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IMPACT OF EFFECTIVE MICROORGANISMS COMPOST ON SOIL FERTILITY AND RICE PRODUCTIVITY AND QUALITY

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ABSTRACT

Agricultural systems which conform to the principles of natural ecosystems are now receiving a great deal of attention in both developed and developing countries. An organic fermented fertilizer; EM-compost was produced from agricultural residues; rice-hull and olive dough with beneficial effective microorganisms; EM. The effect of EM-compost on paddy field fertility and rice quality in comparison with conventional farming was investigated. Statistical models quantify the influence of the EM-compost quantity on soil fertility and rice qualities were described. The application of EM-compost shows a significant positive effect on soil fertility and rice yield and quality. EM-compost enhances the fertility of soil by reducing soil acidity; pH, salinity; EC_e and Na due to the acidic culture of EM and its anti oxidizing effect. The EM-compost provides the rice plant needs of N, P, K, Fe, Cu, Mn, and Zn without changing their levels in soil. The EM-compost increased the water holding capacity of the paddy soil, which reduced significantly the applied irrigation water; AIW and increasing water application efficiency; E_a. With comparing the application of 4 ton EM-compost/fed and the control (46 N units/fed), the N, P, K and average of micro-nutrients have been increased by extent of 53, 232, 121 and 99%, respectively. With increasing the EM-compost, the grain yield, 1000-grains weight, and husked, milled and head rice were significantly increased. The 4 ton EM-compost/fed recorded the lowest value in immature grains and the highest grain hardness compared with the other treatments. Generally, EM-compost would control chemical fertilizer and could be the best for safe environment.

***Keywords*: rice quality, soil fertility, compost, effective microorganisms**

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INTRODUCTION

At the root of poverty and hunger is complex social, political and economic reason. Agriculture is the only dependable vital sector for economy improvement in the developing countries. There are many factors for the low yield like high *pH*, increased alkalinity in soil and water, very low organic matter percentage and reduced soil useful microbial activities. In our endeavor to increased food production by any means, we ignored the vital link in all ecosystems namely the microorganisms (King *et al.*, 1992). New concepts such as alternative agriculture, sustainable agriculture, soil quality, integrated pest management, integrated nutrient management and even beneficial microorganisms are being explored by the agricultural research establishment (Parr *et al.*, 1992). Although these concepts and associated methodologies hold considerable promise, they also have limitations. For example, the main limitation in using microbial inoculants is the problem of reproducibility and lack of consistent results (Parr *et al.*, 1994).

The effects of physical degradation like soil erosion, compaction and water logging are readily apparent. The effects of chemical degradation like salinity and alkalinity, buildup of toxic chemicals and elemental imbalance are main constraints on crop performance (Amaral *et al.*, 1995; Iwamoto *et al.*, 2000). Soils have high range of salinity caused by Na, Cl, CO_3, HCO_3, Cu, SO_4, NO_3 and heavy metals like Li, Cr and Pb etc. In biologically degraded soils, one or more significant populations of microorganisms are impaired, often with resulting changes in biogeochemical processes within the ecosystem (Alvarez-Cohen *et al.*, 1992). Under the deteriorated environment the pests and insects attack the crops and induce plant disease, stimulate soil-born pathogens, immobilize nutrient and produce toxic and putrescent substances that adversely affect plant health, growth and yield at the end.

The concept of effective microorganisms; EM was developed by Professor Teruo Higa, University of the Ryukyus, Okinawa, Japan. EM consists of mixed cultures of beneficial a naturally-occurring microorganism that can be applied as inoculants to increase the microbial diversity of soil and plant. EM contains selected species of microorganisms including predominant populations of lactic acid bacteria and yeasts and smaller numbers of photosynthetic bacteria, actinomycetes and other types of organisms. All of these are mutually compatible with one another and can coexist in liquid culture (Higa and Wididana, 1991a). EM is not a substitute for other management practices. It is, however, an added dimension for optimizing our best soil and crop management practices such as crop rotations, use of organic amendments, conservation tillage, crop residue recycling, and bio control of pests. If used properly, EM can significantly enhance the soil fertility and promotes growth, flowering, fruit development and ripening in crops. It can increase crop yields and improve crop quality as well as accelerating the breakdown of organic matter from crop residues (Higa and Wididana, 1991b).

Rice is highly water consumed. Therefore, it is necessary to search for increasing the water use efficiency; *WUE* of rice irrigation. Mishra *et al.* (2001) found that grain yield significantly affected by water submergence depths. Jha and Sahoo (1988) showed that scheduling irrigation every 6 days with depth of 7 cm after the disappearing of pounded water in the dry seasons gave paddy yield similar to those obtained with continuous flooding (5 ± 2 cm). This scheduling saved 38-47% of irrigation water and increased *WUE* by 60-88%. Dembele *et al.* (2005) observed that 8 cm irrigation depth produced highest rice yield of 7.5 ton/ha compared to submergence depths of 5 and 10 cm.

In rice production, milling quality is an important factor for determining the farmer income. The market value of rough rice is based on its milling quality and yield. Milling quality is defined as the head rice recovery after milling (Brorsen *et al*., 1984). Many studies have been conducted to investigate factors affecting milling quality (Jongkaewwattana *et al*., 1993), field management (Yoshida, 1981) and environmental conditions during crop growth (Yoshida *et al*., 1976). Nitrogen fertilization is one management tool that affects rice yield and milling quality (Wopereis-pura *et al*., 2002).

The objective of this study to produce an organic compost form low quality of agricultural residues using EM and investigate its effects on paddy field fertility in term of *pH*, EC_e, Na, K, Fe, Cu, Mn, Zn, P and N, irrigation water efficiencies in term of applied irrigation water; *AIW*, water use efficiency; *WUE* and water application efficiency; E_a, and rice quality in term of weight of 1000 grains, grain dimensions, grain hardness, empty grain, broken grain, husked, milled and head rice.

MATERIAL AND METHODS

Soil samples of the experimental site were taken every 30cm soil depth up to 120 cm for determination mechanical analysis, physical and chemical properties at Mobarak City for Science Research Technology, Alexandria. Some soil physical properties were determined such as bulk density; *BD*, saturated moisture content; θ_s, permanent welting point; *PWP*, field capacity; *FC*, available water; *AW* and saturated hydraulic conductivity; k_s. Electrical conductivity; EC_e and *pH* were determined in 1:5 soil water suspensions and its extract. Organic matter content; *OM* was determined. Soluble cations and anions were measured in the soil paste extracts that were prepared for each sample. The basic available nutrients values in soil were measured according to Black *et al.* (1982) and Page (1982). Some soil characteristics are summarized in Table 1 and 2.

Table (1): Some soil physical characteristics of the experimental sites.

Soil depth (cm)	Particle size distribution (%)			Soil texture class	*BD* g cm^{-3}	θ_s m^{3}m^{-3}	*PWP* m^{3}m^{-3}	*FC* m^{3}m^{-3}	*AW* m^{3}m^{-3}	k_s mm h^{-1}
	Sand	Silt	Clay							
0- 30	25.98	22.93	51.09	Clay	1.35	0.491	0.303	0.428	0.125	0.64
30- 60	25.01	23.88	51.11	Clay	1.34	0.493	0.303	0.428	0.125	0.68
60- 90	24.10	23.04	52.86	Clay	1.32	0.499	0.315	0.437	0.122	0.60
90-120	23.02	25.00	54.98	Clay	1.31	0.506	0.327	0.448	0.121	0.48
Average	24.53	23.71	52.51	Clay	1.33	0.497	0.312	0.435	0.123	0.60

Table (2): Some soil chemical characteristics of the experimental sites.

