RICE STRAW COMPOSTING WITH TWO METHODS AND ITS EFFECT ON CANOLA GROWTH

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ABSTRACT

In Egypt, disposal of rice straw and organic wastes is of great concern as well as improvement of soil properties and plant yields. Compost made of rice straw and animal manure could improve both organic waste recycling and plant growth. The aim of this study was to evaluate two methods, turned and static piles without agitation during the composting process, for composting rice straw and the suitability of the produced compost for the agricultural purposes. In a first experiment at pilot scale, the effects of turning and composting time for turned and static piles on germination index and compost composition were studied. Turning did not have a clear effect while it increased costs of composting. Compost stability/ maturity were tested by measuring a absorbance ratio (E4/E6) and seed germination index (GI).The results showed that optical density of water extracts increased with composting time like germination index. Therefore, it can be used for easier quality control. In a second experiment in pots, the effect of the turned compost on canola growth was studied. The study demonstrated that the dry weight and relative increase (R.I %) of dry weight of canola plants increased with the application of compost to soil. The application of compost at 10g kg^{-1} soil had a greater effect on increasing yield. It is concluded that composting of rice straw and animal manure by static pile is a low cost technology. Rice straw compost can also increase the plant growth and improve the efficiency of rice straw disposal.

Keywords:- Composting; Rice straw; Animal manure; Static pile; Turned pile; Optical density; Seed germination index; Plant growth .

INTRODUCTION

Rice straw becomes a very serious problem in Egypt lately that is because of the huge production of straw about (20 million ton year^{-1}). It is considered a problem for the farmers who store it near their house or field because the straw is a suitable media for the insects and pests. The farmers start to burn it causing the black cloud and severe pollution in Egyptian atmosphere (Bahnasawy et al., 2002). Composting is a method to improve recycling. In addition of the environmental pollution, today, height tended environmental awareness has sparked renewed interest in composting as a means to prevent or reduce environmental pollution. Anitha and Srkar (2006) showed that composting is a process by which crop residues are degraded, to conserve nutrients in a confined environment. Composting is increasing recognized as a viable treatment method for animal manure. One advantage is the possible recycling in agriculture or horticulture. Because of its high concentration in organic matter, composts have been used for years as soil amendments. Composting has other advantages such as killing pathogens and weed seeds, and reducing the volume and weight of manure (Epstein, 1997).

A variety of composting technologies have been adapted. It could be divided into four groups: passive aeration, aerated static piles, turned windrows, and in-vessel. Passive composting depends on oxygen diffusion, thermal convection and wind blowing (Rynk, 2000) and its low technology method. Aerated static piles are popular because they provide a higher level of control of the process, minimize the need to turn the pile, and encourage rabid rates of decomposition (Sylvia et al, 1998). Turned windrow piles are arranged in triangular shaped rows that are mechanically agitated or turned periodically to replenish oxygen. They are space-intensive as well as labor intensive, and results in odor production and ammonia loss (Rynk, 1992). In-vessel composting takes places in either partially or completely enclosed containers employing various forced aeration and mechanical turning technologies, which are costly in terms of capital and maintenance costs (Tehobanoglous and burtan, 1991). The evaluation of the static and turned piles will be enable to select the best method for rice straw composting that our farms can easily adopt to produce soil amendment to improve soil properties and crop productivity.

Compost maturity has become a critical issue before land application because immature compost can be detrimental to plant growth and the soil environment (Wu et al., 2000). One component of compost maturity refers to the phytotoxicity associated with the compost. Immature composts contain more growth inhibiting substances than mature compost. Some of these growth inhibiting compounds include salts, ammonia, phenolic substances, heavy metals, and organic acids (BBC laboratories, 1999). Phytotoxicity is one of the most important criteria for evaluating the suitability of compost for agricultural purposes (Brewer and Sullivan, 2003; Tiquia et al., 1996). Germination index (GI), a factor of relative seed germination and relative root elongation, has been widely used to evaluate the phytotoxicity of compost (Bernal et al., 1998), but it is an expensive and long measurement.

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The objectives of this study were to evaluate static and turned piles for composting of rice straw, optical density as indicator for maturity, and assess the effect of the produced compost on canola growth.

