropical and sub-tropical regions mainly for its pod yield. In Zimbabwe, where it is used as a form of relish, its production is exclusively by small-scale farmers, while its economic importance lies in internal trade. Unfortunately, as with most local vegetables, this crop has so far received only very limited research attention in the country. In actual fact, most research work on horticulture in Zimbabwe has concentrated on the large-scale commercial sector and the small-scale sector has been in a state of neglect [1].

As a result of the low-input system commonly adopted for okra production, green pod yields in most instances have been relatively modest. Even in cases where high yielding cultivars have been grown, the inherently low fertility status of the soils, coupled with minimal applications of fertilizers, remains the principal limiting factor to production. In many of such situations yields of 2-3 t ha^{-1} of green pods can be expected [2]. Positive responses by okra green pod yield to applications of inorganic nitrogen and phosphorus have been reported in India, Nepal and Nigeria [3-6]. However, most of the reports on phosphorus effect on green pod yield have been rather conflicting, with response being to modest levels of P [6, 7]. There is no known published work on use of organic manures on okra in a semi-arid sub-tropical environment. Organic manure is an important resource for crop production and soil sustainability, it is a source of almost all essential plant nutrients. It also provides an excellent source of organic matter when added to soils, restoring some organic matter depleted by many agricultural practices.

As a result of high energy costs, inorganic fertilizers have since become very expensive and also scarce, especially in developing countries [8]. For instance, the cost of commercial fertilizers in Zimbabwe has more than quadrupled over the last eight years [9]. Consequently, uneasy access of the resource-poor farmers to these commodities is already becoming a source of concern. As long as organic manures are available and comparable with inorganic fertilizers in yield improvements, their use as sources of plant nutrients for growing vegetable crops could assume increasing importance. This is coupled with the known beneficial effects of animal manure on soil physical and chemical properties[10] and their ability to supply macro- and trace elements not contained in the inorganic fertilizers [11]. Nevertheless, the appropriate rate and timing of animal manure application for okra production in Zimbabwe are yet to be determined. Noteworthy is the fact that manures may not always supply sustainable amounts of nutrients to crops because they are generally low in plant nutrient contents and are applied during land preparation. The objective of this study therefore was to determine the influence of rate and time of cattle manure application on okra plant nutrient composition and green pod yield.

Materials and Methods

Field trials were conducted during two cropping seasons (2000/01 and 2001/02) at the Crop Science experimental blocks, University of Zimbabwe, Harare (lat. 17°50'S, long. 30°03'E; 1,550 m above sea level) to study the response of okra green pod yield and yield indices to cattle manure application rate and timing. Harare, with a long-term annual rainfall of 750-1,000 mm, has a semi-arid sub-tropical climate.

The soil of the 2000 trial site had a pH($CaCl_2$) of 5.0, total N 24 mg kg^{-1}, available P 5.23 mg kg^{-1} and exchangeable K 0.18 cmol kg^{-1}, Ca 6.12 cmol kg^{-1} and Mg 2.55 cmol kg^{-1}. The corresponding values for the trial of 2001 were: pH($CaCl_2$) of 5.2, total N 41 mg kg^{-1}, available P 6.10 mg kg^{-1} and exchangeable K 0.19 cmol kg^{-1}, Ca 6.13 cmol kg^{-1} and Mg 2.48 cmol kg^{-1}. The cattle manure used in both trials was sourced from the University of Zimbabwe dairy barn. Manure used in the trial of 2000 contained total N 2.51, P 0.87, K 0.12, Ca 1.37, Mg 0.47, organic C 36.28, sand 49.70 g kg^{-1}. The corresponding values for the trial of 2001 were: total N 3.41, P 1.40, K 0.64, Ca 2.38, Mg 0.98, organic C 52.18, sand 23.01 g kg^{-1}. Experimental cultivar was Clemson Spineless which is a very popular, high yielding okra variety grown in Zimbabwe. The treatments were factorial combinations of four manure rates (0, 6, 12 and 18 t ha^{-1}) and two times of application [4 and 8 weeks after planting (WAP)]. The experiment was a randomized complete block design with four replicates. The gross plot size was 3.5 m x 6.0 m (21.0 m^2) and the net plot size was 2.1 m x 5.5 m (11.55 m^2). The trials were sown 70 cm between rows and with 40 cm intra-row spacing. Stands were thinned to 2 plants/stand 4 weeks later. Manure was applied in bands along the rows and then worked into the soil. The crop protection measures were taken against aphids and fungal infection. The trials were weeded manually as necessary.

