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Primary, Residual and Cumulative Effects of Compost Application on Egyptian Clover (*Trifolium alexandrinum* L.) and Barley (*Hordeum vulgare* L.) Yields and Quality under Centre Pivot Irrigation System

[1]A.A. Yaseen, [2]M.S. Abd El-Salam, [2]A.K.M. Salem, [1]Sahar M. Zaghloul, [2]T.A. Elewa, [3]Aml R.M. Yousef and [2]E.M. Abd El Lateef

[1]Plant Nutrition Dept., Agric. Biol. Res. Inst.,
[2]Field Crops Res. Dept., Agric. Biol. Res. Inst.,
[3]Horti. Crops Technol. Dept., Agric. Biol. Res. Inst.,
National Research Centre, 33 El-Buhouth St., Dokki, Giza, Egypt

Abstract: Large-scale field trials with compost were carried out in the winter 2020/2021 and 2021/22 seasons under centre pivot irrigation on a private farm at km100 on the Cairo-Alexandria desert road. The trials investigated the effects of primary, residual and cumulative effects of compost application on Egyptian clover (*Trifolium alexandrinum* L.) and barley (*Hordeum vulgare* L.) yields and quality under a centre pivot irrigation system. The results indicated that there is no significant effect of compost application at 10 m^3 fd^{-1} was observed at the first cut of berseem. At subsequent harvests, however, the forage yield from the compost - treated area was significantly greater than the yields from the untreated area: the latter declined with each harvest to 2.52 t fd^{-1} at the third cut, compared to 5.04 t fd^{-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. Barley was cultivated on the same pivot area in the 2021/22 season to study the cumulative and residual effects of compost application. The results showed that straw production was raised by more than 50% with cumulative applications of compost compared with normal farmer practice, and grain yield was increased by more than 20% relative to the conventional management. Concentrations of heavy metals (Ni, Cd, Pb, Cr and Co) in the berseem were below the limits of analytical detection. 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. Soil analysis after barley showed that the concentrations of extractable nitrogen were significantly greater ($P < 0.001$) in the compost treated soil than in soil from the control (farmer practice) area. Extractable nitrogen from the primary plot was also significantly greater than the residual area. The control and residual plots had similar levels of extractable phosphorus but surprisingly, the primary plot had a significantly lower concentration ($P = 0.044$). There were no significant effects on soil potentially toxic elements PTE concentrations between the plots, except for total Mn (lower on the residual plot) and extractable Ni which was elevated on both compost treated plots. In general, the application of compost improved the nutritional quality of fodder as an animal feed on alkaline sandy desert soil. Another conclusion is the yield response of barley to compost is entirely consistent with the results from berseem.

Key words: Egyptian clover • Barley • Yields • Primary residual • Cumulative • Compo • Nutrients • Soil properties

INTRODUCTION

The newly reclaimed soils in Egypt are characterized by low fertility, high salt content, and poor moisture retention [1]. The areas under reclamation are mostly calcareous and light soils and since animal manure is not readily available for soil application, alternative materials such as compost should be tested and used to meet the

Corresponding Author: Prof. Dr. E.M. Abd El Lateef, Field Crops Res. Dept., Agric. Biol. Res. Inst., National Research Centre, 33 El-Buhouth St., Giza, Egypt.

organic matter requirement of these soils [2]. Recycling organic waste as a crop fertilizer, as opposed to its disposal at a landfill, would reduce greenhouse gas emissions [3,4]. In the EU in 2017, 26% of MSW (municipal solid waste/ bio-waste) was landfilled, 30% was recycled, and a further 17% was composted [5].

Beneficial effects of the organic matter applied to the soil in compost are seen by crops as well as improved performance [6]. Various studies had assessed the benefits of organic manures including compost on the physical characteristics of Egyptian soils and in increasing crop yields [7]. The expansion of agriculture through the reclamation of desert lands demands manure and other sources of organic fertilizer. Compost, is regarded as a natural resource to be applied efficiently to the areas under reclamation [8]. The application of compost to the soil improves the chemical, physical, and biological characteristics of soil. It improves water retention and soil structure by increasing the stability of soil aggregates [9]. Moreover, the effects of the organic matter applied to the soil in compost are seen in increased efficiency of mineral fertilizer utilization by crops and improved performance [10].