MATERIALS AND METHODS

Co-composting of animal wastes rice straw

The animal wastes and rice straw were obtained from local farms. The rice straw was air dried and cut into small pieces, about 5-15 mm in length. The C/N ratio of the rice straw and animal wastes were 64.0 and 22.8, respectively. Animal wastes were homogenized with rice straw to give a C/N ratio (30-35) as recommended by (Haug, 1993). Water was added to give a moisture content (60 %), which is considered optimum for composting (Keener et al., 2000).

Composting methods

Six piles were constructed in Sakha Agricultural Research Station, to test the turned and static piles, each approximately 3 m length, 2.5 m width and 1.5 m height. Each pile was placed on a bed of corn stalks and covered with plastic sheets for insulation. Three static piles were left to compost depending on natural ventilation for replenishing O_2. A single perforated plastic pipe (10 cm dim) was placed in the middle of each side between compost and plastic sheet to ensure small ventilation despite plastic sheet. Three turned piles were turned twice per week for the first 3 weeks and once per week for another 7 weeks. The pile was monitored for another 6 weeks, for a total study period of 16 weeks.

Canola growth experiment

A pot experiment was conducted to evaluate the finished compost for agricultural purposes. Canola (*Brassica napus*) was grown in a completely randomized experimental design with five replicates. Each pot contained 9 kg of surface soil samples (0-30 cm) that was collected from El-Mahla El-Kobra area, Gharbia governorate. The Particle size distribution of the used soil (0-30 cm) was 30.68 % silt, 11.79 % sand and 57.28 % clay. Its main characteristics were 1.15% organic matter, 3.74 % $CaCO_3$, 7.95 pH and EC of 1.85 dS^{-1}. These soil characteristics were determined according to Black (1982). The rice straw compost after turned piles was added at levels 10 and 20 g dry weight kg^{-1} dry soil and mixed thoroughly. Seven seeds of canola were sown in each pot. After 4 weeks plants thinned to 3 plants per pot.The plants were harvested 17 weeks after sowing.

Compost analysis

Compost samples were periodically collected from center of each pile, placed in polyethylene bags. Sub samples were air-dried and ground to pass through a 2 mm screen for chemical analyses.

Temperature was monitored manually at the pile center with a mercury thermometer and the mean of the three replicates was calculated. The moisture content of compost samples was determined by drying the samples at 105°C for 24 h (Tiquia et al., 1996). Ash content was determined in a muffle oven at 550°C for 8 h, and organic matter was calculated as the difference between ash and dry weight (50% from OM of compost was considered organic C) (AFNOR, 1991). pH and EC were determined in extract of the saturated compostl using pH and conductivity meters, respectively. Total nitrogen in raw materials and compost was determined by Kjeldahl method (Stevenson, 1982). Total heavy metal concentrations were measured by atomic absorption and total phosphorus was measured calorimetrically using spectrophotometer after wet digesting the air dried compost digested in concentrated H_2SO_4 + H_2O_2 (Cotteine et al., 1982).

Stability/ maturity indices

Germination test was measured in triplicate using cress (*Lepidium sativum*) as described by Mathur et al. (1986). Compost layers of 2 cm thickness were laid in Petri dishes, covered with filter paper, and then soaked to water saturation for the percent germination. Optical density (OD) of water extracts of compost with respect to their absorption at 465 nm (E4) and 665 nm (E6) wavelengths was considered to reflect the degree of condensation of the aromatic nucleus of humus (Mathur, 1991). Samples of the compost were suspended in hot water at 60°C in 1:10 wet weight ratio and shaken for 30 min. The suspensions were centrifuged at 10000 rpm and the supernatant passed through 15 µm filter paper. The absorbance at 465 and 665 nm was measured by the spectrophotometer.

RESULTS

TURNED VERSUS STATIC PILES FOR COMPOSTING

Temperature, pH and Electrical Conductivity

Initial compost temperatures ranged from 34°C in the static piles to 39°C in the turned piles. As composting proceeded, these temperatures increased rapidly. By days 2-7, compost piles reached thermophilic temperature. Highest peak temperature (58°C) was observed after 7 days for each pile (Fig. 1). The temperature then remained above 55°C for 7 days in the static and 14 days in the turned piles. After which it remained above 45°C until 46 days in the static piles and 35 days in the turned piles and decreased to reach ambient levels at 120 days. The difference between temperatures in the turned and static piles during the composting process was considered weak.

