Evaluation of Organic Wastes Composting for Rice Production in the Chad[1]

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SUMMARY

The purpose of this research is to setup the organic waste composting technology and to evaluate the effort of those compost on rice production in the Chad. The results showed that the total production of the main crop residues in the Chad was about 4,048,210 tons in 2001. The total estimated amount of N, P, and K from the main crop residues in the Chad was 26,706 tons, 4,001 tons and 38,427 tons in 2001, respectively. The total production of the main livestock manure in the Chad was about 36,589,000 tons in 2001. The total estimated amount of N, P, and K from the main livestock manure in the Chad was 227,747 tons, 166,374 tons and 357,038 tons in 2001, respectively. The results indicated that there were two ingredients of compost could be appropriated and suitable for rice production. Cattle waste compost formula I made from cattle waste, rice straw and rice hull at the ratio of 40 : 40 : 20 by dry weight basis could get a stable quality. The N, P, K, and OM content of this cattle waste compost formula I were about 6.3 g/kg, 1.3 g/kg, 7.6 g/kg, and 616 g/kg, respectively. Cattle waste compost formula II made from cattle waste and sorghum straw at the ratio of 40 : 60 by dry weight basis could get a stable quality. The N, P, K, and OM content of this cattle waste compost II were about 5.3 g/kg, 1.0 g/kg, 9.6 g/kg, and 589 g/kg, respectively. From the results of rice experiment, the application of cattle waste compost 5 t/ha plus 100 kg/ha compound fertilizer ($N-P_2O_5-K_2O$ = 20-10-10) and urea 150 kg/ha had the best grain yield of rice and increasing soil fertility. However, these ingredients of cattle waste compost and fertilization can be recommended to farmers for rice production in the Chad.

Key words: cattle waste compost, rice production, organic fertilization.

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INTRODUCTION

The term "soil organic matter" covers all kinds of plant tissues and animal residues in the soil. Organic matter is often used as an index of soil fertility. A high level of organic matter in the soil suggests that the soil is relatively fertile, while a low level of organic matter in the soil usually means that the soil is lower in fertility [9,10]. However, the application of organic fertilizer or compost can significantly increase the content of soil organic matter. Generally, organic matter influences soils in four ways: The physical, chemical, biological and nutrient properties of the soil [2,8,14].

Organic fertilizers are very important for the maintenance and improvement of soil fertility, due to their multiple roles in the improvement of the physico-chemical and biological properties of soils [7,18,19]. However no organic material can give the full range of benefits by itself. A proper combination of carbonaceous and nitrogenous organic materials to make mature compost may make these materials into a more effective and complete fertilizer [4,6]. Through the composting process, the properties of organic wastes can be changed to allow decomposition to proceed at a more favorable rate, making these materials easier to handle and more suitable as organic fertilizers [11]. The key principles of composting process are to maintain appropriate size, density, porosity, scale and moisture as to induce microorganisms going on chain reaction decomposition onto organic matter [20]. The selection and application rate of organic fertilizers must be based mainly on the fertility conditions of the soil, and the nutrient requirements of individual crops [3,7,10]. The purpose of this research was to evaluate the nutrition effect of the organic material on the rice yield enhancement in the Chad.

MATERIALS AND METHODS

This study was conducted with a survey of amounts, chemical properties of organic materials, two compost production experiments, and one fertilizer experiment in rice field.

Organic material, soil sampling and analysis

Soil samples (0-15cm) were collected randomly from all plots at harvest stage of rice. The soil samples were air dried, and then ground to pass through a 2-mm screen. The soil pH (1:1 w/w soil: water ratio), EC (1:1 w/w soil: water ratio), organic matter content (Walkley and Black method) [15], Bray No. 1 extractable P [17], 1 N ammonium acetic acid extractable K, Na, Ca and Mg [12,13], 0.1 N hydrogen chloride extractable Cu, Mn, Zn and Fe were determined [1,5,16]. Organic materials were oven dried at 65℃ to a constant weight, and then ground to pass through a 40 mesh screen. Total N, P, K, Ca and Mg were determined after digestion of the samples [12,13,17]. Organic matter content (Walkley and Black method) [15], pH (1:5 w/w soil: water ratio), and EC (1:5 w/w soil: water ratio) were determined too.

