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Effect of Mechanized Compost Application on Forage Yields of Berseem and Fodder Maize under Centre Pivot Irrigation System

[1]E.M. Abd El Lateef, [2]A.A. Abd-Elmonsef,
[1]M.S. Abd El-Salam, [3]M.A. Farrag and [1]T.A. Elewa

[1]Field Crops Res. Dept., Agric. Div., National Research Centre,
33 El-Behooth St., Giza, Egypt
[2]Ag. Eng. Res. Inst., Ag. Res. Center, Dokki, Giza, Egypt
[3]Agricultural Economic Department Agric. Div., National Research Centre,
33 El-Behooth St., Giza, Egypt

Abstract: Demonstration field trials with compost were carried out in the winter 2017/18 and 2018/19 and summer 2018 and 2019 seasons under centre pivot irrigation on a private farm at km 100 on the Cairo-Alexandria desert road. The trials investigated the effects of compost applied at 24 and 48 m^3 per hectare on berseem and maize forage yields and quality. No significant effect of compost application at 24 m^3 ha^{-1} was observed at the first cut of berseem when the average crop yield was 12.48 t ha^{-1} (fresh weight). At subsequent harvests, however, the forage yield was significantly increased by compost treatment, compared with the farmer's usual crop management practice. There was an increase of 25% in overall crop performance due to compost application from an average of yield where the compost applied at 24 m^3 ha^{-1} increased crop yields from 27.84 to 34.8 t ha^{-1}, (fresh weight) after three cuts. A second pivot irrigator was treated with compost at 48 m^3 ha^{-1} in the summer season and cropped with fodder maize producing 17.4 t ha^{-1} of fodder, compared with 6.48 t ha^{-1} on the untreated control area under normal farmer practice. There was some evidence of beneficial increases in the N, P and K content of the crop and the amounts of Fe, Mn, Zn and Cu in the plants were also usefully elevated by compost application compared to the untreated control, which received only a base dressing of inorganic fertilizers. The simple analysis of the mechanization cost of compost spreading indicated the cost of full mechanized handling of the sludge is at least 4 times the cost of loading the spreader by manual labour. In general, the application of compost improved the nutritional quality of fodder as an animal feed on an alkaline sandy desert soil.

Key words: Berseem · Fodder maize · Mechanization · Nutrients · Compost

INTRODUCTION

The newly reclaimed soils in Egypt are characterised by low fertility, high salt content and poor moisture retention [1]. These poor soils need ameliorating with organic matter such as compost to improve their characteristics to meet the organic matter requirement of these soils [2]. Application of organic fertilizer sources to various crops could crop performance and soil physical characteristics [3, 4]. Compost, is regarded as a natural resource to be applied efficiently to the areas under reclamation [5]. Better water retention and soil structure and increased efficiency of mineral fertilizer utilization could be achieved by compost application [6, 7]. Egyptian clover or berseem (*Trifolium alexandrinum* L.) is the most important legume forage crop dominant in the Egyptian agriculture in winter for all livestock. It is a dry or fresh feed to poultry and animals with high nutritive value [8, 9]. Since it is multi-cutting forage crop it is preferred by farmers. The cultivated area reached 1.07 million hectare $year^{-1}$ [10].

Maize (*Zea mays* L.) is one of the major cereal crops, it is ranks the third following wheat and rice in world production as reported by Food and Agriculture

Corresponding Author: E.M. Abd El Lateef, Field Crops Res. Dept., Agric. Div., National Research Centre, 33 El-Behooth St., Giza, Egypt. E-mail: profabdellateef@gmail.com.

Organization [11]. Maize is grown for forage purposes. Fodder maize the most important forage after grass compared to other cereal crops. Its rapid growth and taste is palatable to the animal with a high dry matter production and relatively and high-energy content and considerable protein compared to other cereal crops. It is therefore directly fed to farm animals as fresh or silage [12-14]. Oad *et al*. [15] reported that the integrated application of organic and inorganic fertilizer significantly affected all the maize plant parameters. It was concluded that the inorganic nitrogen application is the common practice of the farmers, but if, farmyard manure will be supplemented there may be significant increase in fodder maize yield.

The objective of this trial is to provide a large-scale demonstration of the mechanized application of organic matter for arable cropping under centre pivot irrigation. This is likely to represent the nearest example of fully mechanized land-spreading of compost which is possible under Egyptian cropping and economic conditions.