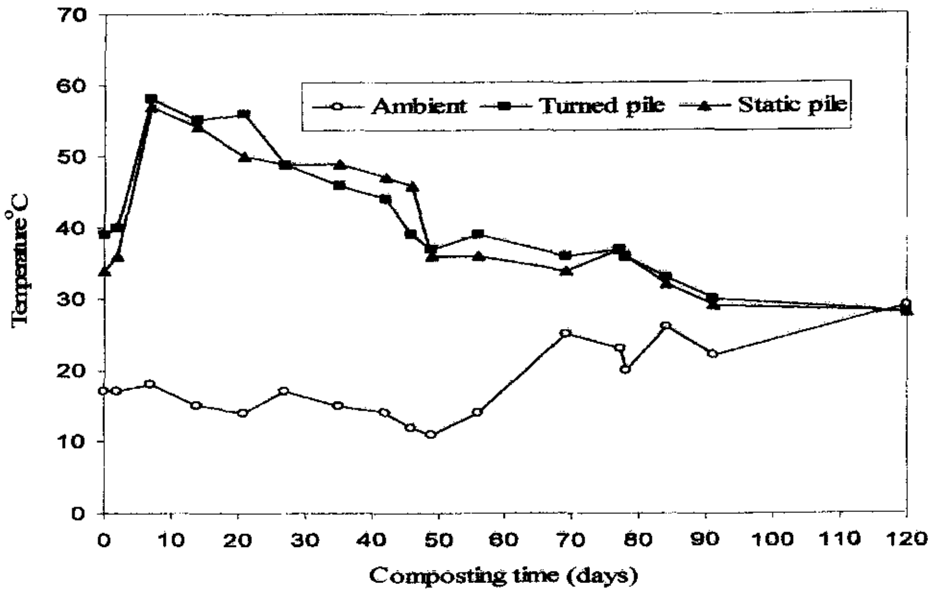

Fig.1. Changes in average temperature during composting of the static and turned piles.

In all piles, the pH decreased during 14 days after beginning the composting process (Table 1). Then, the pH increased above 8 at 58 days. After which it decreased to neutral values until the end of the composting period.

Soluble salts, as estimated by EC (Table 1), were initially around 3.4 dS m^{-1} in all piles. The EC increased to maximum values 6.93 dS m^{-1} in the static piles after 58 days and 5.66 dS m^{-1} in turned piles after 69 days. Soon after, the EC values gradually decreased to 4.30 dS m^{-1} in the static and 3.90 dS m^{-1}in the turned piles at 120 days, respectively.

C/N ratio, organic matter and ash contents

Rice straw is rich in C (44.8 %), poor in N (0.7%) and high C/N ratio (64.0), which limits the composting process. This high C/N could be decreased by adding manure C/N (30.9) in turned and (32.5) in static piles (Fig. 2). The C/N decreased with composting time for turned and static piles to about 13% at the end of the composting period.

Table 1. Changes in average of pH and EC during composting of the piles.

Composting time (days)	Turned piles pH	Turned piles EC (dS m^{-1})	Static piles pH	Static piles EC (dS m^{-1})
0	7.34	3.41	7.41	3.39
3	6.75	4.81	6.75	4.81
14	6.20	5.25	6.10	4.81
46	7.35	5.47	7.36	4.66
58	8.01	4.95	8.32	6.93
69	7.47	5.66	7.72	6.69
78	7.47	3.84	7.62	6.31
92	7.43	3.82	6.97	5.47
120	7.17	3.90	6.95	4.30

The organic matter in the piles remained steady at 80% for the first 7 days and decreased to 70% after 58 days. After that, the organic matter decreased rapidly to 41% for both piles at the end composting period (Table 2). The ash content of two composting types increased with composting time (Table 2). The ash content increased rapidly from 25% to around 60±1% for all piles at 120 days. The mass of organic matter was about 70% of initial mass.

