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Composts of Wood Industry Wastes for Clay Soil Conditioning. I. Growth Response and Water and Fertilizers Use Efficiency by Two Successive Crops (Broad Bean and Corn)

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Abstract: A two successive years completely randomized block field experiment with four replications for each treatment was conducted on a heavy clay compacted soil at Abou- El Matameer, Behera governorate to study the effect of two application rates (10 and 20 m^3/fed.) of composted ligno -cellulosic materials (LCM) either solely or mixed with farmyard manure (FYM) or Kattamia compost (KC) at the ratio of 1:1 on growth, yield and water and fertilizers use efficiency by broad bean (*vicia faba L.Giza 2*) followed by corn (*Zea mays* L. hybrid 310). Soil conditioning with the studied composts positively affect on plant growth production and consequently water and fertilizers use efficiency being higher with the application rate of the compost. These effects were assembled in plant height, number and weight of pods/plant, total dry matter/plant, weight of 100 seeds, seeds, straw and biological yields for broad bean and plant height, number of leaves /plant, fresh and dry weight of leaves and stem, seed index, seeds, straw, and biological yields for *corn.* A conclusion was drawn that mixtures of LCM and examined FYM or KC yielded higher growth productions and water and fertilizers use efficiency by the studied crops, with this respect FYM may be preferable.

Keywords: clay soils, composts, soil conditioners, wooden waste, water use efficiency, fertilizer use efficiency, broad bean, corn

INTRODUCTION

Heavy clay soils have several major problems which include a) high water retention capacities, inadequate aeration and poor drainage, b) low rate of infiltration, c) large volume changes i.e., alternating expansion and contraction when wetted and dried, d) crusting and cracking that adversely affect root penetration and seedling emergence. When dried cracks cause more evaporation, e) great stickiness, plasticity and limited moisture range during which they can't be satisfactory tilled and the high power requirement needed to plow them, f) compaction under heavy tillage machinery, and g) high heat capacity of the soil and its effect on delaying seed germination, soil fauna and plant growth particularly in cold seasons. Although clay soils have the advantages of high nutrient holding capacity, the problems mentioned above adversely affect most of the bio chemical properties and nutritional status of such soils[1,2,3].

Wood industry wastes include sawdust, bark, wood shavings, wood chips and finely divided wood fibers. Such ligno-cellulosic materials (LCM) are available in large quantities that reach 15% of the manufactured wood. A continuous removal of such wastes from the production sites to be transformed to effective and low price soil conditioners, through composting, has become necessary[4].

A two successive years field experiment was conducted on a heavy clay compacted soil at Abou- El Matameer, Behera governorate to study the effect of treating the soil with two application rates (10 and 20m3/fed) of composted LCM either solely or after mixing with other manures or composts. Broad been (*vicia faba*) followed by corn (*Zea mays*) were the indicator crops. Examined conditioners improved hydrophysical, mechanical and chemical properties of the soil with different values being higher with the application rate of the conditioner[5]. The conditioning effects of examined composts on vegetative growth, yields and both water and fertilizers use efficiency by the crops are the aim of the present work..

MATERIALS AND METHODS

A two successive years completely randomized block field experiment with four replications for each treatment was conducted on a heavy clay compacted soil at Abou- El Matameer, Behera governorate. Analytical data of the soil and irrigation water are presented in Table 1. Broad bean (*vicia faba L.Giza 2*) followed by corn (*Zea mays L.* cv. hybrid 310) were

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Table1: Analitical data of soil and irrigation water.

a-Hydrophysical properties

Particle size distribution Sand %	Silt %	Clay %	Textural class	Bulk density Mg/m^3	Total Porosity %	Water holding capacity %	Field capacity %	Wilting percentage	Hydraulic conductivity $m.day^{-1}$	mean diameter of soil pores (µ)
4.7	39.5	55.8	clay	1.421	46.4	32.3	29.2	20.1	0.006	0.48

b-Chemical properties

EC (1:5) dSm-1	pH (1:2.5)	$CaCO_3$ %	Organic matter %	CEC cmol kg^{-1}	Available nutrient (µg/g) Nitrogen	phosphorus	Potassium
1.08	8.05	3.57	0.72	43.05	51	22	64

c-Analysis of the irrigation water used

EC dSm-1	pH	Cations (meq\l) Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Anions (meq\l) $CO_3^{-2}+HCO_3^{-1}$	Cl^{-}	SO_4^{-2}	$SAR_{adj.}$
0.38	7.4	1.15	0.95	1.58	0.12	1.24	2.04	0.52	2

*determined after Page et.al.1982 [6] and Klute, 1986 [7].