Experimental Design and Cultivation of Rice

Fertilizer experiments were carried out in the agricultural research farm of ROC technical mission in the Chad during the fall crop season of 2001. The experimental farm was used pump irrigation. The variety of rice was Tainung-Sen 2. The fertilizer trial treatments included (Table 1): A. cattle waste compost 10 t/ha; B. cattle waste compost 5t/ha plus urea 100 kg/ha; C. cattle waste compost 10 t/ha plus compound fertilizer (N-P_2O_5-K_2O: 20-10-10) 100 kg/ha and urea 150 kg/ha; D. cattle waste compost 5 t/ha plus compound fertilizer (N-P_2O_5-K_2O: 20-10-10) 100 kg/ha and urea 150 kg/ha; E. compound fertilizer (N-P_2O_5-K_2O: 20-10-10) 100 kg/ha plus urea 150 kg/ha; F. Blank. A randomized complete block design with three replications of each treatment was used. Compost was applied before transplanting. NPK chemical fertilizer or urea was applied at 10-14 days after transplanting or panicle initiation stage. The survey of growth characteristics and yield of rice were collected at harvest stage.

Table 1. Fertilizer treatments of rice experiment

Treatment	Compost (t/ha)	Compound fertilizer (kg/ha)	Urea (kg/ha)
A	10	0	0
B	5	0	100
C	10	100	150
D	5	100	150
E	0	100	150
F	0	0	0

RESULTS AND DISSCUSION

The Nutrient Content of Organic Materials in the Chad

Crop Residues

The main crops are rice, groundnut, millet, sorghum and maize in the Chad. The N, P and K contents of rice straw were 4.2 g/kg, 1.2 g/kg, and 7.8 g/kg, respectively. The N, P and K contents of rice hull were 3.9 g/kg, 0.5 g/kg, and 4.1 g/kg, respectively. The N, P and K contents of cereal straw were 5.5 g/kg, 0.9 g/kg, and 9.6 g/kg, respectively. The N, P and K contents of groundnut straw were 11.2 g/kg, 1.3 g/kg, and 9.7 g/kg, respectively. Rice straw, rice hull, and other straws and stalks of gramineous crops usually have low nitrogen content, and with large amount of fibrous materials or high C/N ratio [9]. The fibrous materials are an energy source for soil microorganisms, and a good material for the improvement of soil physical properties [18,19]. These materials can be combined with high-nitrogen contain organic wastes, such as swine and poultry manure, to make good compost for crops [4]. These composts are good mulches, which help maintain favorable soil moisture content and temperature, and prevent the accumulation of salts or the multiplication of weeds on the soil surface [9]. However, if they are burned to ash, their fiber and carbon will be completely destroyed, and the ash will have little effect on the soil's physical and biological properties [2,20]. The total production of the main crop residues in the Chad was about 4,048,210 tons in 2001 and 4,451,505 tons in 2000 (Table 2). Therefore, the total estimated amount of N, P, and K from the main crop residues in the Chad was 26,706 tons, 4,001 tons and 38,427 tons in 2001, respectively. In 2000 there were 28,529 tons, 4,370 tons and 42,029 tons, respectively.

Table 2. Estimated amounts of N, P, and K from the main crop residues in the Chad

Crop	Year	Production (tons)	N (tons)	P (tons)	K (tons)
Rice straw	2001	139,582	586	168	1,089
Rice hull	2001	33,581	131	17	138
Cereal straw	2001	3,054,477	16,799	2,749	29,323
Groundnut straw	2001	820,570	9,190	1,067	7,877
Total	2001	4,048,210	26,706	4,001	38,427
Rice straw	2000	251,160	1,055	301	1,959
Rice hull	2000	60,424	236	30	248
Cereal straw	2000	3,355,908	18,457	3,020	32,217
Groundnut straw	2000	784,013	8,781	1,019	7,605
Total	2000	4,451,505	28,529	4,370	42,029