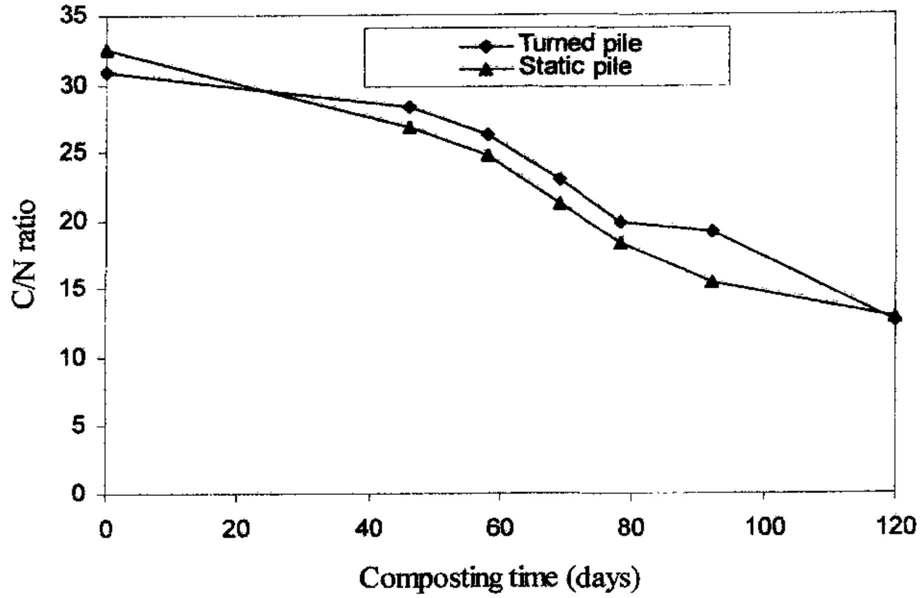

Fig. 2. Changes in average of C/N during composting of the piles.

Table 2. Changes in average of organic matter and ash during composting of the piles.

Composting time(days)	Turned pile		Static pile	
	O.M %	Ash %	O.M %	Ash %
0	81.54	18.46	82.5	17.5
14	80.5	19.5	78.75	21.25
46	75.2	24.8	70.2	29.8
58	73.4	26.6	66.65	33.35
69	65.3	34.7	58.2	41.8
78	59.12	40.88	51.64	48.36
92	54.37	45.63	46.14	53.86
120	42.1	57.9	39.22	60.78

Optical density and seed germination index (GI)

Optical density of water extracts of compost with respect to their absorption at 465 nm (E4) and 665 nm (E6) wavelengths were considered to reflect the degree of condensation of the aromatic nucleus of humus. The E4/E6 ratio increased with composting time in all piles (Fig. 3). The E4/E6 ratio increased from 5.03 and 5.11 to above 9 in all piles at the end of composting process.

Seed germination increased with composting time for the turned and static piles (Fig. 4). GI reached 100% for turned and static piles at the end composting period.

The E4/E6 ratio was linearly correlated with seed germination index (Fig. 5) .The coefficient of determination (R^2) between E4/E6 ratio and seed germination index (GI) was 0.94. The following equation was obtained:

$$GI = -71.99 + 18.32\ E4/E6 \quad \text{[Eq.1]}$$

The significant linear relationship (R^2=0.94) showed that E4/E6 ratio can be used as an indicator of GI.

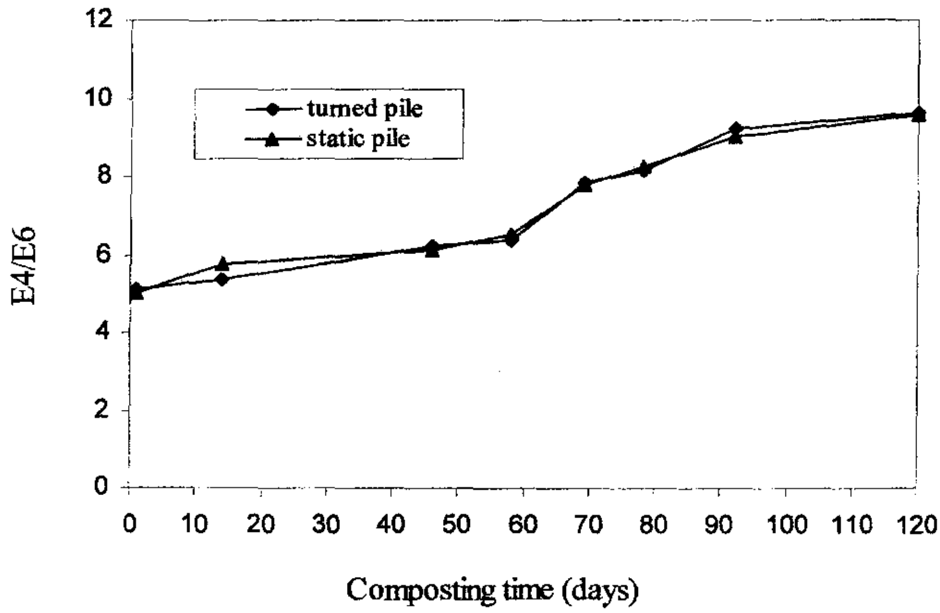

Fig. 3. Changes in average of optical density (OD) during composting of the piles.

