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Producing Eggplant under Incorporation of Rice Straw into Clayey Soil with Decomposing Fungi and Plant Growth Promoting Rhizobacteria

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FIELD experiments were conducted at the experimental Site of Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center, Giza, Egypt during 2013 and 2014 seasons. The objective of this study was to investigate the effect of applying rice straw into soil with or without rice straw decomposing fungi (RSDF) and plant growth promoting rhizobacteria (PGPR) under 50 and 100% of recommended NPK on eggplant production. A randomized complete block design was used with three replications. Liquid culture of *Trichoderma viride* was used as RSDF. Mixture of *Azotobacter chroococcum, Azospirillium brasilense, Bacillus megaterium* and *Bacillus circulans* were used as PGPR. The control treatment under this study was application of 100% NPK without application of rice straw. The obtained results showed that growth characteristics, mineral composition and yield component of eggplant cultivar Black Balady were significantly improved by applying 100% mineral fertilizers with rice straw plus PGPR with or without RSDF. Using 50% mineral fertilizers with rice straw plus RSDF and PGPR gave good yield with no significant differences in comparing with 100% mineral fertilizers without rice straw (control). This work shows that incorporation of rice straw into soil with decomposing fungi and plant growth promoting rhizobacteria led to improve the production of eggplant. As well as, reduce the amount of mineral fertilizers and avoid one of the most serious environmental air pollution (Black Cloud), caused by burning rice straw annually.

Keywords: Eggplant, Rice straw, Rice straw decomposing fungi, *Trichoderma viride,* Plant growth promoting rizobacteria (PGPR).

Eggplant (*Solanum melongena var. esculenta L*) is one of the important vegetable crops grown in the summer season of Egypt. The total cultivated area in Egypt was about 108 thousand feddans, producing about 1.2 million tons on annual basis with an average of 11.1 tons/feddan (feddan equal 0.4 hectare) according to Ministry of Agriculture and Land Reclamation (2013). Eggplant fruits contain a considerable amount of carbohydrates (6.4%), protein (1.3%) and fat (0.3%). They are also a rich source of potassium, magnesium, calcium and iron (Zenia and Halina, 2008).

The problem of agricultural wastes in Egypt became very obvious especially after the harvest of summer crops. Egyptian farmers get rid of these wastes by burning. Burning not only is considered an economic loss but also has harmful effects on the environment, i.e. emission of poison gases to the air and reducing the microbial activities in the soil. Therefore, utilization of agriculture wastes in any other environmentally friendly way is very important (Abou Hussein and Sawan, 2010).

The decomposition of crop stalks biomass in the soil improved the soil fertility by supplying organic matter, plant nutrients and improving the soil texture (Yu & Song, 2003, Abdulla, 2007 and Dai *et al.*, 2010). As well as, soil microbial structure and population. (Glinwood *et al.*, 2011 and Hou *et al.*, 2012).

Decomposition of rice straw is due to the activity of many types of microorganisms, i.e. bacteria and fungi (Sirisena & Manamendra 1995 and Kausar *et al.* 2010). Fungi, i.e. Aspergillus, Fusarium, Trichoderma, Chyptoga, Mucor sp. the main decomposer agents that can break down the rice straw (Nandi *et al.* 2000). Fungal inoculates can accelerate the decomposition of rice straw. Trichoderma sp. is the best indigenous fungi in the decomposition process of rice straw (Irfan *et al.* 2010).

Plant growth promoting rhizobacteria are naturally occurring soil bacteria that aggressively colonize plant roots and benefit plants by providing growth promotion. Inoculation of crop plants with certain strains of PGPR at an early stage of development can improve biomass production through direct effects on root and shoot growth. Inoculation of vegetables with PGPR may result in multiple effects as seen in the enhancement of seed germination, stand health, plant vigor, nutrients content of plant tissues, early bloom and chlorophyll content (Joseph *et al.*, 2007). PGPR influenced the growth, yield, and increase supply with different nutrients, such as nitrogen, phosphorus, potassium, sulphur, iron and copper, produce plant hormones, enhance other beneficial bacteria or fungi (Saharan and Nehra 2011).