Egyptian clover or berseem (*Trifolium alexandrinum* L.) is the most important legume forage crop dominant in the Egyptian agriculture in winter for all livestock. Dried clover is also an important poultry feed [11]. Due to its desirable qualities, it is suggested that it might be the cheapest supplementary protein source in livestock rations [12]. The first forage crop grown under the Egyptian forage conditions is the Egyptian clover. Since it is a multicutting forage crop it is preferred by farmers. The cultivated area reached 1.07 million hectare year^{-1} [13]. Moreover, Berseem decrease or prevent erosion and salting processes of soil, also, it has an important role in cleaning the soil from weed. Egypt suffers from a great loss of agricultural land as a result of erosion and desertification problems.

Barley (*Hordeum vulgare L.*) is one of the main cereal crops produced in the World. Global barley production is estimated about 141.7 million tons [14]. Globally, European Union, Russia, Canada, USA and Argentina are the top five largest world barley producers where, European Union produces the greatest quantities of barley with an estimated production of 20.5 million tons followed by the Russian federations with a production of about 8 million tons, whereas barley production in Canada, USA and Argentina was estimated 7.3, 3.1 and 2.8 million tons, respectively [14]. In the African continent, Morocco, Ethiopia, Algeria, Tunisia and South Africa were the top five largest barley producers for the year 2016 with estimated production of approximately 2.1, 1.85, 1.3, 0.5 million and 0.307 million tons, respectively. More than half of barley area coverage is in developing countries [15]. Barley has a number of advantages that testify to its role in food security [16]. Despite, the importance of barley and its many useful characteristics, there are several factors affecting its production and productivity. The most important factors that reduce yield of barley in Ethiopia are poor soil fertility, low soil pH and soil acidity, water logging, drought, frost, poor crop management practices [17].

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 field trials were carried out in winter 2020/2021and 2021/2022 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 barley (*Hordeum vulgare* L.). The objective of the trials was to investigate the effects of compost application on berseem and maize forage yields and quality of berseem and barley yields. Another objective of this study was to provide a determination of soil characteristics after compost application for arable cropping after two seasons under centre-pivot irrigation system on reclaimed soil.

In 2020/2021 winter season, a circle of 70 feddans (fd) under overhead pivot irrigation was devoted for berseem growing. Half of the circle was treated with 10 m^3 fd^{-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.

Barley (winter crop) was planned to be cultivated on the same pivot areas in the 2021/22 season to study the cumulative and residual effects of compost application. The design of the trials is illustrated in Fig. 1, which also illustrates how the design develops for the second season cropping on the same pivot areas. The physical description and chemical analysis of the soil at the trial are presented in Table 1.

Air-died compost (350 m^3) was delivered to the site and positioned in small heaps of about 10 m^3 around the

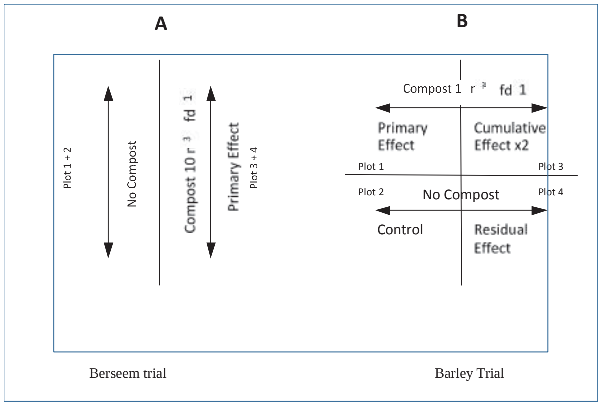

Fig. 1: Designs of berseem and barley trials indicating the directions of compost application in each trial