MATERIALS AND METHODS

Two large-scale field trials were carried out in winter 2017/18 and 2018/19 and summer 2018 and 2019 seasons under centre-pivot irrigation system on a private farm at km 100 on the Cairo-Alexandria Desert Road. The first trial was carried out on berseem (*Trifolium alexandrinum* L.), while the second trial was with fodder maize (*Zea mays* L.). The objective of the trials was to investigate the effects of compost application on berseem and maize forage yields and quality. Another objective of this study was to provide a large-scale demonstration of the mechanized application of compost for arable cropping under centre-pivot irrigation system on reclaimed soil. In 2017/18 and 2018/19 winter seasons, a circle of (29.2 ha) equal to 70 feddans (fd) under overhead pivot irrigation was devoted for berseem growing. Half of the circle was treated with 24 m^3 ha^{-1} of compost. The other half of the area was left untreated and farmed according to normal farmer practice. The whole area received fertilizer after the first cut.

For the summer 2018 and 2019 seasons, a second pivot area of 14.6 ha equal to 35 (fd) was selected for maize growing. For this crop only half of the circle was cultivated and this was divided into two equal areas. One area was treated with 48 m^3 compost and the second area received fertilizer. In subsequent seasons, the whole circle would be cultivated.

Barley (winter crop) is planned to be cultivated on both pivot areas in the 2019/2020 season to study the cumulative and residual effects of compost application. The physical description and chemical analysis of the soil at the trial are presented in Table (1).

Compost was delivered to the site and positioned in small heaps of about 48 m^3 around the edge of the area to be treated. The compost was very dry and analysed. The chemical analysis of the compost is presented in Table (2).

Table 1: Physical description (a) and chemical analysis (b) of the trial site.

a) Physical description of the site.

Slope	1%
Depth to water table	42 m
Drainage	well drained
Soil classification	Typic Caleiorthid (Aridisol)

b) Chemical analysis of soil samples taken down the profile.

Determined		Units	Soil profile depth (cm) 0-20	20-70	70-90
Gravel		% > 2 mm	27.1	10.9	29.1
Ca CO_3		%	5.0	4.0	4.0
Gypsum		%	0.6	1.4	2.0
pH			7.54	7.44	7.44
EC		dS m^{-1}	2.92	3.52	3.09
Cations:	Ca^{2+}	me l^{-1}	9.0	15.0	16.0
	Mg^{2+}	me l^{-1}	1.6	5.0	2.9
	Na^{+}	me l^{-1}	19.0	15.4	12.2
	K^{+}	me l^{-1}	0.3	0.3	0.3
Anions:	HCO^{3-}	me l^{-1}	1.32	1.48	1.08
	Cl^{-}	me l^{-1}	10.8	13.4	10.8
	SO_4^{2-}	me l^{-1}	17.78	20.82	19.25

Table 2: Chemical analysis of the compost used in the trials (Means of two seasons).

Determined	Units	Egyptian clover trial Winter	Fodder maize trial Summer
Dry solids (ds)	%	88.9	-
Volatile solids	% ds	69.6	-
Nitrogen	% ds	2.74	2.56
Phosphorus	% ds	0.29	0.53
Potassium	% ds	0.23	0.24
Iron	% ds	1.11	2.06
Manganese	mg kg^{-1} ds	470.0	966.0
Zinc	mg kg^{-1} ds	480.0	399.9
Copper	mg kg^{-1} ds	234.0	117.0

Mechanized Application of Compost: The original aim of the trial was full mechanization of the compost spreading operation using a foreloader and muckspreader. The target application rate would be achieved by filling a muckspreader with a foreloader with measured quantities and then apply it at a speed calculated from the rate of discharge and width of spread of the muckspreader. The farm had a muck spreader. Consequently, the spreader was filled to the required level. The calibration of the muckspreader required the following information;

- Volume of spreader: 3.4 m^3 (3.8 m long × 1.8 m wide × 0.5 m height)
- Density of compost: 0.74 t m^{-3}
- Weight of compost in spreader: 2.53 t
- Width of spread: 1.8 m

Thus, to reach the target application rate of 24 m^3 ha^{-1} for the berseem trial, the muckspreader had to travel 800 m in order to deliver 3.4 m^3 of sludge. To apply 48 m^3 ha^{-1} for the maize trial, the spreader had to travel 400 m. This was achieved by a process of trial and error by varying forward speed and the rate of discharge.