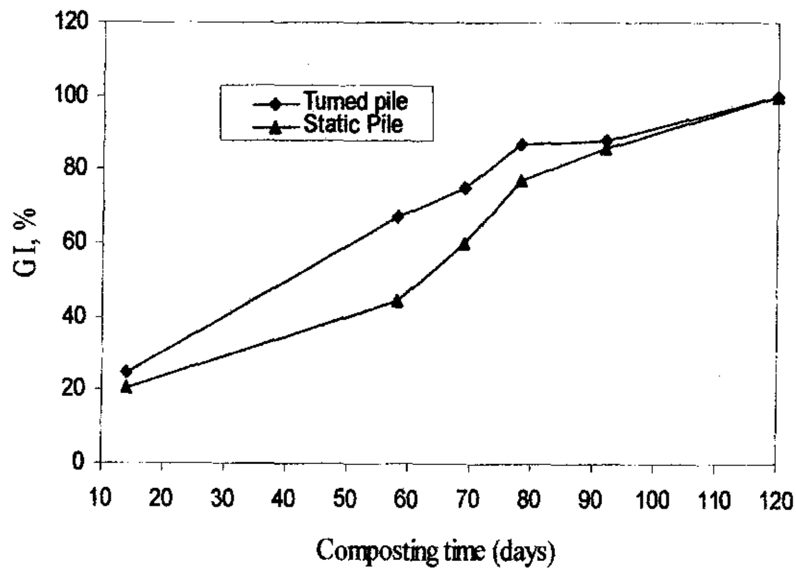

Fig. 4. Changes in average germination index (GI) during composting of the piles.

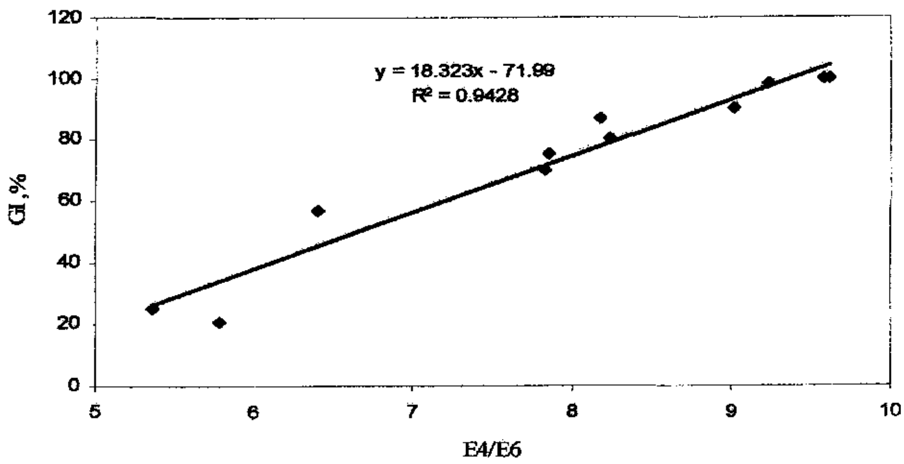

Fig. 5 . The relation between germination index (GI) and E4/E6 of the rice straw compost.

Finished compost quality

The finished compost of rice straw with animal waste, manufactured either by static pile or by turned pile, was high in N and ash contents, lower in C/N ratio (about 13) compared with other composts (Municipal solid waste compost (MSW) and Compost AGRO Egypt Comp.) (Table 3). The heavy metals of finished compost were below the USEPA (1993) limits (2800 Zn, 300 Pb, 420 Mn and 39 Cd mg kg $^{-1}$) by several orders of magnitude.