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					
			Soil profile depth (cm)		
Determinand		Units	0-20	20-70	70-90
Gravel		% > 2 mm	29.80	12.00	32.00
$CaCO_3$		%	5.50	4.40	4.40
Gypsum		%	0.70	1.50	2.20
pH			7.54	7.44	7.44
EC		dS m^{-1}	3.20	3.90	3.40
Cations:	Ca^{2+}	me l^{-1}	9.90	16.50	17.60
	Mg^{2+}	me l^{-1}	1.80	5.50	3.20
	Na^{+}	me l^{-1}	20.90	16.90	13.40
	K^{+}	me l^{-1}	0.30	0.30	0.30
Anions:	HCO^{-3}	me l^{-1}	1.50	1.60	1.20
	Cl^{-}	me l^{-1}	11.90	14.70	11.90
	SO_4^{2-}	me l^{-1}	19.60	22.90	21.20

Table 2: Chemical analysis of the compost used in the trials

Determinand	Units	Berseem trial	Barely trial
Dry solids (ds)	%	80.010	-
Volatile solids	% ds	62.640	-
Nitrogen	% ds	2.466	0.504
Phosphorus	% ds	0.261	0.477
Potassium	% ds	0.207	0.216
Iron	% ds	0.999	1.854
Manganese	mg kg^{-1} ds	423.000	869.400
Zinc	mg kg^{-1} ds	1332.000	89.910
Copper	mg kg^{-1} ds	210.600	105.300

edge of the area to be treated. The compost was very dry and. The chemical analysis of the compost is presented in Table 2.

Compost application to the berseem trial was carried out from 30 September to 10 October 2020 and 2021 for barely trial, following which the soil was cultivated twice with a fixed tine harrow. Multi-cutting berseem (cultivar Sakha-4) was sown in October 2020. Barley (Giza-124 variety) was sown in 2021. Sowing was by mechanical seed drill, where the distance between rows was 2.5 and 5 cm for berseem and barley, 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. None of inorganic fertilizers were supplied until after the first cut. In the 2nd and 3rd cuts ammonium sulphate (20.6%) at 40 kg N fd^{-1} or to phosphoric acid at 22.5 kg P_2O_5 fd^{-1} potassium sulphate 24 K_2O fd^{-1} were applied. Barley was fertilized with nitrogen at the rate of 70 kg N fd^{-1} was applied in two equal doses after 21 and 45 days, from sowing. 15 kg P_2O_5 fd^{-1} (100 kg of calcium super-phosphate 15 % form) was applied as a basal application during soil preparation. . Type of irrigation overhead centre pivot frequency of irrigation approximately every 3 days - the pivot rotates twice a week. First week daily, 2nd and 3rd weeks every 2 days, 4th week every 3 days, then daily. Centre pivot irrigator discharge was measured by Flow meter and it was 40 l 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 [18]. After wet digestion of the samples according to [19], P was determined by spectrophotometry, K by flame photometer [20], 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 [21].

RESULTS AND DISCUSSION

Berseem:

Effects of Compost Application on Berseem Forage Yields: The mean yields of berseem at each cut are presented in Table 3 and Fig. 2. There was no significant effect of compost on berseem yield at the first cut when mean yields were 6.6 and 6.24 t fd^{-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 2.52 t fd^{-1} at the third cut, compared to 5.04 t fd^{-1} from the compost treated area. The

Table 3: Effect of compost application (10 m^3 fd^{-1}) on the yield of berseem at three consecutive harvests (t fd^{-1} fresh weight) compared with normal farmer practice

	1st Cut		2nd Cut		3rd Cut		Total	
	No compost	Treated	No compost	Treated	No compost	Treated	No compost	Treated
Mean	6.6	6.24	4.8	6.12	2.52	5.04	13.92	17.4
$LSD_{0.05}$	ns		1.0		0.94		1.4	
Probability	ns		0.033*		<0.001***		<0.001***	

Table 4: Effects of compost application on berseem protein yield kg fd^{-1}

	1st Cut		2nd Cut		3rd Cut		Total	
	No compost	Treated	No compost	Treated	No compost	Treated	No compost	Treated
Mean	119.2	112.7	63.5	95.5	40.0	94.3	74.2	100.8
$LSD_{0.05}$	ns		11.0		6.6		14	
Probability	ns		0.033*		<0.001***		<0.001***	