Time and Motion Study Comparing Mechanical and Manual Spreading: The bucket loader was hired at a charge of 100 LE h^{-1}. In comparison, labour costs are of the order of 80-100 LE day^{-1}. A simple time and motion exercise showed that four men could fill the spreader in about 30 min. It took about 10 min to spread the sludge giving a 40 min round trip. On the basis of an 8 hour day, about 12 spreader loads could be applied by manual labour. This would be equivalent to 40 m^3 of compost day^{-1} (12 × 3.4 m^3 loads) at a cost of 80-100 LE day^{-1}, or 2.0-2.5 LE m^{-3}. Assuming that a loader would do the same job in 10 minutes, the number of loads day^{-1} would be increased to 24, which is equivalent to 81.6 m^3 of compost. On the basis that the loader charge includes labour and an additional worker is employed to drive the spreader, the total cost day^{-1} would be 900 LE ((8 × 100) + 100). This is equivalent to 10 LE m^{-3}.

This simple analysis suggests that the cost of full mechanized handling of the sludge is at least four times the cost of loading the spreader by manual labour.

Compost application to the berseem trial was carried out from 30 September to 10 October 2017 and 2018 and to the maize trial from 25 June to 1 July 2018 and 2019, following which the soil was cultivated twice with a fixed tine harrow. Multi-cutting berseem (cultivar Sakha-4) was sown in October 2017 and 2018. Maize (Giza-2 variety) was sown in July 2018 and 2019. Sowing was by mechanical seed drill, where the distance between rows was 2.5 and 5 cm for berseem and maize, respectively. Irrigation was carried out by overhead centre pivot about every 3 days and the pivot rotated twice a week in winter season in berseem trial. In the summer season, the frequency of irrigation was every 1-2 days. None of inorganic fertilizers were supplied until after the first cut. In the 2^{nd} and 3^{rd} cuts ammonium sulphate (20.6%) at 96 kgN ha^{-1} Calcium super phosphate at 75 kg $P_2O_5 ha^{-1}$ potassium sulphate 60 kg K_2O ha^{-1} were applied. For maize ammonium sulphate 144 kg N ha^{-1} and potassium sulphate at 60 kg K_2O ha^{-1} was applied. Centre pivot irrigator discharge was measured by Flow meter and it was 40l sec^{-1}. The water was 144 m^{-3} per one hour. Chemical analysis was carried out on 10 composite samples from each treatment for nutrient and heavy metal concentrations. Chemical analysis was carried out on dried and ground samples. Nitrogen was determined by micro-Kjeldahl according to the [16]. After wet digestion of the samples according to [17], P was determined by spectrophotometry, K by flame photometer [18] and Fe, Mn, Cu and Zn were determined by atomic absorption spectrophotometry. The data were statistically analysed using t test and treatment means were compared using least significant differences test (LSD) according to [19].

RESULTS AND DISCUSSION

Effects of Compost Application on Berseem and Maize Forage Yields: The mean yields of berseem at each cut are presented in Table (3). There was no significant effect of

Table 3: Effect of compost application (24 m^3 ha^{-1}) on the yield of berseem at three consecutive harvests (t ha^{-1} fresh weight) compared with normal farmer practice

	1st cut		2nd cut		3rd cut	
	No compost	Treated	No compost	Treated	No compost	Treated
Mean	13.25	12.48	9.6	12.24	5.04	10.08
LSD at 0.05	ns	2.4	1.88			
Probability	ns	0.033*	<0.001***			

Table 4: Effect of compost application (48 m^3 fd^{-1}) on fodder maize yield (t ha^{-1} fresh weight) compared with normal farmer practice

	Fodder maize yield (t ha^{-1})	
	Farmer practice	Compost Treated
Mean yield	6.48	17.4
LSD at 0.05	6.77	
Probability	0.004**	

Table 5: Effects of compost application on the nutrient content of berseem at three consecutive harvests.