In the 2001 trial, plant samples were collected from the border rows at 13 WAP using six plants $plot^{-1}$ for dry mass determination and plant tissue analysis. The samples were dissected into leaves, pods and stalk and dried in an oven at 70°C for 48 h. The dried samples were weighed before grinding with a Wiley mill and then analyzed for their contents of N, P, K, Ca and Mg. Total nitrogen was determined by the micro-Kjeldahl method [12] after digesting with concentrated sulphuric acid. P concentration was determined by the vanado-molybdate yellow method [13] after digesting with 2.4 N perchloric acid. After extracting with mixture of 25% hydrochloric acid and 55% nitric acid, concentrations of Ca and Mg in plant tissue were determined by atomic absorption and K concentration by using the curcumin method[14].

Green pods were harvested at regular intervals to derive cumulative green pod yield and yield-related parameters, such as average pod weight, length and diameter. Pod characteristics were estimated at each green pod picking time using ten randomly selected pods plot $^{-1}$. Ten dry pods were sampled per plot for determination of average dry pod weight and from these, four pods were again sampled for assessment of number and weight of seeds pod $^{-1}$ and 100-seed weight. On the 2001 trial, weeds were removed from the gross plot area at 13 WAP, the dominant weed species identified and then placed in an oven set at 70°C for 72 h. Weed dry mass was determined by weighing with a spring balance.

The data collected were subjected to analysis of variance to test the significance of treatment effects using the F-test [14]. The data were analysed separately for each year and pooled for both years where appropriate. Where the F-test was significant, the means were separated using the Duncan's multiple range test.

Results

Cumulative number and yield of green pods increased significantly with the rates of manure application in both years (Table 1). In the 2000 trial, the highest green pod counts were from 12 t ha^{-1} manure application while the rate of 6 t ha^{-1} gave the highest green pod yield. The yield values for the best manure rates were 131 and 123% of those for the no-manure control in 2000 and 2001 respectively. The corresponding values for green pod counts were 118 and 121% of those for the no-manure control. The no-manure control treatment had the least green pod count and yield in both years. Stand count and height to first pod were significantly increased by manure application up to 12 t ha^{-1} rate in 2001 but there was no response in 2000. There was no significant manure rate x timing interaction, neither any response to time of manure application.

Two of the green pod characteristics were influenced by manure application rate in one or both years but none of them responded to times of manure application (Table 2). Average weight per green pod and pod length were significantly increased by increase in rate of manure application up to 12 t ha^{-1} and 6 t ha^{-1} respectively in 2001. There were only modest differences between the lowest and the highest values for these two parameters. Average green pod weight responded to manure rate in 2000; the values for 12 and 18 t ha^{-1} manure rates were about 15% higher than that for the no-manure control treatment. Average pod diameter was not influenced by manure application rate.

Table 3 shows the effect of manure application rate and timing on average dry pod weight, number and weight of seeds/pod and 100-seed weight in 2000 and plant height, number of pods and reproductive structures plant $^{-1}$ and weed dry mass in 2001. Average dry pod weight and weight of seeds pod^{-1} were influenced significantly by manure application rate but none of the six parameters was influenced by time of manure application. Application rates of 6 and 18 t ha^{-1} produced the highest average dry pod weight, which was about 11% higher than in no-manure control. The 12 t ha^{-1} manure rate gave the highest weight of seeds pod^{-1}, which was about 28% higher than in control. Although not statistically significant, the 12 t ha^{-1} manure rate had the lowest weed dry mass. The dominant weed species in the 2001 trial were *Bidens pilosa*, *Nicandra physaloides*, *Physalis angulata, Oxalis latifolia, Chenopodium album, Cyperus esculentus* and *Cyperus rotundus*.

Stand count, height to first pod, total green pod count and green pod yield pooled for the two years responded

Table 1. Stand count, height to first pod, total green pod number and yield in okra as influenced by rate and time of manure application at Harare, Zimbabwe, 2000 and 2001.