Table 3 .Chemical properties of different composts.

properties	Units	Turned piles	Static piles	MSW *	Agro compost**
Moisture	%	33.5	35.7	-	40.0
pH		7.2	6.9	7.7	7.2
EC	dS m^{-1}	3.9	4.3	4.5	3.3
Total N	%	1.7	1.5	1.3	1.6
OM	%	42.1	39.2	62.0	45.0
Ash	%	57.9	60.8	38.0	55.0
C/N ratio		12.6	12.9	24.4	18.0
Total P	%	0.44	0.38	0.66	1.39
GI	%	100	100	-	-
Ni	mg kg $^{-1}$	12.0	11.0	-	-
Mn	mg kg $^{-1}$	413.0	419.0	-	-
Pb	mg kg $^{-1}$	17.5	22.0	-	-
Cd	mg kg $^{-1}$	2.0	2.2	-	-
Zn	mg kg $^{-1}$	39.5	54.0	-	-

* Municipal solid waste compost (MSW) (Tao et al. 1995).

** Compost AGRO Egypt Comp.(El Menofia for fertilizers& chemicals, Egypt).

Cost benefit analysis for compost pile construction

Data in (Table 4) illustrated the cost of installing static and turned piles. These costs include materials, labour and transportation. The costs of one cubic meter of static and turned piles were about 29.37 L.E and 69.3 L.E, respectively. Most of the cost difference between static and turned piles was due to cost of labour, were about 20 L.E in static piles and 280 L.E in turned piles. While the commercial compost (El Menofia for fertilizer and chemicals Comp.) was sold by about 120 L.E for one cubic meter during 2008. The compost used in our study can save about 50.7 and 90.63 L.E for one cubic meter of static and turned piles, respectively.

Table 4. The cost benefits analysis for compost pile construction.

Materials	quantity	Turned piles	Static piles
		cost L.E	
Rice straw block	14 blocks	52.5	52.5
FYM	3.75 m^3	18.75	18.75
Plastic pipe (10 cm dam.)	1.5 m		20.0
Materials of fertilizer	18 kg Urea+ 20 Kg P_2O_5	25	25.0
Labour	2	280	20.0
Transportation		40	40.0
Total cost	6.0 m^3	416.25	176.25
Total cost /m^3	1.0 m^3	69.3	29.37

EFFECT OF RICE STRAW COMPOST ON PLANT GROWTH.

Dry weight

Generally, the application of compost increased markedly the dry weight of canola plants at application levels of 10 and 20 g kg-1 soil compared with the control (Fig 6). The highest dry weight of canola plants was obtained with addition of compost at 10g kg^{-1} soil compared with others treatments. The relative increase (R.I %) of dry weight of canola plants in the pots treated with compost at 10 and 20 g kg-1 was 34.5 % and 6.7% compared with the control, respectively.

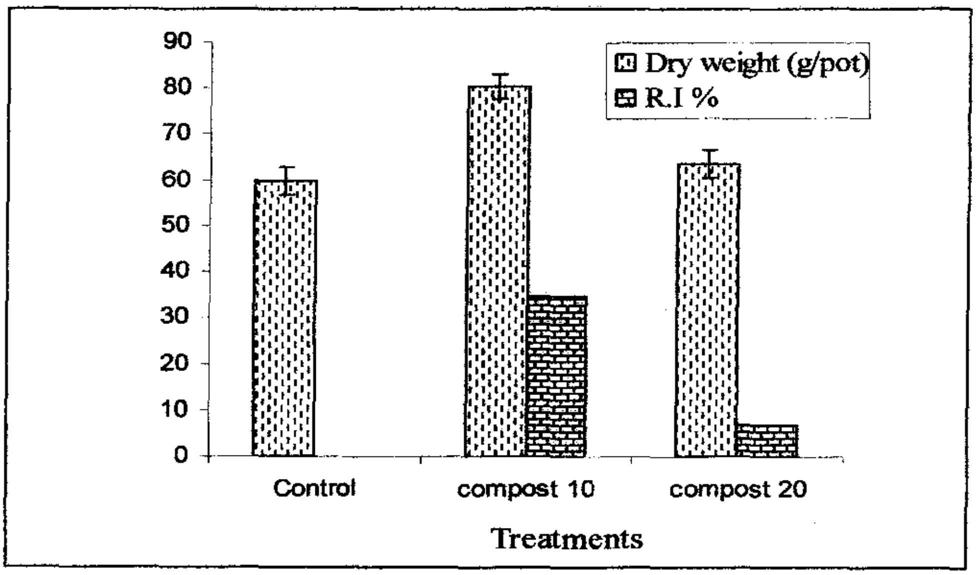

Fig 6. The dry weight and relative increase (R.I %) of dry weight of canola plants under the application of rice straw compost. Values are means ± standard error (n =3).