Soil depth (cm)	*pH*	EC_e dS/m	Soluble cations (meq/L)				Soluble anions (meq/L)			*SAR*	*ESP%*
			Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{2-}		
0- 30	7.9	0.62	3.0	1.5	1.5	0.2	1.4	2.5	2.3	1.0	53
30- 60	7.06	2.06	7.5	5.0	12.0	0.7	4.9	5.0	15.3	4.8	42
60- 90	7.21	1.90	12.5	6.2	10.2	0.7	5.7	10	13.9	3.3	40
90-120	7.35	2.15	10.0	6.0	16.9	1.1	6.4	5	22.6	6.0	50
Average	7.38	1.68	8.3	4.7	10.2	0.7	4.6	5.6	13.5	3.8	46

Soil depth (cm)	Available nutrients (mg/kg soil)						*OM %*	$CaCO_3$ %
	P	K	Fe	Zn	Mn	Cu		
0- 30	1.46	271	12.8	5.54	13.00	6.98	0.69	4.1
30- 60	0.02	243	21.7	2.26	4.82	2.64	0.86	0.9
60- 90	2.70	221	21.1	1.36	3.00	22.90	1.20	3.7
90-120	2.03	286	23.0	0.62	1.74	9.88	0.45	2.2
Average	1.55	255	19.7	2.45	5.64	10.6	0.39	2.7

Preparation of EM Secondary

The 100 litters of EM secondary were prepared by mixing 5 litters of molasses with amount of water, then added water to reach 90 litters, and supplemented 5 litters of effective microorganisms; EM, which produced by Egyptian Ministry of Agriculture. The previous mixture was kept in dark tanks to an aerobically ferment for one week till *pH* is 3.5.

Preparation of EM-compost

EM compost is an organic fertilizer prepared by adding 10 litters of water, 100 ml of molasses and 100 ml of effective microorganisms to a thoroughly mixed material of 16 kg of fine rice-hull and 16 kg of olive dough. Every 25 kg of the mixture was packing in double plastic bags then they kept for 2 weeks to ferment aerobically. The *pH* of the mixture was measured to chick the complete of fermentation.

Field experiment

The experiment was conducted at Khorshed village and Rice Technology Training Center; RTTC laboratories, Alexandria, Egypt during two rice cultivation seasons of 2004 and 2005. The previous crop was wheat. The whole experimental sites were chiseled, disked, and leveled. Field area was fertilized with 100 kg/fed of supper phosphate (15%) fertilizer then the soil was disced by disc harrow to mix the fertilizer. Randomized complete block designs with three replications were adopted. The plot size was 5 m × 6 m. Seven levels of fertilizer treatments; 46 units of N/fed, 23 units of N/fed, 23 units of N/fed + 1 ton of EM compost/fed, 23 units of N/fed + 2 ton of EM compost/fed, 23 units of N/fed + 3 ton of EM compost/fed, 23 units of N/fed + 4 ton of EM compost/fed and 4 ton of EM compost/fed were applied to designated plots. There were spread by grasp with the hand. The units of N chemical fertilizer was in form of Urea, 46% [$CO(NH_2)_2$]. All plots were transplanted by rice variety of Sakha-102 after 30 days during the second week of May in both growing seasons, and were harvested during second week of September in the 1^{st} and 2^{nd} seasons. The spacing between pits was 20 × 20 cm with 3 transplants per pit. Surface basin irrigation was practice using the scheduling irrigation every 6 days to remain submerged water depth of 7 cm. Parshall flume was installed in the irrigation channel to measure the amount of water for each plot according to James (1993). The total amount of water used during the season was calculated and expressed as seasonal applied irrigation water; *AIW*. In case of the EM compost treatments, 15 litters EM secondary/fed were applied with irrigation water weekly to allow the organic matter to ferment quickly, and also to make it available for the rice in more efficient way. Regular spraying of 3.75 cm^3 EM secondary/m^2 was started from an early age of the plant to build immunity and protect it from insect and disease attack. Spraying was conducted at two week's interval until the crop was harvested. To investigate the effect of the application of inorganic nitrogen fertilizer and EM-compost on the soil fertility, the soil acidity; *pH* and the soil salinity indicated by electrical conductivity; EC_e were measured after 30 days (time of rice transplanted) and after 125 days (time of harvesting). Also, the available level of nutrients; Na, K, NH_4, NO_3, Fe, Cu, Mn, Zn and P were evaluated after harvesting time for different depths.

Rice grain yield; *GY*

Plants samples of three different areas of one square meter from each plot were manually harvested and left three days for air drying. The harvested rice crop from 1 m^2 was weighted, then threshed and rice grain was weighted and converted to kg/fed to determine grain yield; *GY*.

Irrigation water efficiencies

The maximum paddy rice evapotranspiration (water consumptive use); ET_c was calculated in relation to reference evapotranspiration; ET_o and recommended FAO paddy rice coefficient; K_c. The ET_o was calculated based on the meteorological data of Egyptian Central Laboratory for Agricultural Climate by using FAO Penman-Monteith equation. The K_c's for the first month and second month 1.18 - 1.07, mid season 1.16 – 1.19 and the last month 1.04 were used according to Doorenbos and Kassam (1979). Water used efficiency; *WUE* was calculated as a ratio between the rice grain yield; *GY* and seasonal applied irrigation water; *AIW* (Michael, 1978). Water application efficiency; E_a was calculated as the percentage between the ET_c and *AIW*.

Physical and mechanical properties of paddy

Grains moisture content: For rapid and direct measurement of the rice grains moisture content, the Infra-Red moisture meter (model F-1A) was used with an accuracy of 0.1% and a measurement range from 0 – 100%. The best required moisture content for paddy processing is about 14% wet bases, for that all the samples under studies were dried by natural air to achieve recommended moisture content level.

1000-grains weight (Seed index) was determined using rice grain counter, (model K131 for 500 grains). Ten random samples from each treatment were used. The 1000 grains were drawn from the total number of filled paddy grains from the replicate then weighted.

Grain dimensions; grain length, thickness and width were measured using the grain shape tester (model MK-100) with measuring range from 0 to 20 mm and an accuracy of 0.01mm.

Grain shape is the ratio between the length and width of grain. It helps to select the sieves and adjust the clearance between the rubber rollers.

Milling process

Cleaning: Paddy rice was mechanically cleaned at first to remove foreign materials such as straw, soil particles, mud balls and weed seeds according to their different shapes, sizes and specific weight. Such cleaning was done using a precleaning electric apparatus; Cater-Day Dockage tester (Model TRG). The apparatus consists of four oscillating and replicable sieves. To ensure high degree of cleanliness, recycling in the apparatus was done. Mechanical cleaning may be completed by hand.

Husking: To obtain brown rice (husked rice), a Satake laboratory rubber roll Sheller (model THU-35A) with a capacity of 40 kg/h was used for removing rice hulls. The Sheller consists of two rubber rolls, each of 100 mm diameter and 35 mm wide. The rolls are driven mechanically by 400W motor and rotate in opposite inward directions. Brown rice, husks and immature paddy were separated by an automatic aspirator.

Grain hardness was measured using a hardness tester (model KY–140) with piston of force 196 N maximum and 5 mm^2 pressing cross section. Brown rice hardness was recorded at the breaking force (Kimura, 1991).

Milling: A Satake testing mill (model TM-05), with an input capacity of 200 g of brown rice in one time, was used. This whitening machine consists of abrasive roll of 36 cm diameter and rotates at a speed of 450 rpm. The roll rotates inside a fixed cylinder of 38 cm diameter made of perforated steel. The bran layer is removed from the brown rice as a result of the friction between rice kernels and both cylinders. Milled rice (rice after milling which includes removing all or part of the bran and germ from the husked rice), broken rice (milled rice with length less than one half of the average length of the whole kernel) and head rice were weighted and calculated their percentage obtained from a sample of paddy for each treatment.

Statistical analysis

The data obtained from the two growing seasons were subjected to proper statistical analysis using CoHort Software (2005). The treatment's means were compared using the least significant difference test (LSD) at 5% probability level.