Livestock manure

The main livestock are cattle, goat and sheep, horse, poultry and hog in the Chad. The N, P and K contents of cattle waste were 5.9 g/kg, 4.3 g/kg, and 10.2 g/kg, respectively. The N, P and K contents of goat & sheep waste were 8.9 g/kg, 3.6 g/kg, and 10.4 g/kg, respectively. The N, P and K contents of horse waste were 7.6 g/kg, 6.4 g/kg, and 6.8 g/kg, respectively. The N, P and K contents of poultry waste were 16.2 g/kg, 11.2 g/kg, and 16.5 g/kg, respectively. The N, P and K contents of hog waste were 7.1 g/kg, 5.6 g/kg, and 6.2 g/kg, respectively. The nutrient contents of livestock manure are usually higher than that of crop residues. Livestock manure has a reasonably high content of nitrogen, potassium and fibrous materials. Resource and applications of this manure to the soil can be recommended [6,7,18]. However, its higher content of nitrogen and antibiotics, and its lower content of fibrous material, discourages direct applications of fresh manure to the soil [6,11]. The best way to utilize this manure is to mix it with rice straw, rice hull, sawdust and other fibrous materials, and mature it thoroughly before use. Cattle manure is the major livestock manure in the Chad (Table 3). The estimated amount of cattle manure was 30,528,000 tons in 2001 and 29,949,000 tons in 2000. The total production of the main livestock manures in the Chad was about 36,589,000 tons in 2001 and 35,734,000 tons in 2000 (Table 3).

Therefore, the total estimated amount of N, P, and K from the main livestock manures in the Chad was 227,747, 166,374 and 357,038 tons in 2001, respectively. In 2000 there were 222,259, 162,189 and 349,258 tons, respectively.

Table 3. Estimated amounts of N, P, and K from the main livestock manures in the Chad

Livestock	Year	Production (no)	Manure (1000 tons)	N (tons)	P (tons)	K (tons)
Cattle	2001	3,041,461	30,528	180,115	131,270	311,386
Goat & Sheep	2001	4,585,959	1,255	11,170	4,518	13,052
Horse	2001	496919	4,534	34,458	29,018	30,831
Poultry	2001	148,966	8	130	90	132
Hog	2001	301,875	264	1,874	1,478	1,637
Total	2001	—	36,589	227,747	166,374	357,038
Cattle	2000	2,983,708	29,949	176,699	128,781	305,480
Goat & Sheep	2000	4,541,864	1,243	11,063	4,475	12,927
Horse	2000	470,782	4,296	32,650	27,494	29,213
Poultry	2000	198,873	11	178	123	181
Hog	2000	268,935	235	1,669	1,316	1,457
Total	2000	—	35,734	222,259	162,189	349,258

Compost production

Composting is a method of solid waste management whereby the organic component of the solid waste stream is biologically decomposed under controlled conditions to a state in which it can be handled, stored, and/or applied to the land without adversely affecting the environment [11]. The traditional compost usually made by combining carbonaceous and nitrogenous materials. This is the best organic fertilizer, since it contains reasonable levels of nitrogen, phosphorus and potassium, as well as enough carbon or fibrous material to improve the physico-chemical and biological properties of the soil. In the Chad, the main carbonaceous materials were cereal straw, rice straw and rice hull (Table 2), the main nitrogenous materials was cattle manure (Table 3). Therefore, two ingredients of compost were conducted for compost maturated experiments. Cattle waste compost I made from cattle waste, rice straw and rice hull at the ratio of 40:40:20 by dry weight basis was conducted. The N, P, K, and OM content of this cattle waste compost I were about 6.3 g/kg, 1.3 g/kg, 7.6 g/kg, and 616 g/kg, respectively (Table 4). Cattle waste compost II made from cattle waste and sorghum straw at the ratio of 40:60 by dry weight basis were conducted. The N, P, K, and OM content of this cattle waste compost II were about 5.3 g/kg, 1.0 g/kg, 9.6 g/kg, and 589 g/kg, respectively (Table 5). However, a good ingredient of compost should consider both in quality and stability. The results indicated that these two ingredients of compost could be appropriate and suitable for crops production.