			Mean concentrations			
Cut number	Element	Units	Untreated	Treated	LSD at 0.05	Probability
1	N	(%)	2.06	2.06	ns	>0.05
2	N	(%)	1.51	1.78	0.26	0.044*
3	N	(%)	1.73	1.40	ns	>0.05
1	P	(%)	0.257	0.297	ns	>0.05
2	P	(%)	0.205	0.124	ns	>0.05
3	P	(%)	0.185	0.149	ns	>0.05
1	K	(%)	0.85	1.06	0.20	0.042*
2	K	(%)	1.09	1.06	ns	>0.05
3	K	(%)	1.01	0.97	ns	>0.05
1	Fe	mg kg^{-1}	50.2	77.7	11.1	<0.001***
2	Fe	mg kg^{-1}	81.4	108.1	8.0	<0.001***
3	Fe	mg kg^{-1}	55.1	56.8	ns	>0.05
1	Mn	mg kg^{-1}	25.0	31.9	3.3	<0.001***
2	Mn	mg kg^{-1}	27.8	31.3	3.2	0.034*
3	Mn	mg kg^{-1}	36.5	29.0	5.9	0.016*
1	Zn	mg kg^{-1}	9.3	12.5	ns	>0.05
2	Zn	mg kg^{-1}	9.6	16.8	3.3	<0.001***
3	Zn	mg kg^{-1}	33.4	39.5	ns	>0.05
1	Cu	mg kg^{-1}	4.48	4.96	ns	>0.05
2	Cu	mg kg^{-1}	4.9	7.4	1.2	<0.001***
3	Cu	mg kg^{-1}	7.9	7.0	ns	>0.05

Notes: values in bold denote significant differences

compost on berseem yield at the first cut when mean yields were 13.25 and 12.48 t ha^{-1} for the untreated (normal farmer practice) and the treated areas respectively. However, in the subsequent cuts, the yields from the compost-treated area were significantly greater than the yields from the untreated area, the latter declined with each harvest to 5.04 t ha^{-1} at the third cut, compared to 10.08 t ha^{-1} from the compost treated area. The maintenance of yields in successive harvests in this way is of significant benefit of compost for the farmer.

The total crop yield from the three cuts was calculated from the mean values obtained from each of the cuts, but since the replicate samples at each cut were independent of each other (random quadrats), the cumulative total yields cannot be analysed statistically. Overall, the results show that compost applied at 24 m^3 ha^{-1} increased crop yields from 27.84 to 34.8 t ha^{-1}, an increase of 25%. The results obtained within the range of the results found by [20-24]. The yields of fodder maize are given in Table (4). The compost-treated area produced a significantly higher yield ($P < 0.004$) than the untreated area; 17.4 t ha^{-1} compared to 6.48 t ha^{-1}, an increase of 160%. The yields generally were rather less than may be expected, even for reclaimed lands, probably due to the shallow sowing depth which resulted in reduced crop density. The establishment of arable crops on reclaimed land can be variable due to the difficult soil conditions and seed sown too shallow is more at risk of desiccation. The addition of the organic matter in the compost may assist in moisture retention and improved seedling survival. Oad *et al*. [15] reported that all the maize plant parameters were significantly affected with the incorporation of FYM and nitrogen levels. Yield increases in berseem forage yield due to compost application have been reported in Egypt by Abd El Lateef *et al*. [3] they showed substantial yield benefits from compost addition and it suggested that there was equality in N value between the fertilizer and the composted product. Also, they suggested predictable benefits to crop production and yield from FYM application to agricultural desert land.

Effects of Compost Application on Berseem Nutrient Content: There were only a few statistically significant, beneficial effects due to the compost application on the N, P and K contents of the berseem, bearing in mind that all of the crop received fertilizer after the first cut, according to farmer practice. However, the concentrations of Fe, Mn, Zn and Cu were generally significantly greater in the berseem grown on the compost-treated plot than the untreated one. Since the yields of the compost-treated plot were also generally much greater, the total off-take of these nutrients would be substantial. Thus, in terms of plant and animal nutrition, compost improved herbage quality since these elements are often deficient in such alkaline soils. Even so, the concentrations of Zn and Cu in the berseem from the compost-treated plot only reached the adequacy levels for the ruminant nutrition. The long term effects of the combined application of organic and inorganic fertilizers in improving soil fertility and crop yield have been demonstrated by [25-29]. It may be concluded from this preliminary study that compost application to newly reclaimed soil is effective in improving crop productivity. In other words compost apply macro and micronutrients and improve the building up performance through the organic matter, consequently more water retention capacity which result in better growth and forage or fodder yields. This will increase farmer confidence in organic products as fertilizer materials and soil conditioners, reducing the reliance on inorganic fertilizers for crop nutrition as well as increasing the seed status of some macro and microelements. These results are from only a two applications and a further four are planned in consecutive seasons. Consequently, this will result in significant additions of organic matter to the soil and monitoring of the soil physical condition will be undertaken in due course.

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