This work aimed to study possibility application of rice straw into soil with or without rice straw decomposing fungi and plant growth promoting rhizobacteria, as a good agriculture practices to improve the production of eggplant, and avoid the serious environmental air pollution (Black Cloud), caused by burning rice straw annually.

Materials and Methods

The field experiments were carried out during the two growing summer seasons of 2013 and 2014 at Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center, Egypt. Eggplant seedlings (cultivar Black

Balady) were planted in the field on 24 and 20 of February in the first and second seasons, respectively. The experimental trial was conducted in clay soil using drip irrigation system. Emitter discharge rate was 4 l/hr, the distance between emitters was 0.5 m. Physical and chemical properties of the experimental soil were analyzed before cultivation according to FAO (1980) in Table 1.

TABLE 1. Physical and chemical analyses of the experimental soil.

Clay %	Silt %	Sand %	Texture	pH	EC dS/m	Cations meq/l				Anions meq/l			
						Ca^{++}	Mg^{++}	K^{+}	Na^{+}	Co_3^{-}	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
67.60	18.56	13.84	Clay	7.76	1.33	2.58	0.94	1.82	1.94	-	1.92	2.38	3.25

The soil of the experiment was ploughed and divided into ridges, each plot contained three ridges 0.80 m width and 5 m length. The space between plants was 0.50 m on one side of ridge. Two ton/feddan (0.5 kg/m^2) of rice straw were incorporated into experiment soil during soil preparation except control treatment. The main chemical analyses of rice straw are shown in Table 2. Incorporation rice straw into soil was applied before transplanting date by two weeks.

TABLE 2. Chemical composition of the rice straw.

DM (%)	Ash (%)	O.C (%)	C/N ratio	pH 1:5	N	P	K
					(%)		
92.42	17.56	31.16	67.73	6.46	0.48	0.056	1.53

The recommended dose of NPK as mineral fertilizers (MF) were applied according to Ministry of Agriculture and Land Reclamation (2009) as follows: 140kg N/fed (fed = 0.4 ha) as 683kg ammonium sulphate (20.5% N), 45kg P_2O_5/fed as 290kg calcium super phosphate (15.5%P_2O_5) and 48kg K_2O/fed as 100 kg potassium sulphate (48% K_2O). Calcium super phosphate was added as one dose during soil preparation, whereas ammonium sulphate and potassium sulphate were added at three equal portions, during soil preparation, after 21 and 45 days from transplanting. Half of the abovementioned quantities (70 kg N/ Fed., 22.5 P_2O_5/fed and 24 K_2O/fed) of mineral fertilizers were applied at the same times with 50% MF treatments.

All microorganisms (pure local strains) were kindly provided by the Microbiology Dept. Soil, Water and Environment Research Institute, Agricultural Research Center. *Trichoderma viride* as rice straw decomposing fungi (RSDF) was supplemented to the soil by using liquid culture at a rate of 10 L/feddan (1ml contains 10^7cell) directly after rice straw incorporation and irrigation.

Plant growth promoting rhizobacteria (PGPR) were used as mixture of *Azotobacter chroococcum*, *Azospirillium brasilense* (nitrogen fixing bacteria), *Bacillus megaterium* (phosphate dissolving bacteria) and *Bacillus circulans* (potassium releasing bacteria). PGPR were supplemented to the soil surface beside plants after 2 and 4 weeks from transplanting by using liquid cultures at a rate of 20 ml/plant (1ml contains 10^8cell) according to Mashhoor *et al.* (2002) after diluted by water without Chlorine at 1 : 20 rate.