Table 4. The chemical properties of raw materials and cattle waste compost I

Material	pH	EC (dS/m)	N (g/kg)	P (g/kg)	K (g/kg)	Na (g/kg)	Ca (g/kg)	Mg (g/kg)	Cu (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	OM (g/kg)
Cattle waste	8.03	1.22	13.3	4.6	13.9	3.5	4.6	3.9	18	269	32	676	563
Rice straw	5.70	0.18	1.5	0.8	6.5	2.5	2.4	3.5	2.1	73	16	442	651
Rice hull	5.77	0.15	1.9	0.6	5.7	1.5	2.1	3.2	1.9	78	15	389	627
Compost	7.18	1.77	6.3	1.3	7.6	1.6	2.9	3.7	6.7	319	21	769	616

Table 5. The chemical properties of raw materials and cattle waste compost II

Material	pH	EC (dS/m)	N (g/kg)	P (g/kg)	K (g/kg)	Na (g/kg)	Ca (g/kg)	Mg (g/kg)	Cu (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	OM (g/kg)
Cattle waste	8.12	1.15	12.5	4.0	12.8	3.7	3.9	4.1	17	278	30	626	567
Sorghum straw	5.31	0.29	1.3	0.7	8.9	3.0	1.8	2.6	3.1	75	17	434	516
Compost	7.14	1.65	5.3	1.0	9.6	1.7	2.7	3.9	8.7	431	15	801	589

Temperature has long been recognized as one of the key environmental factors affecting biological activity (6,11). Temperature rising or not is therefore becoming a useful index for assessing whether composting is proceeding well. The result indicated that the temperature of cattle waste compost I would reach 60℃ at the 3-5 days after composting (Fig. 1). The maximum temperature during composting was about 69℃ with occurred at the 6-8 days after composting, and it would fall and lower than 50℃ at about 35 days after composting. For cattle compost II, the temperature would reach 60℃ at the 4-6 days after composting (Fig. 1). The maximum temperature during composting was about 68℃ with occurred at the 10-14 days after composting, and it would fall and lower than 50℃ at about 40 days after composting. As described above, the temperature of compost rising with the process of decomposition, and falls when the organic constituents have become stable at the 35-40 days after composting.

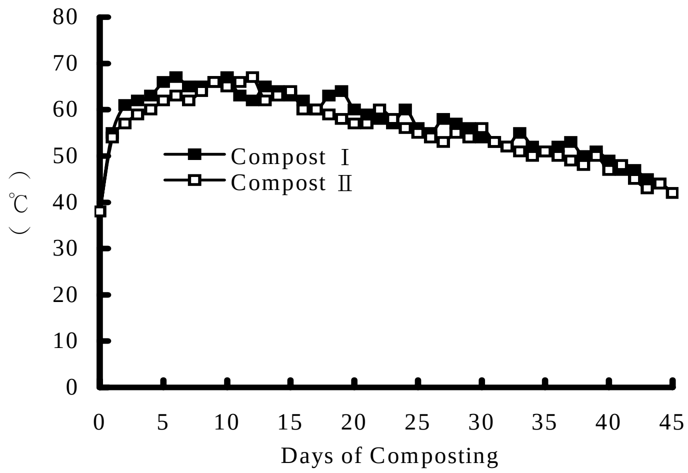

Fig. 1. The changes of temperature during composting.