Treatment	Stands/ plot		Height to first pod (cm)		Total green pods/plot		Total green pod yield (t ha^{-1})	
	2000	2001	2000	2001	2000	2001	2000	2001
Manure rate t ha^{-1}								
0	48.9	38.1 b*	29.6	32.5ab	720.2b	402.4b	7.99 b	9.97 b
6	49.1	41.2ab	29.9	29.3	783.0ab	483.4a	9.58ab	12.36a
12	49.1	44.4 a	32.0	34.9	847.8a	486.5a	10.73a	11.38ab
18	47.9	40.0ab	28.6	28.8	802.1ab	452.8ab	10.34a	11.26ab
s.e.±	0.92	1.52	1.23	1.44	39.80	20.04	0.726	0.550
Manure timing (wks after planting)								
4	48.4	41.1	30.9	31.0	779.1	459.4	9.45	11.36
8	49.1	40.8	29.1	31.8	797.4	453.1	9.87	11.13
s.e.±	0.65	1.08	0.87	1.02	28.15	14.17	0.513	0.389
Mean	48.8	40.9	30.0	31.4	788.3	456.2	9.66	11.24
CV (%)	5.3	10.5	11.6	13.0	14.3	12.4	21.3	13.8

*Means followed by the same letter(s) within the same column are not significantly different at the 5% probability level according to the Duncan's multiple range test.

Table 2. Average green pod weight, length and diameter in okra as influenced by rate and time of manure application at Harare, Zimbabwe, 2000 and 2001.

Treatment	Ave. wt./ green pod		Ave. pod length (cm)		Ave. pod diameter (cm)	
	2000	2001	2000	2001	2000	2001
Manure rate (t ha^{-1})						
0	12.69b*	19.07ab	9.02	10.19b	16.24	14.52
6	14.02ab	19.46a	9.13	10.86a	16.65	15.31
12	14.52a	17.82b	9.39	10.62ab	16.80	15.14
18	14.69a	19.37a	9.47	10.65ab	16.73	15.37
s.e.±	0.540	0.450	0.179	0.173	0.291	0.248
Manure timing (wks after planting)						
4	13.86	19.07	9.23	10.61	16.45	15.17
8	14.00	18.79	9.27	10.54	16.76	15.00
s.e. ±	0.382	0.318	0.127	0.122	0.206	0.176
Mean	13.98	18.93	9.25	10.58	16.60	15.09
CV (%)	10.9	6.7	5.5	4.6	5.0	4.7

*Means followed by the same letter(s) within the same column are not significantly different at the 5% probably level according to the Duncan's multiple range test.

significantly to manure application rate (Table 4). Total number of green pods and green pod yield increased 14 and 25% respectively, in response to manure application, however, there were no differences among the three manure rates (6, 12, and 18 t ha^{-1}). The highest stand count and height to first pod was produced by 12 t ha^{-1} manure application rate. The other manure rates were not significantly different from the no-manure control for the two parameters.

The data for green pod characteristics pooled over years as influenced by rate and time of manure application are shown in Table 5. Average weight of green pod, pod length and pod diameter increased significantly with manure application relative to the no-manure control, even though the three manure rates (6, 12 and 18 t ha^{-1}) were statistically at par. Plants which received manure treatments tended to produce green pods that were heavier, longer and thicker than those of plants in the control plots.

The dry mass of leaves, stem, reproductive structures and total plant at 13 WAP were not significantly influenced by rate and time of manure application (data not shown). The no-manure control was not different from the manured plots with respect to plant dry mass. There was no significant response to time of manure application by any of the parameters considered in the study.

Treatments had only modest influence on the concentration of nutrients in plant tissue (data not shown) in the study. Leaf Ca was slightly higher for 6 and 12 t ha^{-1} manure application rates than for the no-manure control or manure application of 18 t ha^{-1}. N and Mg concentrations in the okra pod and Ca in the leaf were higher in the case of plants that were manured at 4 weeks than those manured at 8 weeks. The okra leaf was a better accumulator of N and Ca than the pod.

Table 4. Stand count, height to first pod, total number of green pods and green pod yield in okra as influenced by rate and time of manure application at Harare, Zimbabwe (pooled for 2000 and 2001).

Treatment	Stands/ plot	Height to first pod (cm)	Total green pods/plot	Green pod yield (t ha^{-1})
Manure rate (t ha^{-1})				
0	43.5 b*	31.1 ab	561.3 b	8.98 b
6	45.2 ab	29.6 b	633.2 a	10.97 a
12	46.8 a	33.5 a	667.1 a	11.05 a
18	43.9 b	28.7 b	627.4 a	10.80 a
s.e.±	0.89	0.95	22.28	0.455
Manure timing (wks after application)				
4	44.8	31.0	619.3	10.40
8	44.9	30.5	625.2	10.50
s.e. ±	0.63	0.67	15.76	0.322
Mean	44.84	30.72	622.3	10.45
CV (%)	7.9	12.3	14.3	17.4

*Means followed by the same letter(s) within the same column are not significantly different at the 5% probably level according to the Duncan's multiple range test

Table 5. Average weight of green pod, pod length and pod diameter in okra as influenced by manure application rate and timing at Harare, Zimbabwe (pooled for 2000 and 2001).