Table 2: The main chemical properties of prepared composts.

Property	LCM	LCM+FYM (1:1)	LCM+KC (1:1)
PH (H_2O)	7.30	7.40	7.55
Salinity:			
EC (1:10) dSm^{-1}	1.25	2.35	3.16
Na^{+} %	0.02	0.05	1.10
Mineral content:			
Ash %	41.15	51.5	49.5
Organic component			
OM %	58.85	48.95	50.5
OC %	34.13	28.39	29.30
ON %	0.93	1.67	1.55
C:N	36.7	17.0	18.9
Macro elements:			
N %	0.96	1.69	1.58
P_2O_5 %	0.18	0.32	0.27
K_2O %	0.35	0.42	0.46
Ca^{+2} %	0.61	0.49	0.88
Mg^{+2} %	0.18	0.24	0.42
Micro elements:			
Fe (µg/g)	110	215	280
Mn (µg/g)	19	63	88
Zn (µg/g)	31	52	69
Cu (µg/g)	10	19	44
Heavy metals:			
Cd (µg/g)	0.5	0.6	0.8
Co (µg/g)	1.0	1.1	1.2
Ni (µg/g)	2.9	3.6	4.1
CEC cmol kg^{-1}	101.4	112.6	118.4

- On dry weight basis.

* determined after Page et.al.1982 [6] and Sukmana, 1983 [11].

the indicator crops. The soil was treated with composted ligno -cellulosic materials (LCM); mixtures of LCM and farmyard manure (FYM) or Kattamia compost (KC) at the ratio of 1:1 for mixture components at two application rates i.e 10 and $20m^3$/feddan. The main properties of composts used are presented in Table 2.

Broad bean and corn seeds were sown on the 20^{th} of November 2003 and 2004 and the 12^{th} of May2004 and 2005, respectively.

Superphosphate (15.5% P2O5), potassium sulphate (48%K2O) and ammonium nitrate (33.5% N) were added at the rate of 150, 50 and 50kg/fed for broad bean, respectively. The same fertilizers were applied at the rate of 150, 50 and 200kg/fed for corn, in sequence. Composts, phosphorus and potassium fertilizers were incorporated into the soil before sowing, while ammonium nitrate was added before the second irrigation for broad bean and divided into two equal doses before the first and the second irrigation for corn.

Vegetative growth was evaluated at 60 and 75 days from sowing for broad bean and corn, respectively. The grown plants continued up to their maturity stages i.e. 5^{th} of April and 30^{th} of August 2004 and 2005 for broad bean and corn crops, respectively.

Water depletion was calculated from the average of four layers from the soil surface to a depth of 0.6 m. Water consumption from each layer was obtained using the equation described by Israelsen and Hansen, 1962[8] as follow:

- $Cu = D \times BD \times (e_2 - e_1) \times 4200/100$

where:

- Cu = water consumption in m3/fed
- D = soil depth in m.
- BD = soil bulk density (Mg/m^3)
- e_1 = soil moisture % before the next irrigation directly
- e_2 = soil moisture % at 24 hours after irrigation (~FC).

Accordingly, water requirements were 1156 and 2800 m^3/fed for broad bean and corn crops, respectively. Water use efficiency was calculated for the different treatments using the following formulae: Water use efficiency (kg/ m^3) = yield (kg/fed)/ water consumption (m^3/fed) (9).

Fertilizers use efficiency by plants was calculated as kg of yield produced by a unit of added nutrient.

The following parameters were considered to evaluate the growth response to the conditioning treatments. Growth response for broad bean included plant height, number and weight of pods/plant, total dry matter/plant, weight of 100 seeds, seeds yield, straw and biological yield. Growth response for *corn* included plant height, number of leaves /plant, fresh and dry weight of stem and leaves, seed index, seed yield, straw yield, and biological yield.