RESULTS AND DISCUSSIONS

Soil acidity; *pH*

The *pH* value of an aqueous solution is the negative logarithm of the hydrogen ion activity. The solubility of several elements such as Cu, Zn and Mn are *pH* dependent, increasing about 100-fold for each pH unit lowering. Figure (1) and Table (3) show the soil acidity as affected by treatments. The figure (1) could be divided to three categories. The first category is the influence of two doses of nitrogen fertilizer. It seems that the decreasing of the N units/fed from 46 to 23 has a little decrease on soil acidity. Furthermore, the soil acidity has been slightly decreased during rice transplanted (30 days) and this decreasing was more after harvesting (125 days). The second category is the influence of the EM-compost at the present of 23 N units/fed on soil acidity. The soil acidity continuously decreased with increasing quantity of EM-compost applications. The decreasing of soil acidity was more after harvesting than during rice transplanted. That attributes to the effective microorganism compost, which is an acidic medium. EM produces organic acids and enhances the fertility of the soil by bring the pH down (Satou, 1998). A statistical model that quantifies the influence of the EM-compost quantity; *M* (ton/fed) and elapse of application time; *t* (days) on soil acidity; *pH*, in the range of experiments is

$$pH = 8.5728 - 0.0017\,t - (0.0008\,t + 0.2787)\,M + (0.0002\,t + 0.024)\,M^2$$

, with $R^2 = 0.9846$

The third category is the influence of the bio-agriculture treatment on the soil acidity. The soil acidity was decreased from 8.7 (at the initial condition) to 7.2 by using 4 ton EM-compost without inorganic fertilizer, after rice harvesting. These results agree with results that obtained by Jillani (1997) and Pairintra and Pakdee (1991).

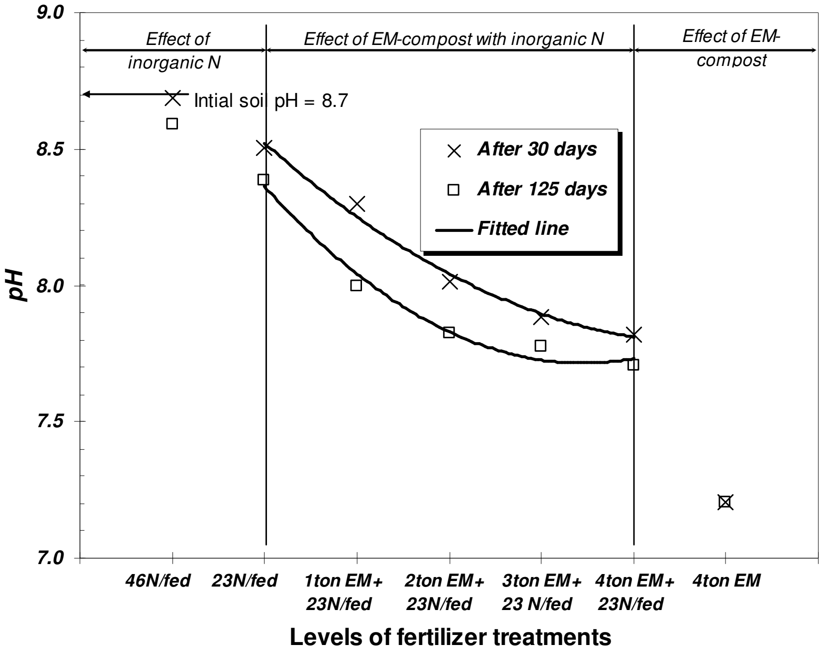

Figure (1): The soil acidity; *pH* as affected by inorganic N and EM-compost.

Soil salinity; EC_e

Figure (2) and Table (3) illustrate the effect of inorganic N fertilizer, EM-compost with 23 N units/fed of inorganic fertilizer and EM-compost on the soil salinity; EC_e. These three effects are evaluated after 30 days and after 125 days. The EC_e did not change when the chemical nitrogen fertilizer was changed from 46 to 23 N units/fed. However, the soil salinity has been slightly decreased to the extent of 5% during rice transplanted and this decreasing was more after harvesting to the extent of 11%. That could be attributed to the leaching of soil salt during water application and the nutrients intake by plants from the available adsorbed chemical on the soil surface. For the EM-compost with 23 N unit/fed, the effect of increase the EM-compost quantity is to decrease the soil salinity; EC_e to the extent of 48% when the EM-compost quantity is increased from nil to 1 ton after 30 days and to the extent of 60% after 125 days.

EC_e of the soil was reduced with the EM treatment (Jillani, 1997). Compost amendments alleviated some effects on EC_e of saline soil (Pairintra and Pakdee 1991). The increasing of the EM-compost quantities from 1 to 4 ton/fed decreases the EC_e by about 9% after 30 days and by about 28% after 125 days. EC_e being an important parameter, has been studied with regard its prediction. The best correlation is shown in figure (2), whose EC_e in (dS/m) is given as

$$EC_e = (-0.0037t + 1.2245)\, M^{(-0.0007t - 0.107)} \quad \text{,with } R^2 = 0.9887$$

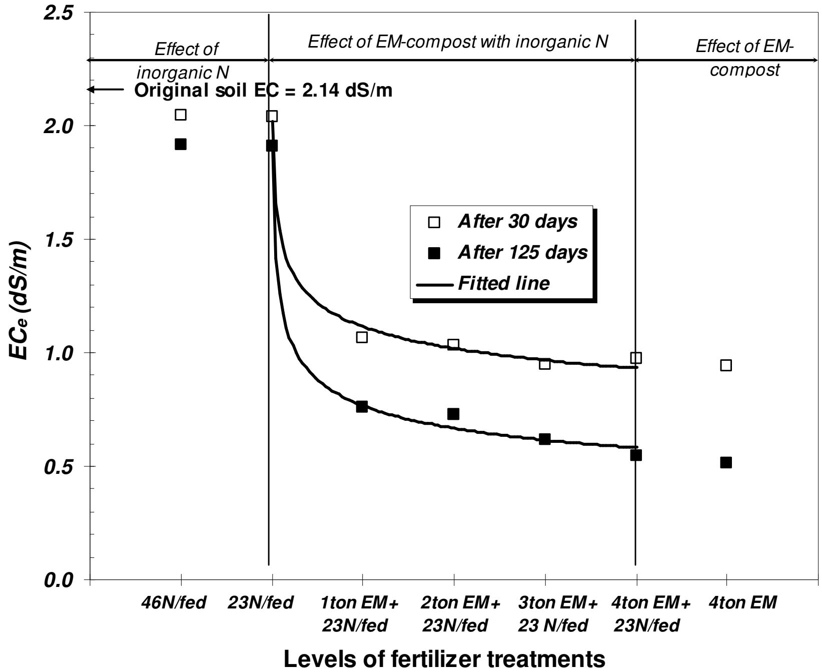

Figure (2): The soil EC_e as affected by inorganic N and EM-compost.

The effect of the EM-compost combined with and without 23 inorganic N units/fed on soil salinity is shown in figure (2). It is pointed out that there is no value to use inorganic fertilizer in the direction of decrease soil salinity. While, the using of 4 ton/fed of EM-compost decreases the EC_e by about 76% after 125 days. That encourages the farmers to recover the salinity of soil by using the EM-compost. The N requirement of crops decreased with an increase in soil salinity (Hussain, *et al.*, 1991).

Sodium; Na Available in soil

Figure (3) shows three periods. The first period is the influence of two doses of nitrogen chemical fertilizer on Na available in soil after harvesting. It shows that there is no significant effect. The second period illustrates that by added 1 ton of EM-compost with 23 N units/fed, the available Na in soil in (mg/kg soil) decreased by extent of 47.2% and this trend continue significantly with increasing the EM-compost (Table 3). The best correlation explain that trend is given by

$$Na = (213.27)\,M^{-0.1298} \quad \text{, with } R^2 = 0.995$$

While for the third period shows the EM-compost of 4 ton/fed decreased the Na by extent of 56.3%. These results agreed with Syed et al. (2002), who stated that the EM treated soil has more beneficial bacteria types such as Rhodobacter, Pseudomonas, Lactobacillus, Furababacterum, and Gluconobacter, which have the ability to convert NaCl to protein and chelates by de-ionzing the salts.