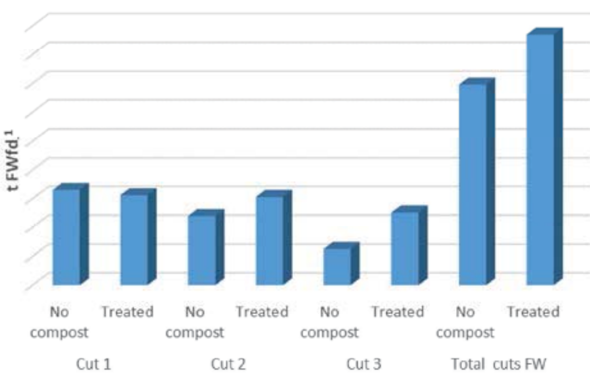

Fig. 2: Effect of compost application (10 m^3 fd^{-1}) on the yield of berseem at three consecutive harvests (t fd^{-1} fresh weight) compared with normal farmer practice

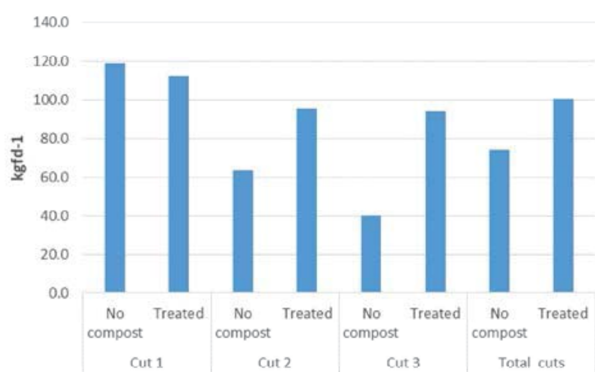

Fig. 3: Effect of compost application (10 m^3 fd^{-1}) on protein yield of berseem at three consecutive harvests (Kg fd^{-1} on DM basis) compared with normal farmer practice

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,. Overall, the results show that compost applied at 10 m^3 fd^{-1} increased crop yields from 13.92 to 17.4 t fd^{-1}, an increase of 25%.

Yield increases in berseem forage yield due to compost application have been reported in Egypt by Abd El Lateef *et al*. [6] 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 the agricultural desert land. 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.

Chemical Constituents of Berseem:

Protein Yield: Data presented in Table 4 and Fig. 3 reveal significant differences among forage cuts in their protein yield fd^{-1}. No significant difference between the treated and untreated plots with compost in the 1st cut, however in the subsequent cuts and the total cuts, the protein yield was greater in the treated plots than the untreated. Similar results were obtained [22] and [23] they obtained an increase of 25% in overall crop performance due to compost application from an average yield where the compost was applied at 24 m^3 ha^{-1}.

Nutrient Content of Berseem: Data presented in Table 5 and Figs. 4 and 5 summarize the nutrient content of the berseem at each of the three cuts. The concentrations of the heavy metals Cr, Co, Cd, Pb, and Ni in the crop were below detection limits. 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

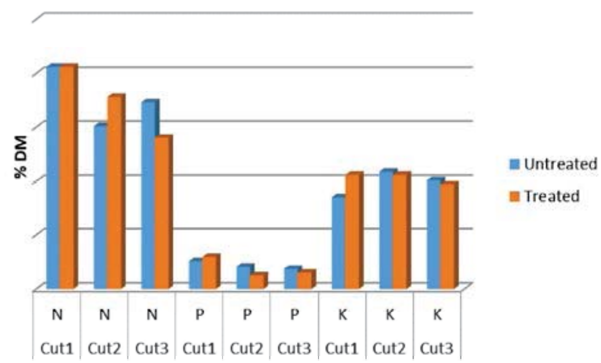

Fig. 4: Effect of compost application on berseem macronutrient content (%)

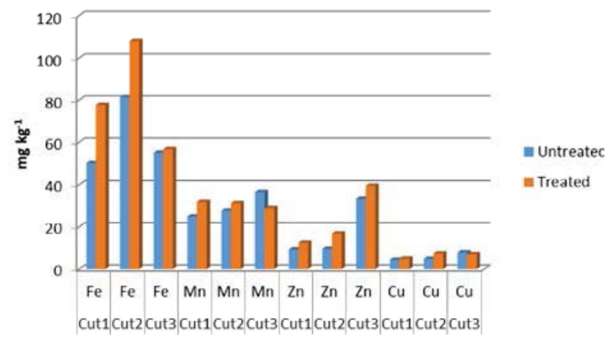

Fig. 5: Effect of compost application on berseem macronutrient content (mg kg^{-1})