Rice production

Effects of the yield of rice

Recycling of organic wastes as compost on arable land could provide part of plant nutrients for the need of crops and maintain soil fertility. The most effective way to use compost is to determine its potential availability of nutrient and to apply proper amounts of nutrients needed for crops of interest [(8,10)]. Therefore, a guideline on the application rate of this compost is necessary. This guideline should consider the amounts of organic matter supplied, amounts of nutrients supplied, compost quality, crops, and soil fertility status [(2,7)]. Table 6 showed the growth characteristics and yield of rice at harvest stage in 2001 fall. There was significant difference in the height and panicle number of rice plant among the treatments. The grain yield of rice was significantly different among the treatments also. The best grain yield of rice were 6.40 t/ha of treatment C (cattle waste compost 10 t/ha plus compound fertilizer 100 kg/ha and urea 150 kg/ha) and 6.47 t/ha of treatment D (cattle waste compost 5 t/ha plus compound fertilizer 100 kg/ha and urea 150 kg/ha). The increase in grain yield of rice was about 105-107% on the treatment C and treatment D as compare with treatment F on which no fertilizer was applied. There were no significant differences in panicle length, grain number per panicle, ripening grain rates and 1000-grain weight, however the panicle weight of treatment F was significantly lower than that of the other treatments (Table 7). However, relative nitrogen efficiencies of compost from organic waste were lower in comparison with chemical fertilizer [(10)]. Combined application of compost and chemical fertilizer had better results than application compost or chemicals only [(3,10)]. Therefore, the application of cattle waste compost 5 t/ha plus compound fertilizer (N-P_2O_5-K_2O: 20-10-10) 100 kg/ha and urea 150 kg/ha was appropriated and suitable for rice production in the Chad.

Table 6. The growth and yield of rice at harvest stage

Treatment[1]	Plant height (cm)	Panicle number (no)	Grain yield per block (gm/m^2)	Grain yield per block Index (%)	Grain yield (t/ha)	Grain yield Index (%)
A	82.7ab[2]	11.4bc	541b	147	4.61b	147
B	85.1aba	15.5ab	553b	150	4.45b	143
C	96.3a	16.4a	753a	205	6.40a	205
D	96.0a	14.9ab	761a	207	6.47a	207
E	93.9a	13.7ab	705ab	191	5.99ab	191
F	74.1b	9.1c	368c	100	3.12c	100

1. See Table 1.

2. Within columns, numbers followed by the same letter are not significantly different, using Duncan's Multiple Range Test ($P \geqq 0.05$).

Table 7. Yield components of rice at harvest stage

Treatment[1]	Panicle length (cm)	Panicle weight (gm)	No. of grain per panicle (no)	Ripening grain (%)	1000 grain weight (g)
A	20.9a[2]	2.86a	151a	87.8a	23.8a
B	24.3a	2.78a	159a	87.9a	22.7a
C	24.8a	3.67a	160a	87.1a	25.0a
D	24.3a	3.64a	165a	87.5a	26.1a
E	22.8a	3.26ab	152a	87.8a	24.0a
F	18.2a	2.65c	148a	87.4a	23.3a

1. See Table 1.

2. Within columns, numbers followed by the same letter are not significantly different, using Duncan's Multiple Range Test (P≧0.05).

Effects of the soil fertility of rice field

Soil organic matter is an important pool for most plant nutrients. The application of compost was a very direct way to increase the contents of soil organic matter (19). The mineralization of soil organic matter was affected by many soil and environmental factors such as soil texture, structure, rainfall, temperature, water content and fertilization (8,14). Before experiment, soil pH was about 5.25. Soil EC was about 0.09 dS/m. Soil organic matter content was about 13.5 g/kg. The concentration of available P was about 6.24 mg/kg. The concentration of exchangeable K was about 121 mg/kg. However, such soil fertility was low except the concentration of exchangeable K. Table 8 showed the soil fertility of rice field at harvest stage. The soil fertility indices of rice field such as soil EC, the content of soil organic matter, the concentration of available P and the concentration of exchangeable K had significant difference among the treatments. The application of compost could increase available nutrient concentration and its mobility, in consequence increases soil fertility (2,3). However, the accumulation of soil organic matter, P, K and EC increased with raising the compost rate (Table 8). The results also indicated that there were not significantly different among the treatments on soil pH, the contents of Ca, Mg, Na and micronutrients. However there was a tendency which accumulation of Ca, Mg and micronutrients contents increased with application of the compost too.