Statistical analysis was performed according to Snedecor and Cochran 1990 (10).

RESULTS AND DISCUSSIONS

As the obtained data of both successive years were not significantly different, their averages were taken into consideration.

Growth Response and Yield of Broad Bean: Plant growth expressed as plant height, number and weight of pods/ plant, weight of 100 seeds and total dry matter/ plant, seed yield, straw yield and biological yield are presented in Table 3. Data show a significant increase in all studied parameters for plants grown on the conditioned soil compared to those of the untreated one being higher with the application rate of the conditioner. With this respect, increments due to applying $10m^3$/fed LCM to heavy clay soil were 14.6% for plant height, 19.6% for number of pods/plant, 27.8% for weight of pods/plant, 55.1% for weight of 100 seeds, 52.8% for total dry matter, 0.17.5% for seed yield, 12.4% for straw yield and 14.5% for the biological yield. Corresponding values for $20m^3$/fed LCM compost were 17.8, 34.7, 38.1, 60.9, 84.2, 29.8, 15.6 and 21.5%, respectively. On the other hand, conditioning heavy clay soil with 10 and $20m^3$/fed LCM+FYM (1:1) increased the aforementioned characteristics by 29.3 and 43.2% for plant height; 44.4 and 70.6% for number of pods/plant, 45.7 and 66.2% for weight of pods/plant, 63.7 and 86.3% for weight of 100 seeds, 91.8 and 165.6% for total dry matter, 46.8 and 113.6% for seed yield, 27.8 and 71.9% for straw yield and 35.7 and 89.2% for the biological yield, respectively.

Data also indicate the beneficial effect of mixing LCM compost with KC before incorporating into the soil on growth characteristics and yield mentioned above. Under these conditions, plant heights were increased by 17.9 and 31.0% that of untreated soil by treating the soil with 10 and $20m^3$/fed, respectively. Relevant values were 35.0 and 50.1% for number of pods, 39.0 and 51.1% for weight of pods/plant, 60.9 and 68.9% for weight of 100 seeds, 85.6 and 110.3% for total dry matter, 29.9 and 62.7% for seed yield, 15.7 and 35.8% for straw yield, 21.6 and 47.0% for the biological yield.

Growth Response and Yield of Corn: Plant growth expressed as plant height, number of leaves/ plant, fresh and dry weight of leaves and stem, seed index, seed yield, straw yield and biological yield are presented in Table 4. Data show a significant increase in all studied parameters for plants grown on the conditioned soil compared to those of the untreated one being higher with the application rate of the applied composts. With this respect, increments due to applying $10m^3$/fed LCM to clay soil were 9.3% for plant height,

Table 3: Effect of wooden waste composts on growth parameters and yield of broad bean plants grown on clay soil.

Composts used	Appl. rate m^3/fed.	Plant height cm	No. of pods/Plant	Wt. of pods/plant(g)	Total dry matter /plant (g)	Wt. of 100-seeds(g)	Yield seed kg/fed	Yield straw kg/fed	Yield biological kg/fed
Untreated	-	87.6	10.8	14.6	19.2	36.8	590.00	832.00	1422.00
LCM	10	100.5	12.9	18.7	29.4	57.1	693.00	935.23	1628.23
	20	103.3	14.6	20.2	35.4	59.3	765.81	961.54	1727.35
50%LCM+	10	113.3	15.6	21.3	36.9	60.3	866.31	1063.22	1929.53
50%FYM	20	125.5	18.4	24.3	51.0	68.6	1260.46	1429.78	2690.24
50%LCM+	10	103.3	14.6	20.3	35.7	59.3	766.11	962.88	1728.99
50%KC	20	114.8	16.2	22.1	40.4	62.2	960.11	1129.50	2089.61
LSD $_{0.05}$	compost (A)	4.3	0.8	ns	3.4	7.9	18.70	23.97	36.61
	rates (B)	3.5	0.7	ns	2.8	6.4	15.27	19.57	29.89
	A x B	ns	1.2	3.1	4.8	11.1	26.44	33.90	51.78

Table 4: Effect of wooden waste composts on growth parameters and yield of corn plants grown on clay soil.