The Experimental Treatments

- Recommended dose of NPK as mineral fertilizers without rice straw (100% MF).
- 100% MF + rice straw (100% MF + RS).
- 100% MF + rice straw + rice straw decomposing fungi (100% MF + RS + RSDF).
- 100% MF + rice straw + plant growth promoting rhizobacteria (100% MF + RS + PGPR).
- 100% MF + rice straw + rice straw decomposing fungi + plant growth promoting rhizobacteria (100% MF + RS + RSDF + PGPR).
- 50% MF + RS
- 50% MF + RS + RSDF
- 50% MF + RS + PGPR
- 50% MF + RS + RSDF + PGPR

The experiment was arranged in a completely randomized block design, with three replicates for each treatment.

After 60 days from transplanting, three plants per replicate were randomly chosen to measure plant height, stem diameter (under the first bottom leaf directly), number of leaves/plant, chlorophyll reading in the fourth upper leaf by using Minolta Chlorophyll Meter Spad 501. Total nitrogen, phosphorous and potassium percentage were determined in the dry matter of fourth upper leaf according to Cottenie *et al.* (1982). Total nitrogen was determined by Kjeldahl method according to the procedure described by FAO (1980). Phosphorus percentage was determined using spectrophotometer according to Watanabe and Olsen (1965). Potassium percentage was determined spectrometrically using Phillips Unicum Atomic Absorption Spectrometer as described by Chapman and Pratt (1961). Fresh and dry shoot weight was measured at harvesting. Early yield (recorded during the first two harvests) and total yield for each plot were recorded after each harvesting accumulatively and were collected per meter square.

Data of the two seasons were analyzed statistically by the analysis of variance using one way ANOVA according to Snedecor and Cochran (1980) with using SAS package. Comparison of treatment means was done using Tukey test at significance level 0.05.

Results and Discussion

Vegetative characteristics of eggplant plants as affected by the different treatments are presented in Tables 3 and 4. The results showed that the treatments of 100% MF plus rice straw plus plant growth promoting rhizobacteria (PGPR) with or without rice straw decomposing fungi (RSDF) significantly increased vegetative growth of eggplant plants, these treatments gave the highest values of vegetative characteristics expressed as fresh and dry shoot weight, leaves number, plant height, stem diameter and chlorophyll reading compared to the other tested treatments. The treatments of 100% MF plus rice straw with or without RSDF increased of fresh and dry shoot weight compared to 100% MF without rice straw treatment, while there were no significant differences among these treatments in other vegetative characteristics. On the other hand, the treatments of 50% MF plus rice straw plus PGPR with or without RSDF decreased of fresh, dry shoot weight and plant height compared to 100% MF without rice straw treatment, while there were no significant differences among these treatments in other vegetative characteristics. Whereas, 50% MF plus rice straw with or without RSDF gave the lowest vegetative characteristics during the two growing seasons. The positive effect of 100% MF plus rice straw plus PGPR with or without RSDF treatments might be due to the decomposition of rice straw in the soil, that improved the soil fertility by supplying organic matter and improving the soil texture (Yu & Song, 2003 and Abdulla, 2007). This effect might also be due to the beneficial effects of PGPR, that help in increasing nitrogen fixation in rhizosphere, increase supply of other nutrients and produce plant hormones (Saharan and Nehra, 2011). All these led to improve the plant growth. These results are in agreement with those obtained by Joseph *et al.* (2007) on chickpea, Glinwood *et al.* (2011), Hou *et al.* (2012) on hot pepper and Latha *et al.* (2014) on eggplant.

TABLE 3. Effect of incorporation of rice straw into soil with RSDF and PGPR on fresh, dry weight and leaf number of eggplant plants during 2013 and 2014 seasons.