Treatment	Ave. wt./green pod (g)	Ave. pod length (cm)	Ave. pod diameter (cm)
Manure rate (t ha^{-1})			
0	15.88 b*	9.60 b	15.38 b
6	16.74 ab	10.00 a	15.98 a
12	16.74 ab	10.00 a	15.97 a
18	17.03 a	10.06 a	16.05 a
s.e. ±	0.352	0.125	0.192
Manure timing (wks after planting)			
4	16.46	9.92	15.81
8	16.45	9.91	15.88
s.e. ±	0.248	0.088	0.135
Mean	16.45	9.92	15.84
CV (%)	8.5	5.0	4.8

*Means followed by the same letter(s) within the same column are not significantly different at the 5% probably level according to the Duncan's multiple range test

Discussion

Level of survival of plant stands was lower under the zero manure treatment (control) ostensibly due to low soil fertility. On the other hand, burning of susceptible young okra plants was caused by high concentration of ammonia and uric acid in the soil under the highest manure rate. This calls for extra caution when applying high rates of animal manure to tender plants by banding application method, in spite of its obvious advantages [9]. Weil and Kroonje [16] had opined that when organic manures above agronomic rates are applied, there might be a release of phytotoxic quantities of NH_3, NO_3 and salts. Okra plant mortality can occur depending on the type of organic amendment that is applied [17]. Obi and Ebo[18] cautioned that reliance solely on organic inputs for crop production would raise the problem of procurement as well as that of toxicity, especially at high rates of application.

Green pod yield mostly followed the same

Table 3. Weight per dry pod, number of seeds, weight of seeds, 100-seed weight, plant height, number of pods per plant, number of reproductive structures in okra and weed dry mass at Harare, Zimbabwe, 2000 and 2001.

Treatment	Wt./dry pod (g)	No. seeds/ pod	Wt. seeds/ pod (g)	100-seed wt (g)	Plant ht (cm)	No. pods /plant	No. reprod. structures	Weed dry mass (g m^{-2})
	--------------- 2000	-------------------			---------------- 2001	----------------		
Manure rate t ha^{-1}								
0	7.66b*	60.4	3.54b	5.87	130.6	4.6	4.7	97.4
6	8.54a	66.8	4.09ab	5.95	132.1	4.5	4.7	81.2
12	8.12ab	67.2	4.49a	5.97	135.1	4.8	5.0	56.8
18	8.47a	64.4	3.84ab	5.97	137.8	4.8	5.0	82.1
s.e. ±	0.227	2.88	0.287	0.123	3.16	0.25	0.49	16.83
Manure timing (wks after planting)								
4	8.29	65.97	5.98	5.98	133.9	4.9	5.0	67.5
8	8.10	63.23	5.90	5.90	133.8	4.5	4.7	91.2
s.e.±	0.161	2.038	0.087	0.087	2.24	0.18	0.18	11.90
Mean	8.20	64.60	5.94	5.94	133.9	4.7	4.8	79.4
CV (%)	7.8	12.6	5.9	5.9	6.7	15.0	14.9	60.0

*Means followed by the same letter(s) within the same column are not significantly different at the 5% probably level according to the Duncan's multiple range test.

trend as the number of green pods produced. The response to manure application by green pod yield was greater in 2000 than in 2001 as significant response was up to 12 and 6 t ha^{-1} respectively. The experimental field in 2000 had lower soil fertility with respect to total nitrogen and available phosphorus contents of the soil relative to the field used in 2001, hence the higher manure requirement in the first year. This can also be explained by the poorer quality of manure that was applied in 2000, when the total nitrogen content (2.51%) was far lower than that in the 2001 manure (3.41%) coupled with a very high sand content (49.7%). Local literature has reported soil contents of manure of 50-90%; total N of 0.5-1.2%, which are indicative of poor quality manure [19]. Quality of manure was therefore a major determinant of the response of okra to manure application in the present investigation. From the economic standpoint, we have now found the best manure rate for okra production in this environment to be about 6 t ha^{-1}. Response to the first 6 t ha^{-1} of manure gives credence to the widely held belief that soil fertility is a more potent limiting factor on crop production than soil moisture. However, failure of the second 6 t ha^{-1} to give a comparable green pod yield increment could in fact be an indication that other limiting factors might be at play. The chief of which is likely to be soil moisture in the semi-arid environment such as Harare, Zimbabwe. This trend of response was similar to the one reported for various food crops to animal manure application in semi-arid Kenya [20]. Also, the greater effectiveness of manure use at lower rates might have been due to our adoption of banding application method.