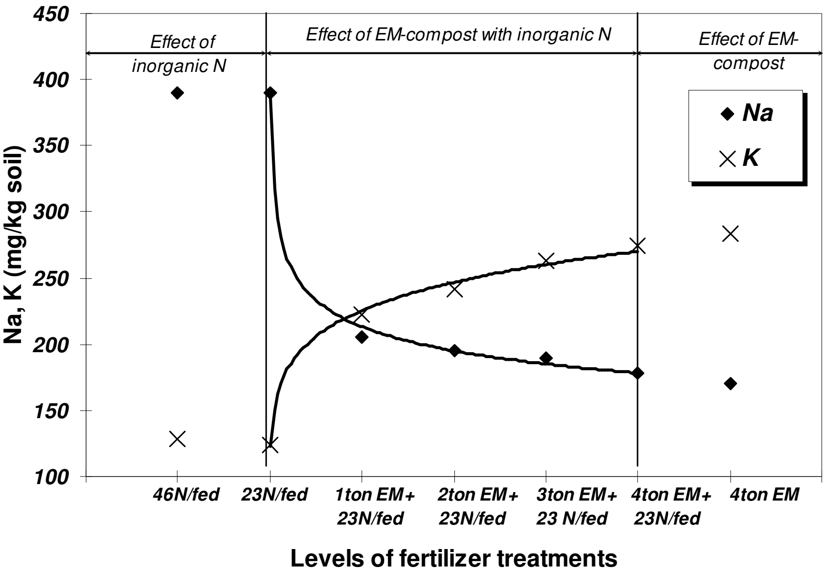

Figure (3): Available Na and K as affect by inorganic N and EM-compost.

Potassium; K available in soil

K is the third most used element in fertilizers. K is known to affect cell division, the formation of carbohydrates, translocation of sugars, various enzyme actions, and the resistance of some plants to certain diseases, cell permeability, and several other functions. Over 60 enzymes are known to require potassium for activation (Miller and Donahue, 1990). Figure (3) and Table (3) show the available of K in (mg/kg soil) as affect by inorganic N and EM-compost. With the EM-compost, the available K in soil increased significantly after harvesting. The best correlation clarify that relationship is specified by

$$K= (225.3)\, M^{0.1313} \qquad \text{, with } R^2 = 0.9978$$

That means at the certain level of the EM-compost could provide the rice plant needs of K without changing the K available in soil. While, using the chemical fertilizer only, the K in soil reduced from 255 to 126 mg/kg soil (Table 2 and figure 3).

Copper; Cu and iron; Fe available in soil

Cu is essential in many plant enzymes (oxidases) and is involved in many electron transfers. Fe is a structural component of cytochromes, hemes and numerous other electron-transfer systems, including nitrogenase enzymes necessary for the fixation of dinitogen gas. Iron is an important part of the plants' oxidation-reduction. As much as 75 percent of the cell iron is associated with chloroplasts (Miller and Donahue, 1990). Figure (4) and Table (3) illustrate the behavior of the available Cu and Fe in soil with different treatments after harvesting. The available Cu and Fe in soil

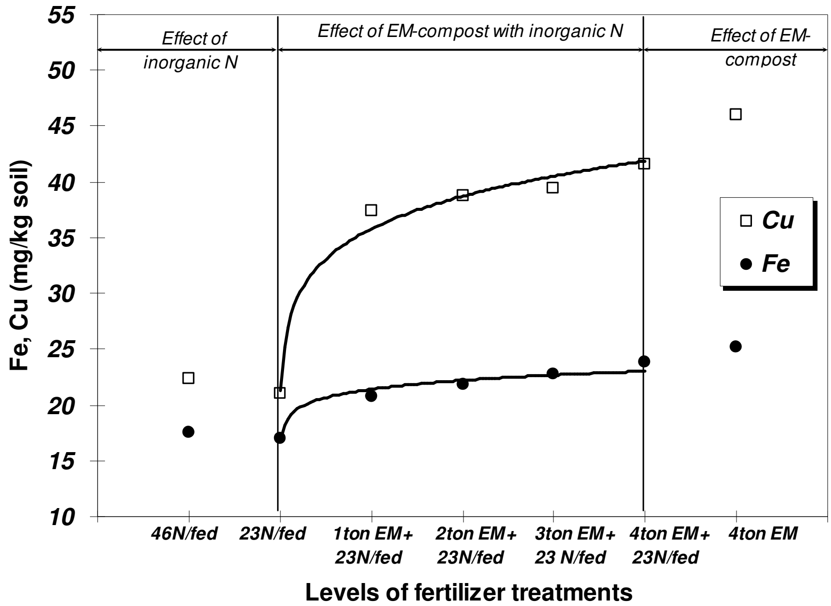

Figure (4): Available Cu and Fe as affect by inorganic N and EM-compost.

were slightly decreased with decreasing the chemical fertilizer level. When increasing the EM-compost, the amount of available Cu and Fe increased significantly. That because of EM produces Chelating agents (Siderophores) which make Fe and micro nutrients to be available to plants. By using the statistical model, the relationships between available Cu and Fe in mg/kg soil and amount of EM-compost in ton/fed are described by the following equations in the range of experiments

$$Cu = (35.786)\, M^{0.1131} \quad \text{, with } R^2 = 0.9915$$

$$Fe = (21.417)\, M^{0.052} \quad \text{, with } R^2 = 0.9565$$

It is observed that at application of 4 ton EM-compost/fed without N inorganic fertilizer provided the soil with the highest amount of available Cu and Fe. That may attribute that the use of chemical fertilizer makes these microorganisms dormant.

Manganese; Mn, Zinc; Zn and phosphorus; P available in soil

Figure (5) and Table (3) show the impact of different treatments on the available Mn, Zn and P after harvesting. As single use of the chemical fertilizer, the available Mn, Zn and P in soil did not change noticeably. While, with applying EM-compost, the available Mn and Zn sharply increased. The available P increased gradually with increasing the EM-compost. That could be attributed to the available the photosynthetic bacteria in EM-compost, which increases the coexistence and co-prosperity with Microhiza fungi that released the P and others nutrients from soil and the compost components. By using the statistical model, the relationships were described in the range of experiments as

$$Mn = (7.9597)\, M^{0.1017} \quad \text{, with } R^2 = 0.9936$$

$$Zn = (4.2059)\, M^{0.1563} \quad \text{, with } R^2 = 0.9984$$

$$P = 1.5315 + 0.1058\, M + 0.178\, M^2 \quad \text{, with } R^2 = 0.9847$$

It should be noted that the Zn is essential for numerous enzyme systems and is capable of forming many stable bonds with nitrogen and sulfur ligands. Mn is involved in many enzyme systems and in electron transport. It is believed that organic matter decomposition aids manganese solubility. P is the second key plant nutrient. P is an essential part of nucleoproteins in the cell nuclei, which control cell division and growth, and deoxyribonucleic acid (DNA) molecules, which carry the inheritance characteristics of living organisms. In its many compounds P has roles in cell division, in stimulation of early root growth, in hastening plant maturity, in energy transformations within the cell (Miller and Donahue, 1990).

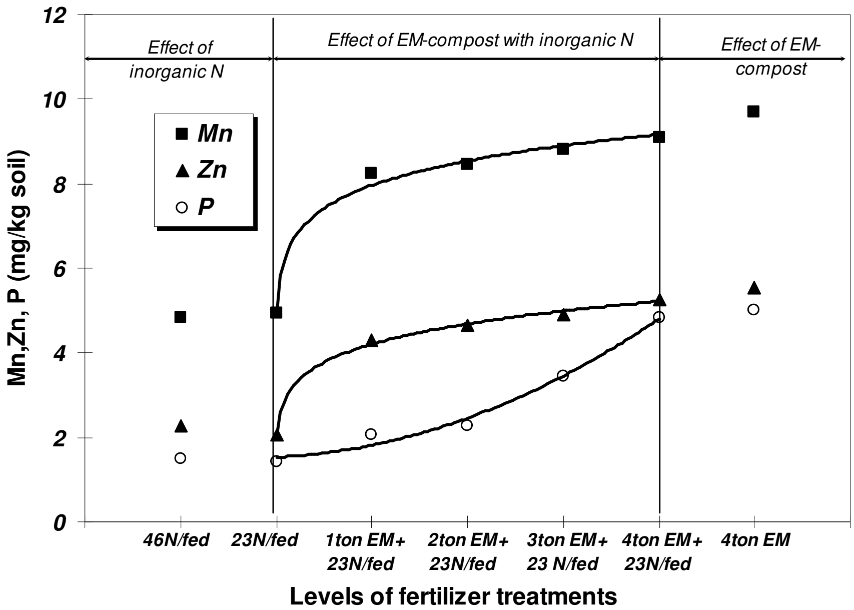

Figure (5): Available Mn, Zn and P as affect by inorganic N and EM-compost.