DISCUSSION

OPTICAL DENSITY AS INDICATOR COMPOST STABILITY/MATURITY

Application of unstable or immature compost inhibits seed germination, reduces plant growth, and damages crops when phytotoxicity occurs, due to insufficient biodegradation of organic matter (Wu et al., 2000). Phytotoxicity can result from several factors the most important of which are a lack of oxygen, the accumulation of toxic compounds such as alcohols, low molecular weight organic acids (Zucconi et al., 1981; Hirai et al., 1983), short and long chain fatty acids (Sesay et al., 1997), phenolic acids (Ishii and Kadoya, 1993), salts, ammonia, and heavy metals (BBC lab., 1999). Seed germination index (GI) is good indicator for phytotoxicity but its a tedious work (Brewer and Sullivan, 2003). In this study, optical density was found to be associated with changes in GI. The coefficient of determination (R^2) between E4/E6 ratio and GI was 0.94. The highly significant correlation between GI and optical density demonstrates that it is possible to measure seed germination more easily and rapidly by reducing longer and more expensive analytical procedures.

The E4/E6 ratio of water extracts of compost increased with composting time (Fig. 3) because the extracts contained less condensed aromatic substances at compost maturity (Mathur et al., 1993) and more humic substances. Since high absorbance is one of the most significant characteristics of humic substance (Orlov, 1995), the change of absorbance of water extractable organic matter reflects the degree of humification and maturation of compost. Chefetz et al. (1998) found that the percentage of humic-like substance of water soluble organic increased during the late stages of composting. The formation of humic type substances increased as the E4/E6 ratio (Chen et al., 1977). Therefore, the optical density is proposed as a predictor of compost maturity in the case of composting rice straw and animal wastes by either static or turned piles. These results agree with there obtained by Amer et al (2007) who showed that the absorbance ratio (E4/E6) the water extract promises to be facile test. The threshold of 7 is proposed because it corresponds to GI of 80-85% that eliminates phytotoxicity (Tiquia et al., 1996).

THE DIFFERENCE BETWEEN THE TURNED AND THE STATIC PILES DURING THE COMPOSTING PROCESS.

The differences in the temperature and chemical properties between the turned and the static piles during the composting process were weak. The increase of temperature in static and turned piles during the thermophilic phase resulted from a biodegradation of organic matters. The temperature was greater than 55°C for more than 3 days, the minimum requirements for a proper disinfection of waste materials from animal and plant pathogens as well as weed seed suppression (BCMOE, 1993). A thermophilic phase in which temperatures rose above 45°C remained 35 days in the turned piles and 45 days in the static piles. According to temperature measurements, the passive aeration was suitable for replenishing O_2 in the static piles. It confirmed observations of Zhu et al. (2004) who showed that a passive aeration was suitable for a small-scale farm while forced aeration system should be considered to apply in the middle and large-scale swine farms.

The initial pH values of the mixtures were 7.34 in turned and 7.41 in static piles (Table 1), which is optimum for the microbial activity (Carey, 1997). Changes in pH with time reflect CO_2 evolution during composting. During the decomposition, release of CO_2 and organic acids formation would account for the early reduction in pH (Brady, 1990). The pH values increased with time, as a consequence of the mineralization of proteins, amino acids and peptides to ammonia (Masters, 1998). The similar evolution of pH and temperature in static and turned piles indicated that biochemical processes were similar in both piles.

The increase in electrical conductivity can be attributed to the release of easily decomposable compounds in the interstitial liquid. The decrease in electrical conductivity was likely a result of leaching and precipitation of salts in both piles.

Decrease of the C/N ratio in the static and turned piles reflects the organic matter mineralization and an adequate evolution of the microbial composting process. The loss of C exceeded the loss of N, resulting in C/N ratio decrease (Rechcigl, 1995). The C/N ratio of bodies of microorganisms ranges from 5 to 30 (Alexander, 1970; Hughes, 1980). During composting, a series of microorganisms grow and die contributing additional N-rich material to mass, decreasing the C/N ratio. The C/N ratio of the piles was around 12 at the end of composting period in two piles. A C/N ratio of 10 to 12 is usually considered to be an indicator of stable and decomposed organic matter (Jimenez and Garcia, 1989).