Composts used	Appl. rate m^3/fed.	hight of plant (cm)	No.of Leaves/plant	Fresh weight of leaves (g)	Fresh weight of stem (g)	Dry weight of leaves (g)	Dry weight of stem (g)	seed index (g/100grains)	yield Seed ton/fed	yield Straw ton/fed	yield Biological ton/fed
Untreated	-	155.8	10.1	119.9	431.5	26.2	64.3	29.9	1.46	0.91	2.37
LCM	10	170.3	11.7	131.5	479.6	33.4	80.8	33.5	3.49	2.91	6.40
	20	184.2	13.1	150.9	510.8	39.0	88.9	39.7	3.81	3.20	7.01
50%LCM+	10	177.4	12.7	147.5	498.8	38.6	87.2	38.8	3.73	3.18	6.91
50%FYM	20	195.8	14.8	158.4	528.2	42.5	93.3	43.6	3.92	3.38	7.30
50%LCM+	10	176.5	12.1	144.4	489.7	36.8	85.8	36.1	3.67	3.09	6.76
50%KC	20	190.6	13.3	154.3	522.7	39.4	90.6	40.5	3.87	3.23	7.10
LSD $_{0.05}$	compost (A)	3.5	Ns	2.9	5.5	1.9	2.5	2.5	0.04	0.04	0.06
	rates (B)	2.8	0.6	2.4	4.5	1.6	2.0	2.1	0.03	0.03	0.05
	A x B	4.9	1.0	4.1	ns	2.7	3.5	3.6	ns	ns	ns

15.3% for number of leaves, 9.7% for fresh weight of leaves, 11.2% for fresh weight of the stem, 27.8% for dry weight of leaves, 25.6% for dry weight of the stem, 12.1% for the seed index, 139.0% for seed yield, 219.8% for straw yield and 170.0% for the biological yield. Corresponding values for 20m^3/fed LCM compost were 18.2, 29.1, 25.9, 18.4, 49.2, 38.1, 32.8, 161.0, 251.7 and 195.8%, respectively. On the other hand, conditioning heavy clay soil with 10 and 20m^3/fed LCM+FYM (1:1) increased the aforementioned characteristics by 13.9 and 25.7% for plant height; 25.2 and 46.1 %for number of leaves; 23.1 and 32.1 for fresh weight of the leaves, 15.6 and 22.4% for fresh weight of the stem, 47.6 and 62.6% for dry weight of leaves, 35.5 and 45.0% for dry weight of the stem, 29.9 and 46.0% for seed index, 155.5 and 168.5% for seed yield, 249.5 and 271.4% for straw yield and 191.6 and 208.0% for the biological yield, respectively.

Data also indicate the beneficial effect of mixing LCM compost with KC before incorporating into the soil on growth characteristics and yield mentioned above. Under these conditions, plant heights were 113.3 and 122.3% that of untreated soil by treating the soil with 10 and 20m^3/fed, respectively. Relevant values were 19.7 and 31.7 %for number of leaves; 20.5 and 28.8 for fresh weight of the leaves, 13.5 and 21.2% for fresh weight of the stem, 40.7 and 50.7% for dry weight of the leaves, 33.3 and 40.7% for dry weight of the stem, 20.9 and 35.6% for seed index, 151.4 and 165.1% for seed yield, 239.6 and 255.0% for straw yield and 185.2 and 199.6% for the biological yield, respectively.

Water and Fertilizers Use Efficiency by Broad Bean and Corn Plants: Values of water use efficiency (WUE) and fertilizers use efficiency (FUE) by broad bean and corn plants are presented in Tables 5 and 6, respectively). Data show the ability of conditioned soil

Table 5: Effect of wooden waste composts on water and fertilizers use efficiency by broad bean plants grown on clay soil.