Available nitrogen in soil

Nitrogen is the key nutrient in plant growth. It is a constituent of plant proteins, chlorophyll, nucleic acids and other plant substances. Adequate nitrogen often produces thinner cell walls, which results in more tender, more succulent plants; it also means larger plants and hence greater crop yields (Miller and Donahue, 1990). Figure (6) and Table (3) show the available NH_4 and NO_3 as affected by treatments after harvesting. The figure shows three phases. The first phase is the influence of two doses of nitrogen fertilizer. It seems that the decreasing of the N units/fed from 46 to 23 has a little decrease on available nitrogen. The second phase is the influence of the EM-compost at the present of 23N units/fed on NH_4 and NO_3. The available nitrogen steadily increased with the increasing the EM-compost applications. The reason of that increasing could be due to the presence of the photosynthetic bacteria, which enhances the

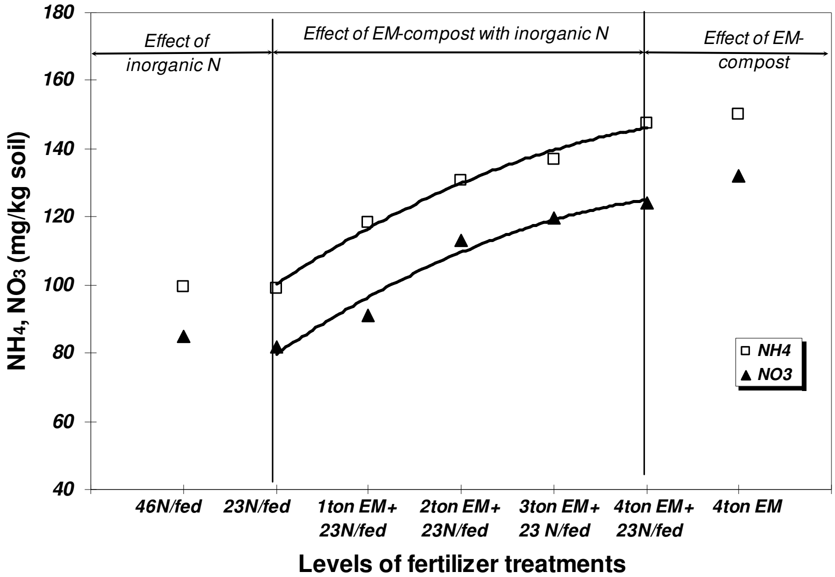

Figure (6): Available nitrogen as affect by inorganic N and EM-compost.

Table (3): The statistical analysis for the effect of different fertilizer applications on some soil fertility.

Treatments	*EC_e* dS/m		*pH*		Na	K
	30 days	125 days	30 days	125 days	mg/kg soil	mg/kg soil
46 N/fed	2.047a	1.917a	8.687a	8.590a	389.75a	128.2f
23 N/fed	2.040a	1.910a	8.503ab	8.387a	389.76a	123.6g
1 ton EM+ 23N/fed	1.067b	0.757b	8.300bc	7.997b	205.69b	222.7e
2 ton EM+ 23N/fed	1.033b	0.726bc	8.013cd	7.827bc	195.61c	242.0d
3 ton EM+ 23N/fed	0.947b	0.618bcd	7.887d	7.777bc	189.93d	263.0c
4 ton EM+ 23N/fed	0.972b	0.544cd	7.820d	7.707c	178.21e	274.8b
4 ton EM /fed	0.943b	0.512d	7.207e	7.205d	170.53f	283.4a
LSD 0.05	0.143	0.196	0.320	0.272	3.72	3.9

Treatments	Fe mg/ kg soil	Zn mg/ kg soil	Mn mg/ kg soil	Cu mg/ kg soil	P mg/ kg soil	NH_4 mg/ kg soil	NO_3 mg/ kg soil
46 N/fed	17.55f	2.26f	4.82g	22.40f	1.507e	99.6e	84.7f
23 N/fed	17.02g	2.05g	4.95f	21.08g	1.433e	99.0e	81.7g
1 ton EM+ 23N/fed	20.70e	4.30e	8.25e	37.35e	2.073d	118.5d	91.1e
2 ton EM+ 23N/fed	21.80d	4.65d	8.45d	38.70d	2.273c	130.7c	113.3d
3 ton EM+ 23N/fed	22.80c	4.90c	8.80c	39.45c	3.437b	136.7b	119.6c
4 ton EM+ 23N/fed	23.89b	5.25b	9.10b	41.55b	4.840a	147.5a	124.1b
4 ton EM /fed	25.20a	5.55a	9.70a	46.00a	5.000a	149.9a	132.1a
LSD 0.05	0.20	0.10	0.09	0.42	0.172	3.2	1.2

coexistence and co-prosperity with Astobacter in EM-compost which fixed the air nitrogen. A statistical model that quantifies the influence of the EM-compost quantity; M (ton/fed) on the NH_4 and NO_3 are

$$NH_4 = 100.11 + 18.226\,M - 1.6827\,M^2 \quad \text{, with } R^2 = 0.9883$$

$$NO_3 = 79.635 + 18.636\,M - 1.8246\,M^2 \quad \text{, with } R^2 = 0.9658$$

The third phase is the influence of the EM-compost without N fertilizer. Figure 6 illustrates that there is no importance to apply inorganic fertilizer in the direction providing N rice needs. That promotes the farmers to cover the rice needs from nitrogen by applying the EM-compost.

Rice grain yield; *GY*

Figure (7) and Table (4) illustrates the comparison between the effect of EM-compost and the conventional N fertilizer on the yield of rice. The effect of EM-compost with half amount of recommend N fertilizer on rice yield was decreased the *GY* by 289.5 kg. As shown in the figure (7), with increasing the EM-compost the grain yield was significantly increased. That may be attributed to the EM-compost enhances the fertility of soil by reducing soil acidity; *pH*, salinity; EC_e and Na and provides the rice plant needs of N, P, K, Fe, Cu, Mn, and Zn. That developed vigorous root system, which sustained the growth and rice yield. The relationship between *GY* (kg/fed) and *M* (ton EM-compost/fed) can be expressed as:

$$GY = 4402.6 + 181.81\,M - 22.825\,M^2 \quad \text{, with } R^2 = 0.9985$$

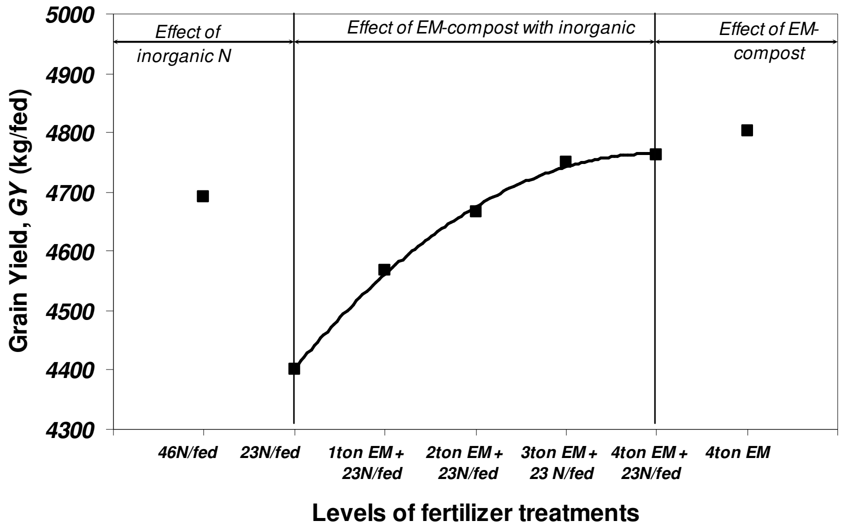

Figure (7): Rice grain yield as affect by inorganic N and EM-compost.