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

Cut number	Element	Units	Mean concentrations Untreated	Treated	$LSD_{0.05}$	Probability
1	N	(%)	2.4720	2.4720	ns	>0.050
2	**N**	**(%)**	**1.8120**	**2.1360**	**0.26**	**0.044***
3	N	(%)	2.0760	1.6800	ns	>0.050
1	P	(%)	0.3084	0.3564	ns	>0.050
2	P	(%)	0.2460	0.1488	ns	>0.050
3	P	(%)	0.2220	0.1788	ns	>0.050
1	**K**	**(%)**	**1.0200**	**1.2720**	**0.20**	**0.042***
2	K	(%)	1.3080	1.2720	ns	>0.050
3	K	(%)	1.2120	1.1640	ns	>0.050
1	**Fe**	**mg kg^{-1}**	**60.2000**	**93.2000**	**11.1**	**<0.001*****
2	**Fe**	**mg kg^{-1}**	**97.7000**	**129.7000**	**8.0**	**<0.001*****
3	Fe	mg kg^{-1}	66.1000	68.2000	ns	>0.050
1	**Mn**	**mg kg^{-1}**	**30.0000**	**38.3000**	**3.3**	**<0.001*****
2	**Mn**	**mg kg^{-1}**	**33.4000**	**37.6000**	**3.2**	**0.034***
3	**Mn**	**mg kg^{-1}**	**43.8000**	**34.8000**	**5.9**	**0.016***
1	Zn	mg kg^{-1}	11.2000	15.0000	ns	>0.050
2	**Zn**	**mg kg^{-1}**	**11.5000**	**20.2000**	**3.3**	**<0.001*****
3	Zn	mg kg^{-1}	40.1000	47.4000	ns	>0.050
1	Cu	mg kg^{-1}	5.4000	6.0000	ns	>0.050
2	**Cu**	**mg kg^{-1}**	**5.9000**	**8.9000**	**1.2**	**<0.001*****
3	Cu	mg kg^{-1}	9.5000	8.4000	ns	>0.050

Notes: values in bold denote significant differences

Table 6: Grain and straw yield of barley showing residual, primary and cumulative effects of compost application to reclaimed land under Centre Pivot irrigation system

Treatment	Grain yield (Ardab fd^{-1})
Control	14.7 b
Residual	17.4 a
Primary	15.6 ab
Cumulative	18.0 a
$LSD_{0.05}$	2.5
	Grain yield (t fd^{-1})
Control	1.8 b
Residual	2.1 a
Primary	1.9 ab
Cumulative	2.2 a
$LSD_{0.05}$	0.3
	Straw yield (t fd^{-1})
Control	1.6 c
Residual	2.1 b
Primary	1.9 b
Cumulative	2.5 a
$LSD_{0.05}$	0.3

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 was 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 recycle and use of nutrients from organic manure has been given more consideration for insuring sustainable land use and agricultural production development. The long term effects of the combined application of organic and inorganic fertilizers in improving soil fertility and crop yield have been demonstrated by [24-28].

B. Barely: Grain and straw yields of barley are presented in Table 6. In this trial, compost application to the centre pivot was designed to provide treatments which examined:

- Cumulative application
- Primary application to previously unamended soil
- Residual value from the previously treated crop, compared with
- Unamended control following normal farmer practice.