Applying high amounts of cattle manure to okra under a low-input system such as the small-scale cropping system in Zimbabwe will not be economic or sustainable. The 6 t ha^{-1} rate, particularly in the context of a low-input system, represents a better return for labour, a major limiting factor [20]. Even from the perspective of the herd size of smallholder farmers, availability of that large quantity of animal manure for use on a local vegetable crop appears unrealistic. Undoubtedly, the quantities of manure that are likely to be available to farmers would be limited because of low livestock number per household. Avila [21] revealed that the average manure production per livestock unit in rural Zimbabwe is 1.2 t yr^{-1}.

That weed dry weight was not affected by manure application is suggestive of the fact that increasing manure rate did not increase weediness. This is indicative of the management given the cattle manure used in the study, which came from a dairy herd fed with hay and with minimal degree of field grazing. Questions about manure being a source of weed introduction and dissemination have often been raised. Baig et al.[22] asserted from their study with different organic sources that organic manures had seed bank of different weed species in viable condition and acted as a major source of weed infestation within crop field. Our result refutes their finding but it lends further credence to the findings by Gibberd [20] indicating that the degree of plot weediness was not increased by manure application. Proper curing of manure by heaping before applying to fields is capable of drastically reducing weed seed viability [23, 24].

On average, manure rates did not produce statistical differences in plant height, dry weight of plant components and total plant dry weight. Nonetheless, the various plant-size parameters were generally slightly higher in cases where manure was applied than when not. In virtually every instance, there were no statistical differences between the first manure increment and the highest one. Oikeh and Asiegbu [25] reported similar results for tomatoes in Nigeria, as manure did not produce statistical differences in stem diameter, plant height and number of leaves per plant. Early application of manure slightly favoured okra stem dry weight and total plant dry weight in our study. Studies by Nwanguma[17] on okra in Southwestern Nigeria revealed that the root and shoot growth of okra in poultry manure-amended soil were not different from those in control.

Overall, average green pod weight, length and diameter were significantly greater for the manured plants than for the control. The response of average green pod weight to manure rate was in close relation with response by green pod in t ha^{-1} in both years. Average green pod weight is therefore another important yield determining component in okra. In many respects, our results are in consonance with those reported for pepper by Aliyu [10]. He reported that given four farmyard manure (FYM) rates ranging from 0 to 30 t ha^{-1}, all the rates were statistically similar and higher than the control with respect to fruit length and diameter. Contrary to our finding for okra, however, the number of pepper fruits $plant^{-1}$ was increased by FYM rates of 20 and 30 t ha^{-1}.

Manure application improved average weight of dry pod and weight of seeds pod^{-1} significantly relative to the control but values for the manure rate increments were statistically at par. Number of seeds per pod and 100-seed weight (seed size) did not respond to manure rate or timing. Katung et al.[26] from their studies on okra at Samaru, Nigeria reported that number of seeds $plant^{-1}$, seed dry weight $plant^{-1}$ and seed yield ha^{-1} were not influenced by FYM rates ranging from 0 to 10 t ha^{-1}, while a 20 t ha^{-1} rate of application even significantly depressed these three seed parameters. They attributed their observation to the slow release of nutrients from FYM. This would largely explain why in our own study we failed to detect any significant difference between applying manure at 4 WAP and at 8 WAP. Considering that much of the nutrients in animal manure will be in organic form, some reasonable length of time would be required for these to be converted to their mineral forms and made available for uptake by plants. This also explains the very modest influence of manure application on the nutrient composition of the okra plant. The okra variety used in our study might have been an important factor. Ogunlela et al.[27] demonstrated through their study in semi-arid Nigeria varietal influence on nutrient accumulation in okra plants. Besides, the dynamic nature of mineral composition of a plant tissue and the phenological changes may radically affect tissue composition. We, however, observed that N and Mg concentrations in the okra pod and Ca in the leaves were higher for plants manured at 4 WAP than those manured at 8 WAP since such plants had the advantage of time for translocation of these nutrients to the pod. The okra leaf is a better accumulator of N and Ca than the pod. Our results support the explanation given by Russell [28] that cation concentrations in most plant tissues, such as actively functioning leaves and fruits, are not only characteristics of the crop but also fairly independent on the soil or fertilization.

Conclusions

For good performance of okra in a semi-arid subtropical environment such as Zimbabwe under a low external input system, an early application of cattle manure of 6 t ha^{-1}, depending on manure quality, will be appropriate for good production.

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