Figure (7) shows also the effect of the decrease of N fertilizer from 46 units to 23 units could be compensated by 2 ton EM-compost/fed. On the other hand, it is observed that at application of 4 ton EM-compost/fed without N fertilizer provided the *GY* greater than 4 ton EM-compost/fed with N fertilizer. That could be attributed to the use of chemical fertilizers that cause the decline in soil organic matter and biomass carbon and decrease in diversity and activity of soil flora and fauna (Satou, 1998). As a result the chemical fertilizers make the microorganisms dormant.

Applied irrigation water; *AIW*

Table (4) shows the *AIW* were decreased significantly by extent of 2.8, 3.4, 6.5 and 12.7% with increasing the application of EM-compost from nil to 1, 2, 3 and 4 ton/fed, respectively. That decreasing reflects the increasing of the soil water holding capacity through the different EM-compost doses. Syed *et al.* (2002) declared that EM increases soil aggregation, the water holding capacity, cation exchange capacity (*CEC*), buffering capacity and the humus. The EM-compost contains the photosynthetic bacteria, which enhances the coexistence and co-prosperity with Microhiza fungi, which responsible on increasing the absorbing the soil water. It is observed that at application of 4 ton EM-compost/fed without N inorganic fertilizer saved seasonally 927 m^3 water/fed in comparing with the control treatment (46 N units/fed).

Water use efficiency; *WUE*

The effect of inorganic N fertilizer and EM-compost on *WUE* is presented in Table 4. The maximum *WUE* was recorded at application of 4 ton EM-compost/fed without and with N fertilizer and ranging from 0.908 to 0.88 kg *GY*/m^3 of water. Decreasing the doses of EM-compost from 4 to 3, 2, and 1 ton/fed resulted in decreasing the *WUE* by extent of 9.7, 14.1 and 16.5%, respectively. Obtained results confirmed that the effect of 1 ton EM-compost/fed and 23 N units/fed on *WUE* is equivalent to the effect of recommended N fertilizer dose (46N unit/fed).

Water application efficiency; E_a

E_a were significantly affected by different application of N fertilizer and EM-compost (Table 4). The maximum E_a was 65% at 4 ton EM-compost/fed, while the smallest E_a was 55.5% without EM-compost treatments.

Table (4): Irrigation water parameters as affected by fertilizer treatments.

Treatments	*AIW* m^3/fed	*GY* kg/fed	*WUE* kg *GY*/m^3 water	E_a %
46 N/fed	6220 a	4691 c	0.754 cd	55.5 e
23 N/fed	6199 b	4402 f	0.710 d	56.0 e
1 ton EM+ 23N/fed	6024 c	4567 e	0.758 cd	57.1 d
2 ton EM+ 23N/fed	5987 d	4667 d	0.779 bc	57.6 d
3 ton EM+ 23N/fed	5796 e	4749 b	0.819 b	59.5 c
4 ton EM+ 23N/fed	5413 f	4763 b	0.880 a	64.0 b
4 ton EM/fed	5293 g	4804 a	0.908 a	65.0 a
LSD 0.05	3.52	14.61	0.052	0.64

Physical and Mechanical Properties of paddy

These measurements of quality are useful indicator for total milled rice yields. Rice is produced and marketed according to grain size and shape. The physical dimensions, weight and uniformity are of prime importance.

1000-grains weight; W_{1000} (Seed index)

A degree of weight where a rice grain is packed in a fixed volume can offer a good indicator to know grade of rice. Stuffing of rice varies according to grain shape, grain size, coarseness on the surface, and the structure of tester. Figure (8) shows the relationship between the 1000-grains weight; W_{1000} and the different levels of EM-compost with other conventional N fertilizer. It is noticed from Table (6) that there were no significant differences in W_{1000} with decreasing in application of N

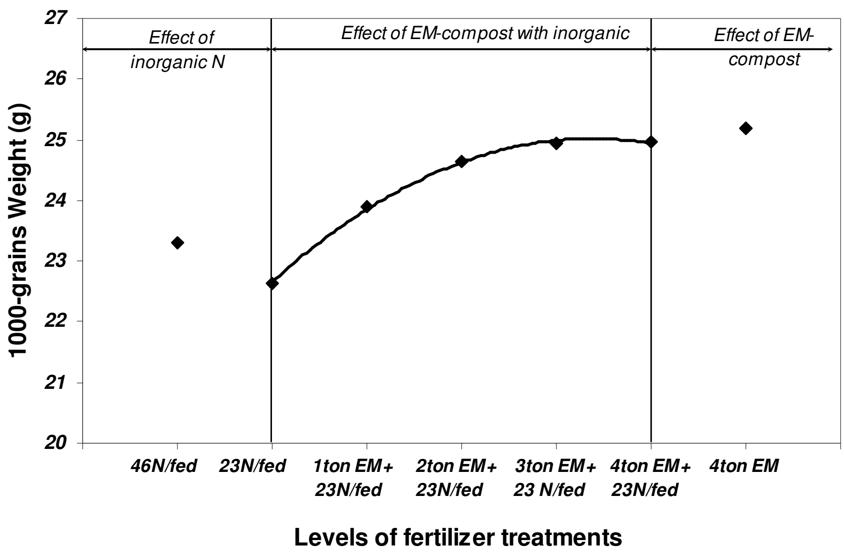

Figure (8): 1000-grains weight as affected by inorganic N and EM-compost

fertilizer from 46 units/fed (control treatment) to 23 units/fed as well as increasing in application of EM-compost from 2 to 3 or 4 ton/fed. The results showed that 4 ton of EM- compost/fed recorded a significant increase in W_{1000} by extent of 8.2% over the control. The relationship, which described the effect of the EM-compost quantities; *M* (in ton) on W_{1000} (in g), could be expressed in the following empirical equation:

$$W_{1000} = 22.658 + 1.3996\,M - 0.2073\,M^2 \qquad \text{, with } R^2 = 0.9981$$

Empty grains; *E*

Test weight provides a measure of the amount of unfilled, shriveled, and immature grains based on the size standards established for the grain. Figure (9) illustrates the percentage of empty grains as affect by inorganic N and EM-compost. The results turned out that the empty grains; *E* (%) decreased with increasing the amount of EM-compost (ton/fed); M. That relationship could be stated as:

$$E = 1.6618 - 0.1398 \ln(M) \qquad \text{, with } R^2 = 0.9877$$

However, Table (6) confirmed that there were no significant differences in empty grains with decreasing in inorganic N from 46 to 23 units/fed or with increasing in EM-compost from 1 to 2, 3 or 4 ton/fed. On other hand, application of 4 ton EM-compost/fed recorded a significant decrease in empty grains by extent of 54.2% under the application of 46 N units/fed.

Grain dimensions and shape index

Rice, unlike most other cereals, is consumed as a whole grain. Therefore physical properties such as size, shape, uniformity, and general appearance are of utmost importance. The dimensions of rough grains for each treatment and the ratio of length/width have emerged in Table (5), which shows clearly that the using of EM-compost did not change the dimensions and shape of rice in compared with conventional N fertilizers.