The results show that grain yield was significantly increased by the residual effects of compost application

Table 7: Effect of primary, residual and cumulative compost application on soil properties after barley trial

Determined	Treatment: Control	Residual	Primary	F probability	$LSD_{0.05}$	Grand mean	cv (%)
pH	7.8	7.7	7.7	0.627ns	na	7.7	2.5
EC (dS m^{-1})	1.1	0.8	1.4	0.442ns	na	1.1	71.0
OM (%)	1.8	0.4	0.3	0.305ns	na	0.8	208.0
Extractable (mg kg^{-1})							
N	42	73	109	<0.001***	28.2	75	45.7
P	41	40	22	0.044*	16.2	35	41.0
K	158	98	147	0.189ns	na	135	40.7
Total (mg kg^{-1})							
Fe	4600	6344	5328	0.642ns	na	5424	51.2
Mn	56	73	92	0.305ns	na	74	48.4
Zn	80	108	168	0.140ns	na	119	60.3
Cu	93	147	119	0.058ns	na	120	31.1
Cr	23	56	33	0.073ns	na	38	63.6
Co	1.6	1.9	2.5	0.266ns	na	2.0	42.9
Cd	0.70	0.82	0.84	0.628ns	na	0.79	31.5
Pb	18	14	24	0.382ns	na	19	57.2
Ni	21	27	15	0.243ns	na	21	53.9
DTPA extractable (mg kg^{-1})							
Fe	24.6	13.5	18.1	0.136ns	na	18.7	47.2
Mn	15.7	3.4	11.7	0.002**	5.8	10.3	64.0
Zn	1.17	1.42	3.05	0.077ns	na	1.90	77.9
Cu	0.40	0.54	0.49	0.553ns	na	0.48	40.6
Cr	0.15	0.39	0.35	0.108ns	na	0.30	64.8
Co	0.10	0.10	0.29	0.132ns	na	0.17	104.8
Cd	0.19	0.03	0.03	0.108ns	na	0.09	167.0
Pb	0.42	0.37	0.53	0.078ns	na	0.44	26.5
Ni	0.25	0.45	0.66	<0.001***	0.16	0.45	45.6

Ns: not significant; na: not applicable

to the previous crop (berseem) and by the cumulative effects of two application of compost (from applications from the previous and current crops), compared with the untreated control. The primary application yield was marginally higher than the control, albeit not significantly at P = 0.05. The straw yield was markedly increased by cumulative compost application, compared to the other treatments. There was no significant difference in straw yield between the residual and primary plots, which were significantly greater than the normal farmer practice control. Indeed straw production was raised by more than 50% with cumulative applications of compost compared with normal farmer practice, and grain yield was increased by more than 20% relative to the conventional management. The obtained results are in agreement with those obtained by [16, 17, 29].

Soil samples were taken from the treatment areas and the results of the subsequent chemical analysis are presented in Table 7. The concentrations of extractable nitrogen were significantly greater (P<0.001) in the compost treated soil than in soil from the control (farmer practice) area. Extractable nitrogen from the primary plot was also significantly greater than the residual area. The control and residual plots had similar levels of extractable phosphorus but surprisingly, the primary plot had a significantly lower concentration (P = 0.044). There were no significant effects on soil PTE concentrations between the plots, except for total Mn (lower on the residual plot) and extractable Ni which was elevated on both compost treated pots. There was a tendency for total PTEs to be increased by compost but this was reflected in small increases in DTPA extractable PTEs.

In this respect some investigators pointed out that after three years of application of different organic matter treatments, no significant differences in soil total C and N were found with organic matter treatment [30]. However, after 10 years in the Askov trials, the soil 12 of 15 from the treatment receiving FYM had ~10% higher carbon concentrations compared to the mineral fertilized only treatment [31]. A 50% increase in soil carbon in a highly weathered tropical soil was found after just one year of compost amendment [32]. Sharma *et al*. [33] also indicated that the use of organic fertilizer might have made the soil more porous and pulverized, to allow better root growth and development, thereby resulting in higher root cation exchange capacity (CEC). According to Sanchez [34] the application of organic fertilizer directly influences the availability of native or applied phosphorus. It may be concluded from this preliminary study that compost application to newly reclaimed soil is effective in improving crop productivity. It is unlikely that a single factor in compost was responsible for this but is more likely to be due to the mixture of nutrients, micronutrients and organic matter that compost supplies. The main conclusions are: Yield response of barley to compost is entirely consistent with the results from berseem. Data from independent field trials provide assurance to farmers that compost has immediate and residual value for crop production. Yield responses to compost application are consistent and predictable when other management factors are not limiting to the potential yield of the crop. 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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