Composts Used	Appl. Rate m^3/fed.	Seed	Straw	Biological
	WUE kg/m^3			
untreated	-	0.51	0.72	1.23
LCM	10	0.60	0.81	1.41
	20	0.66	0.83	1.49
50%LCM+ 50%FYM	10	0.75	0.92	1.67
	20	1.09	1.24	2.33
50%LCM+ 50%KC	10	0.66	0.83	1.50
	20	0.83	0.98	1.81
LSD $_{0.05}$	Compost (A)	0.04	0.04	0.06
	rates (B)	0.03	0.03	0.05
	A x B	0.06	0.06	0.08
	NUE (kg/kg N)			
untreated	-	35.2	49.7	84.9
LCM	10	41.4	55.8	97.2
	20	45.7	57.4	103.1
50%LCM+ 50%FYM	10	51.7	63.5	115.2
	20	75.3	85.4	160.6
50%LCM+ 50%KC	10	45.7	57.5	103.2
	20	57.3	67.4	124.8
LSD $_{0.05}$	Compost (A)	1.1	1.4	2.2
	rates (B)	0.9	1.2	1.8
	A x B	1.6	2.0	3.1
	PUE (kg/kg P_2O_5)			
untreated	-	25.4	35.8	61.2
LCM	10	29.8	40.2	70.0
	20	32.9	41.4	74.3
50%LCM+ 50%FYM	10	37.3	45.7	83.0
	20	54.2	61.5	115.7
50%LCM+ 50%KC	10	33.0	41.4	74.4
	20	41.3	48.6	89.9
LSD $_{0.05}$	Compost (A)	1.8	2.4	3.6
	rates (B)	1.5	1.9	2.9
	A x B	2.6	3.4	5.1
	KUE (kg/kg K_2O)			
untreated	-	24.6	34.7	59.3
LCM	10	28.9	39.0	67.8
	20	31.9	40.1	72.0
50%LCM+ 50%FYM	10	36.1	44.3	80.4
	20	52.5	59.6	112.1
50%LCM+ 50%KC	10	31.9	40.1	72.0
	20	40.0	47.1	87.1
LSD $_{0.05}$	Compost (A)	0.9	1.2	1.8
	rates (B)	0.8	1.0	1.5
	A x B	1.3	1.7	2.6

Table 6: Effect of wooden waste composts on water and fertilizers use efficiency by corn plants grown on clay soil.

Composts used	Appl. Rate m^3/fed.	Seed	Straw	Biological
	WUE kg/m^3			
untreated	-	0.52	0.33	0.85
LCM	10	1.25	1.04	2.29
	20	1.36	1.14	2.50
50%LCM+	10	1.33	1.14	2.47
50%FYM	20	1.40	1.21	2.61
50%LCM+	10	1.31	1.10	2.41
50%KC	20	1.38	1.15	2.54
LSD $_{0.05}$	Compost (A)	0.04	0.04	0.04
	rates (B)	0.03	0.03	0.03
	A x B	0.06	ns	ns
	NUE (kg/kg N)			
untreated	-	21.8	13.6	35.4
LCM	10	52.1	43.4	95.5
	20	56.9	47.8	104.6
50%LCM+	10	55.7	47.5	103.1
50%FYM	20	58.5	50.5	109.0
50%LCM+	10	54.8	46.1	100.9
50%KC	20	57.8	48.2	106.0
LSD $_{0.05}$	Compost (A)	0.7	0.5	0.8
	rates (B)	0.6	0.4	0.7
	A x B	ns	ns	ns
	PUE (kg/kg P_2O_5)			
untreated	-	62.8	39.1	101.9
LCM	10	150.1	125.2	275.3
	20	163.9	137.6	301.5
50%LCM+	10	160.4	136.8	297.2
50%FYM	20	168.6	145.4	314.0
50%LCM+	10	157.9	132.9	290.8
50%KC	20	166.5	138.9	305.4
LSD $_{0.05}$	Compost (A)	4.7	3.3	5.3
	rates (B)	3.8	2.7	4.3
	A x B	ns	ns	ns
	KUE (kg/kg K_2O)			
untreated	-	60.8	37.9	98.8
LCM	10	145.4	121.3	266.7
	20	158.8	133.3	292.1
50%LCM+	10	155.4	132.5	287.9
50%FYM	20	163.3	140.8	304.2
50%LCM+	10	152.9	128.8	281.7
50%KC	20	161.3	134.6	295.8
LSD $_{0.05}$	Compost (A)	3.5	1.7	2.7
	rates (B)	2.9	1.4	2.2
	A x B	ns	ns	ns