Table (5): Effect of fertilizer treatment on grains dimension and shape

Treatments	**Length** (mm)	**Width** (mm)	**Shape index**
46 N/fed	8.240 a	3.392 a	2.432 ab
23 N/fed	8.232 a	3.476 a	2.369 ab
1 ton EM+ 23N/fed	8.024 a	3.428 a	2.345 b
2 ton EM+ 23N/fed	8.306 a	3.372 a	2.465 a
3 ton EM+ 23N/fed	8.310 a	3.460 a	2.404 ab
4 ton EM+ 23N/fed	8.128 a	3.388 a	2.401 ab
4 ton EM /fed	8.272 a	3.476 a	2.382 ab
LSD 0.05	0.288	0.179	0.119

Husked rice; *HR*

Figure (10) shows the relationship between the percentage of husked rice; *HR* and the effect of different EM-compost levels with other conventional N fertilizer. Table (6) illustrates that there were slightly differences in husked rice with decreasing in application of N fertilizer from 46 to 23 units/fed. Application of EM-compost slightly increased husked rice. The results showed that 4 ton of EM-compost/fed recorded increase in *HR* by extent of 5.5% over the control. The relationship between EM-compost quantities; *M* (ton/fed) and husked rice; *HR* (%) could be as:

$$HR = 79.12\, M^{0.0067} \quad \text{, with } R^2 = 0.974$$

Grain Hardness; *H*

Grain hardness is resistant strength just before being crushed by outside strength. The grain hardness has close relation to grain quality. Generally the grain with higher moisture content or chalky grain shows low rigidity, and consequently milling yield will be less. The effect of fertilization treatments on grain hardness is presented in figure (11) and Table (6). The grain hardness was decreased by extent 17.4% with decreasing in application of N fertilizer from 46 to 23 units/fed. While, increasing EM-compost rates significantly increased the grain hardness. The grain hardness was increased by extent 30.1% using 4 ton EM-compost without inorganic fertilizer. A statistical model that quantifies the influence of the EM-compost quantity; *M* (ton/fed) and grain hardness; *H* (N), in the range of experiments is

$$H = 4.3472 + 0.9726\, M - 0.1173\, M^2 \quad \text{, with } R^2 = 0.991$$

Milled rice; *MR*, broken rice; *BR* and head rice; *HdR*

High head rice yield is one of the most important criteria for measuring milled rice quality. The accurate measurement of the amounts and classes of broken grains is very important. The effect of inorganic N and EM-compost on milled rice and head rice are shown in figure (10), while broken rice is shown in figure (8). Table (6) illustrates that there were slightly decrease in milling recovery (percentage of milled rice) and head rice recovery (percentage of head rice) with decreasing in application of N fertilizer from 46 to 23 units/fed. The half amount of the recommended N fertilizer gave the lowest milled rice and head rice values, while it gave the highest broken rice. With increasing the application of EM-compost,

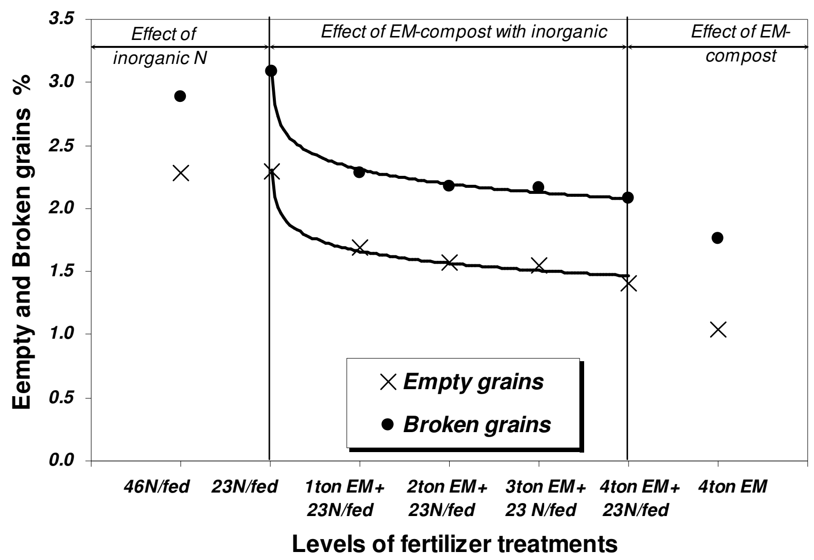

Figure (9): Empty and broken grain as affect by inorganic N and EM-compost.

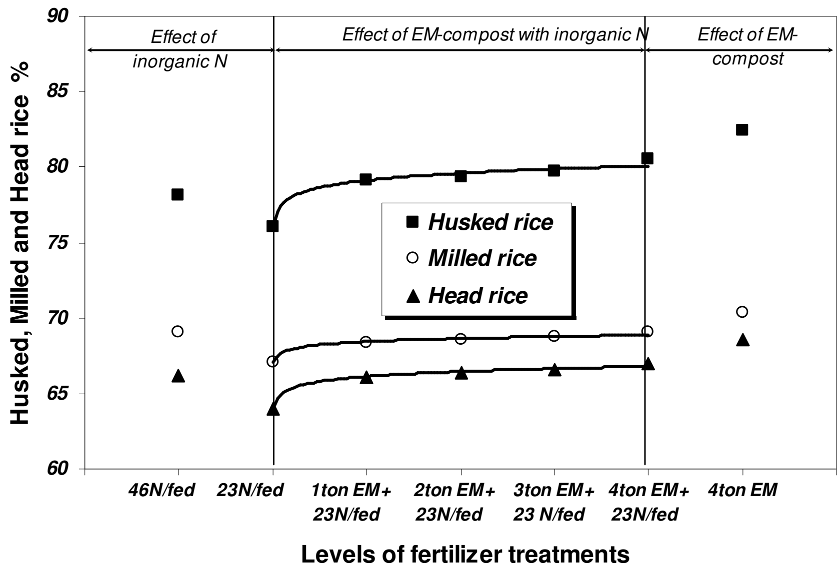

Figure (10): Husked, milled and head rice as affect by inorganic N and EM-compost.

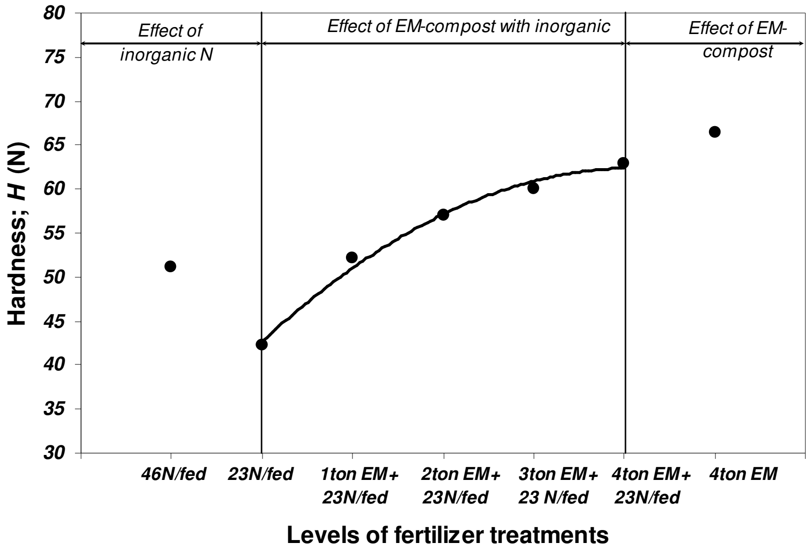

Figure (11): the grain hardness as affect by inorganic N and EM-compost.