Table 8. Soil fertility of rice field at harvest stage

Treatment[1]	pH	EC	OM	Bray-1 P	Extr. K[3]	Extr. Ca[3]	Extr. Mg[3]	Extr. Na[3]	Extr. Cu[4]	Extr. Mn[4]	Extr. Zn[4]	Extr. Fe[4]
		(dS/m)	(g/kg)	------------------------------				(mg/kg)				------------------------------------
A	5.44a[2]	0.06ab	17.5a	8.91a	135a	712a	240a	94a	2.6a	111a	2.8a	784a
B	5.45a	0.06ab	16.4ab	7.82ab	121ab	727a	251a	84a	2.9a	115a	2.9a	733a
C	5.50a	0.09a	17.1a	8.76a	132a	725a	256a	92a	2.4a	105a	2.9a	724a
D	5.50a	0.08a	15.4ab	7.76ab	119ab	731a	249a	82a	2.6a	119a	2.8a	754a
E	5.51a	0.07a	12.5b	7.06b	97b	694a	251a	92a	2.7a	114a	2.9a	772a
F	5.50a	0.05b	12.9b	6.96b	92b	710a	241a	89a	2.5a	112a	2.6a	759a

1. See Table 1.
2. Within columns, numbers followed by the same letter are not significantly different, using Duncan's Multiple Range Test (P≧0.05).
3. 1 N ammonium acetic acid extractable.
4. 0.1 N Hydrogen chloride extractable.

CONCLUSION

Rice consumption becomes more important in the republic of Chad. However, production does not match the increasing demand leading to a massive importation of grain rice. The lack of input supplies and equipment, the poor maintenance of irrigation facilities, are the main causes of low crop productivity. A program of technology transfer has been implemented by Taichung District Agricultural Research and Extension Station which sponsored by Taiwan International Cooperation and Development Fund (Taiwan ICDF) through Organic Waste Composting onto the Rice Yield Increase Project in Bongor in 2000 as to promote the rice productivity. Under this project new varieties of rice (Tainung-Sen 2.) and techniques of producing and using of compost were introduced. Consequently, irrigated rice yields under the project, are 2 times higher than those obtained by traditional practices. Therefore, it is confident of being appreciated to apply cattle manure composting onto the increase of rice production in the Chad.

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摘　　要

本試驗目的在於建立適用於查德稻作推廣區之堆肥製作材料配方及使用技術。由研究結果顯示，2001年查德地區的農業有機廢棄物總量4,048,210公噸，換算成氮總量爲26,706公噸，磷總量爲4,001公噸，鉀總量爲38,427公噸。2001年查德地區的畜產有機廢棄物總量36,598,000公噸，換算成氮總量爲227,747公噸，磷總量爲166,374公噸，鉀總量爲357,038公噸。依據有機材料種類及特性，有兩種牛糞堆肥配方適用於稻作推廣區應用參考。其中牛糞堆肥I主要材料乾物量比例牛糞：稻草桿：稻殼約爲40:40:20，腐熟牛糞堆肥I的氮含量約爲6.3 g/kg，磷含量約爲1.3 g/kg，鉀含量約爲7.6 g/kg，有機質含量約爲616 g/kg。牛糞堆肥II主要材料乾物量比例牛糞：高粱桿約爲40:60，腐熟牛糞堆肥II的氮含量約爲5.3 g/kg，磷含量約爲1.0 g/kg，鉀含量約爲9.6 g/kg，有機質含量約爲589 g/kg。由水稻肥料試驗結果顯示，使用牛糞堆肥5 t/ha配合複合肥料(N-P_2O_5-K_2O:20-10-10) 100 kg/ha及尿素150 kg/ha處理可以獲得最高的稻穀產量與較理想穩定的土壤肥力，因此，適當的製作與使用牛糞堆肥，以及配合適量的化學肥料等肥培管理方法，可以推薦查德稻作推廣區農民應用參考。

關鍵字：牛糞堆肥，水稻栽培。

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