to produce higher yields by the same amounts of irrigation water or added nutrients. Increments in WUE or FUE by broad bean plants for seed, straw and biological yield were 17.7 and 29.4%; 12.5 and 15.3%; and 14.6 and 21.1% that of untreated soil due to applying LCM at the rates of 10 and 20m^3/fed, respectively. More increments were obtained by mixing LCM with the same amounts of other organic materials i.e., FYM or KC. The corresponding increase when using 10 and 20m^3/fed LCM +FYM (1:1) were 47.1 and 113.7% for seed; 27.8 and 72.2% for straw; and 35.8 and 89.4 % for biological yield, in sequence. When incorporating 10 and 20m^3/fed LCM +KC (1:1), these increments were 29.4 and 62.8%; 15.3 and 36.1% and 21.9 and 47.1%, respectively. The same was true with corn compared to the untreated soil, increments were 140.4 and 161.5% for the seed yield; 215.2 and 245.5% for the straw yield; 169.4 and 194.1 % for the biological yield with 10 and 20m^3/fed LCM compost, respectively. Relevant values for [LCM + FYM (1:1)] compost were 155.8 and 169.2%; 245.5 and 266.7%; 190.6 and 207.1%, in sequence and for [LCM + KC (1:1)] were 151.9 and 165.4%; 233.3 and 248.5% and 183.5 and 198.8%, respectively. These increments in plant growth, yield and WUE or FUE by plants may be due to the conditioning effect of composted LCM solely or after mixing with other organic materials i.e., farmyard manure (FYM) or Kattamia compost (KC). In part II of this research work[5] some physico chemical properties of the soil at the end of the growing seasons of both broad bean and corn were evaluated. Soil conditioning with the studied composts positively affected physico-chemical properties of the heavy clay compacted soil. These effects were assembled in the following: A) Improving hydrophysical and mechanical properties of treated soil through 1-promoting good soil structure with suitable pore size distribution that provide the plant with balanced aeration and available water 2-modifying the dynamic soil water characteristics i.e. the downward water movement through infiltration and the upward ones via evaporation. 3-improving the mechanical strength of the soil that can be satisfactory tilled with lower power requirements. B) Improving chemical properties and nutritional status of the soil through 1-lowering pH and its effects on nutrients availability; 2-increasing organic matter and organic nitrogen % and modifying C/N ratio to be suitable for both growing plants and soil fauna; 3-increasing both CEC and specific surface area of the soil and their effect on increasing the rate of bio-chemical reactions in the soil 4- raising the concentration of available nutrients in the soil. With only one exception (soil salinity), improvements of soil physico- chemical properties are positively affected by the rate of applied composts.

Studies of other investigators indicate our results. Of these are the studies of Sommerfeldt and Mackay, 1987[12] who used mixtures of bark, sawdust, wood shavings and peat moss and those of N'dayegamiye and Isfan, 1991[13] for testing each of wood shavings, sawdust or peat moss mixed with cattle manure in 2:1 ratios by volume as soil amendments.

It is interesting to note that organisms largely responsible for the breakdown of the organic materials require large quantities of nitrogen. Therefore, adding materials supplying large amounts of nitrogen (such as fresh, green grass clippings or sawdust with fresh farm animal manure) is necessary for rapid decomposition[14]. A nitrogen- containing fertilizer may be added when a high nitrogen organic source is not available. This is why applying composts of mixture of LCM (slow decomposable materials) with other organic materials i.e. FYM or KC (rabid decomposable materials) gave better and earlier results than those of LCM compost solely[5]. A conclusion was drawn that mixing the slow biodegraded materials with high C:N ratio such as (LCM) with other easily degraded residues with relatively lower C:N ratio (FYM or KC) speeds the improving effect of the former. This brings the C:N ratio down and closer to appropriate level, thus the improving effect of mixtures of composts appears earlier (after the 1st crop) compared to that of LCM compost only.

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