Table (6): Statistical analyses for characteristics rice grain quality

Treatments	W_{1000} (g)	Empty grains%	Husked rice%	Hardness (kg)	Milled rice%	Broken grains%	Head rice%
46 N/fed	23.30bc	2.28a	78.17cd	5.21d	69.04ab	2.89a	66.15b
23 N/fed	22.63c	2.30a	76.05d	4.31e	67.07c	3.08a	63.99c
1 ton EM+23N/fed	23.90b	1.69b	79.12bc	5.31d	68.34bc	2.28b	66.05b
2 ton EM+23N/fed	24.63a	1.57b	79.32bc	5.81c	68.54bc	2.18b	66.37b
3 ton EM+23N/fed	24.93a	1.55b	79.69bc	6.12bc	68.74abc	2.16b	66.58b
4 ton EM+23N/fed	24.97a	1.41b	80.52ab	6.41b	69.07ab	2.09b	66.98ab
4 ton EM/fed	25.20a	1.05c	82.46a	6.78a	70.34a	1.76c	68.57a
LSD 0.05	0.69	0.35	2.29	0.36	1.77	0.30	1.75

milled rice and head rice slightly increased and the broken rice decreased. The relationship between EM-compost quantities; *M* (ton/fed) and milled rice; *MR*, head rice; *HdR* and broken rice; *BR* (%) could be as:

$$MR = 68.435\ M^{0.0045} \quad \text{, with } R^2 = 0.9732$$

$$HdR = 66.122\ M^{0.0072} \quad \text{, with } R^2 = 0.9906$$

$$BR = 2.3092 - 0.1662 \ln(M) \quad \text{, with } R^2 = 0.9964$$

The result also indicated that application of 4 ton EM-compost/fed without N fertilizer gave the highest values of milled rice and head rice. On other hand, 4 ton EM-compost/fed recorded a significant decrease in broken rice by extent of 39% under the control application (46 N units/fed) due to the increasing of the grain hardness. That could be attributed to the roots became biologically extremely active to releasing all types of essential nutrients, which more available in the soil treated with EM-compost.

CONCLUSION

EM-compost is easy to prepare and enhanced bacteria population, which increase soil fertility and is not only reclaimed soil but it gives also good production and quality. Comparing the results of the effect of inorganic N fertilizer and EM-compost on paddy field fertility, irrigation water efficiencies and rice quality, it is clear that:

1. The EM-compost enhances the soil fertility by reducing *pH*, EC_e and Na. That due to the culture of EM an acidic medium and an anti oxidizing effect on de-ionized Na.
2. EM-compost increased the N, P and K in soil and they were more available for plant compared to chemical fertilize.
3. EM-compost increased the absorbing the water, P and others nutrients on soil due to EM rich with photosynthetic bacteria, which enhance the coexistence and co-prosperity with Microhiza fungi.
4. EM-compost increased the available nitrogen in soil due to Astobacter which fixed the air nitrogen. EM-compost makes Fe, Cu, Mn, and Zn to be more available to plants due to EM produce chelating agents.
5. EM-compost decreased applied irrigation water; *AIW* and increased the water use efficiency; *WUE* and water application efficiency; E_a.
6. The EM-compost enhances soil fertility and benefit environment to produce a high rice yield and quality.
7. EM-compost increased the good physical properties of rice quality; 1000-grains weight, grain hardness, husked, milled and head rice.

The results demonstrate that the EM-compost, with their many benefits to rice quality, controls to the use of N chemical fertilizers. Therefore, the implementation of this technology, rice quality can be improved and the environment protected. It offers opportunity to develop new and improved fertilizer recommendations for rice fertilizer management.

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الملخص العربي

أثر كمبوست الكائنات الحية الدقيقة النافعة على خصوبة التربة و أنتاجية و جودة الأرز

أحمد الشافعى[1] محمد يحيى[2] فاطمة النقيب[3]

يعتبر الأرز أحد أهم المحاصيل الزراعية فى مصر و أدى زيادة الطلب على الأستهلاك إلى العمل على زيادة الانتاجية بأستخدام أصناف جديدة عالية المحصول وأيضا زيادة أستخدام معدلات أعلى من الاسمدة النيتروجينية و التى أدت بدورها إلى زيادة تلوث المياه السطحية و الجوفية و زيادة ملوحتها بالأضافة إلى أثرها السلبي على صحة الحبوب ، لذا في الأونه الأخيرة ، تلقى نظم الزراعة الحيوية قدرا كبيرا من الاهتمام في كل من البلدان المتقدمة والبلدان الناميه خاصة بعد اختر ع العالم الياباني هيجا لتكنولوجيا بيولوجية جديدة تعرف بتكنولوجيا الكائنات الحية الدقيقة النافعة و هى مجموعة من الكائنات الحية الدقيقة مختلفة النفع وغير معدلة وراثياً و موجودة طبيعياً. و يهدف البحث إلى استخدام هذه التكنولوجيا في أنتاج كمبوست من المخلفات الزراعية كسرس الأرز و كسب الزيتون المعالج بالكائنات الحيه الدقيقة النافعة الذي يمكن أستخدامه للحد من استخدام معدلات عالية من التسميد النتروجينى ، وقد اجريت تجربتين خلال موسمين 2004، و 2005 لدراسة اثر هذا الكمبوست على خصوبة التربة وأنتاجية و جودة الخصائص الفيزيائية والميكانيكية لحبوب أرز سخا 102 مقارنة بالزراعة التقليدية ، و أتبع في التصميم الاحصائي للتجربة نظام القطعات العشوائية الكاملة واشتملت علي سبع معاملات من التسميد 46 وحدة أزوت /للفدان (معاملة قياسية)، و أربع معاملات بمعدل 1طن ، و 2طن ، و 3طن ، و 4طن كمبوست مضافا إليها 23وحدة أزوت/للفدان، و معاملتين 23وحدة أزوت/للفدان، و 4طن كمبوست/للفدان بدون إضافة نيتروجينية.

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وقد تم أستنباط معادلات تجريبية تصف أثر زيادة معدل كمبوست الكائنات الحية الدقيقة النافعة على خصوبة التربة و أنتاجية و جودة الأرز، كما أوضحت النتائج والتحليل الأحصائي مقارنة بالمعاملة القياسية أن كمبوست الكائنات الحية الدقيقة النافعة قد زادت من خصوبة التربة وذلك عن طريق الخفض المعنوي لكل من درجة الحموضة، وملوحة التربة، و الصوديوم الذائب وذلك بسبب نواتج التمثيل الغذائي لهذه الكائنات الحية الدقيقة النافعة و التي لها تأثير مضاد للأكسدة و تقلل من التأثير الضار للأكسجين النشط و تكوين الروابط الحرة. كذلك زادت أملاح الفوسفات و البوتاسيوم الذائبة في التربة زيادة معنوية حيث تقوم الكائنات الحية الدقيقة النافعة بإفراز الأحماض التي تقوم بإذابة و تحرير العناصر المعدنية الموجودة في التربة، وكذلك زادت محتوي التربة من النيتروجين عن طريق تثبيت الكائنات الحية الدقيقة النافعة لأزوت الهواء الجوي، و كذلك زادت نسبة العناصر الصغرى مثل الحديد و النحاس و المنجنيز و الزنك بسبب إفراز الكائنات الحية الدقيقة النافعة لبعض المواد المخلبية التي تيسر للنبات امتصاص العناصر الصغرى.

كما خفضت في كمية مياه الري المستهلكة و زادت كل من كفاءة أستخدام المياه وكفاءة إضافة المياه و ذلك بسبب تحسين بناء التربة عن طريق تجميع الحبيبات و ربطها مع بعضها بواسطة خيوط هيفات الفطريات و تكوين الدوبال الناتج من تحليل المواد العضوية و التي بدورها تزيد من السعة التشبعية للتربة.

أكدت النتائج أن استخدام معاملة 4طن/فدان من كمبوست الكائنات الحية الدقيقة النافعة (بدون تسميد أزوتي) و مقارنتها بالمعاملة القياسية أدى إلى زيادة إنتاجية الأرز بمقدار 113 كجم/فدان ،و أدت إلى زيادة وزن 1000 حبة بنسبة 8%، بينما قلت نسبة الحبوب الفارغة بنسبة 54%، ولم تظهر فروق معنوية في أبعاد و شكل الحبوب، و أدت إلى زيادة الأرز الكارجو بنسبة 5.5 %، و زادت درجة صلابة حبوب الكارجو بنسبة 30%، وانخفضت كسر الحبوب بنسبة 39%، و وصلت تصافى التبييض إلى 68.57% بزيادة 4% عن المعاملة القياسية. بالإضافة إلى كل هذه الاثار الايجابية لكمبوست الكائنات الحية الدقيقة النافعة على خصوبة التربة وجودة وأنتاجية الأرز فإن لها الأثر الكبير في ترشيد أستخدام الاسمدة الكيماوية و استفادة من المخلفات و المساهمة في بيئة آمنة.