The decrease of organic matter in the piles was attributed to easy degradation of C compounds (e.g. sugars, hemicelluloses, amino acids, and proteins), which are degraded during the thermophilic stages by microorganisms as C and N sources. However, less degradable compounds, such as lignin, are decomposed gradually (Li and Zhang. 2000). The high ash content in two composting types can be attributed to the high silicon content in rice straw, which was used as bulking agent (Mengel and Kirkby, 1987).

The finished compost of rice straw with animal waste, manufactured by static piles with static ventilation appeared to have a lower cost (29.37 L.E m^{-3} of compost produced) than the turned piles, while the resulting compost was similar. This is important for economic development of rice straw composting and it is a simple technology that Egyptian farmers can adopt to recycle efficiently rice straw and improve soil properties.

EFFECT OF RICE STRAW COMPOST ON CANOLA GROWTH

The observed increase in dry weight of canola plants in the pots treated with rice straw compost at 10 or 20 mg kg $^{-1}$soil, these may be attributed to the improving action of compost on the physical properties as well as nutrients status in the soil which enhance plant growth (Rechcigl, 1995). Dry weight of canola plants in the pots treated with compost at 20 g kg^{-1} soil was less than that treated with compost at 10 g kg^{-1} soil. This trend could be explained due to increased elements originated from compost in soil solution and which produced a condition of nutritional unbalance in plants particularly at relatively high levels of compost.

CONCLUSION

The optical density (E4/E6 ratio) of water extracts of compost for static and turned piles was highly correlated to germination index. We suggested that the E4/E6 ratio can be used as a cheap, rapid and simple substitute for germination index to measure compost maturity. It can serve as a tool used by compost producers. The threshold of 7 can be used as a predictor of germination index above 80%. The results showed weak difference between the turned and static piles during the composting process in the temperature and chemical properties. The static piles were simpler and had the least operation costs compared to turned piles. Therefore farmers can adopt static composting to recycle rice straw and improve plant yields. Application of rice straw compost by rate of 10 g kg^{-1} soil is the most suitable for maximizing canola plants growth, under the experimental conditions.

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الملخص العربى

تصنيع سماد عضوى من قش الارز بطريقتين وتأثيره على نمو نبات الكانولا

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اصبح التخلص من قش الارز والمخلفات العضوية فى مصر موضع اهتمام مثل تحسين التربة والانتاج. والكمبوست المصنوع من قش الارز والسماد الحيوانى يعمل على اعادة استخدام المخلفات العضوية وزيادة نمو النباتات. وتهدف الدراسة الى تقييم طريقتين لكمبوست قش الارز احدهما يستخدم التقليب والاخر ثابت بدون اجراء اى تقليب للكومة خلال فترة الكمر وتأثير المنتج على نمو نبات الكانولا . واتضح ان التقليب ليس له تاثير واضح ويرفع من تكلفة الانتاج. وقد تم اختبار درجة النضج المكمورة بتتبع نسبة الانبات والكثافة الضوئية عند طول موجى ٤٦٥ و٦٦٥ نانومتر ووجد ان الكثافة الضوئية لمستخلص الكمبوست تزيد مع زمن الكمبوست مثل نسبة الانبات. وجد ايضا ارتباط معنويا بين دليل الانبات والكثافة الضوئية ولذلك يمكن استخدام الكثافة الضوئية لمستخلص الكمبوست لتعبير عن نسبة الانبات والحكم على جودة الكمبوست بطريقة سريعة. وفى التجربة الثانية درس تاثير الكمبوست المستخدم فيه التقليب عل نمو نبات الكانولا. اظهرت النتائج ان المادة الجافة والزيادة النسبية لنبات الكانولا تزيد مع اضافة الكمبوست للارض. واضافة الكمبوست بمعدل ١٠ جم/كجم ادى الى زيادة محصول الكانولا افضل من اضافته بمعدل ٢٠ جم/ كجم. ونستنتج من ذلك ان الكمبوست المصنوع من قش الارز والسماد الحيوانى بطريقة الكومة الثابتة ذات تكنولوجيا منخفضة التكاليف. واضافة كمبوست قش الارز الى الارض عمل على زيادة نمونبات الكانولا ويرفع من كفاءة التخلص من قش الارز.