Treatments	Fresh weight g/plant		Dry weight g/plant		Leaf No/plant	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
100% MF (control)	950d	958d	266c	270c	32.33c	33.33bc
100% MF + RS	1033c	1050c	284b	287b	32.67c	33.43bc
100% MF + RS + RSDF	1087c	1092c	289b	291b	33.00c	34.33b
100% MF + RS + PGPR	1225b	1247b	320a	326a	37.67b	39.33a
100% MF + RS + RSDF + PGPR	1300a	1310a	333a	336a	40.67a	41.67a
50% MF + RS	710f	717f	193f	194f	25.67d	26.33d
50% MF + RS + RSDF	740f	750f	189f	192f	26.33d	27.33d
50% MF + RS + PGPR	830e	853e	214e	220e	30.33c	30.67c
50% MF + RS + RSDF + PGPR	883e	897e	236d	240d	30.67c	31.33bc

Means in same column by similar letters are not statistically different at 0.05 level according to Tukey test.
MF = mineral fertilizer RS = rice straw
RSDF = rice straw decomposing fungi PGPR = plant growth promoting rhizobacteria

TABLE 4. Effect of incorporation of rice straw into soil with RSDF and PGPR on plant height, stem diameter and chlorophyll reading of eggplant plants during 2013 and 2014 seasons.

Treatments	Plant height cm		Stem diameter mm		Chlorophyll reading spad	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
100% MF (control)	77.00 b	79.33 cd	13.00b	13.78cd	41.30bc	42.29 bc
100% MF + RS	76.67 b	79.67 cd	13.33b	14.12c	42.00b	42.99 b
100% MF + RS + RSDF	78.67 b	82.33 bc	13.33b	14.39bc	42.23b	43.22 b
100% MF + RS + PGPR	84.67 a	88.33 ab	16.00a	16.54ab	44.13a	45.12 a
100% MF + RS + RSDF + PGPR	90.00 a	92.67 a	16.33a	16.89a	44.60a	45.59 a
50% MF + RS	56.67 d	57.33 f	8.33 c	8.62 f	37.07d	38.05 d
50% MF + RS + RSDF	59.33 d	61.33 f	8.67 c	9.98 ef	38.03d	38.82 d
50% MF + RS + PGPR	68.67 c	72.00 e	11.50b	11.89de	40.13c	40.62 c
50% MF + RS + RSDF + PGPR	70.67 c	74.00 de	11.67b	12.32cd	40.8 bc	41.287c

Means in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MF = mineral fertilizer RS = rice straw

RSDF = rice straw decomposing fungi PGPR = plant growth promoting rhizobacteria

The effect of treatments on the nutritional status in eggplant plants is shown in Table 5. The obtained results in both seasons revealed that application of 100% MF plus rice straw plus PGPR with or without RSDF treatments gave the highest concentrations of N, P and K in eggplant leaves. On the other hand, the lowest N, P and K percentage of eggplant leaves were obtained by 50% MF plus rice straw with or without RSDF treatments. While, the treatments of 50% MF plus rice straw plus PGPR with or without RSDF were moderated, as these treatments decreased concentration of N in leaves compared to 100% MF without rice straw treatment, whereas there were no significant differences among these treatments in concentrations of P and K. These findings may be due to addition of rice straw as organic residues into soil, the decomposition of this organic material improves physical, chemical and biological properties of soil, it also improves the nutrient cycling and availability to the plants (Yu & Song, 2003, Abdulla, 2007 and Dai *et al*., 2010). In addition, the presence of PGPR can increase nitrogen fixation, phosphate dissolving and potassium releasing (Saharan and Nehra, 2011). All these increases of nutrient uptake and promote the nutritional status of eggplant plants. These results are in harmony with those obtained by Shehata *et al*. (2010) and Shahein *et al*. (2013) working on celery and lettuce respectively they reported that the biofertilizer increased NPK content in the leaves.

TABLE 5. Effect of incorporation of rice straw into soil with RSDF and PGPR on NPK percent of eggplant leaves during 2013 and 2014 seasons.

Treatments	N		P		K	
	%					
	1st season	2nd season	1st season	2nd season	1st season	2nd season
100% MF (control)	4.039b	4.192 b	0.352 bc	0.358 bc	3.577 cd	3.623d
100% MF + RS	4.087b	4.219 b	0.370 bc	0.380 bc	3.690 bc	3.828bc
100% MF + RS + RSDF	4.102b	4.252 b	0.403 b	0.415 b	3.827 b	3.969b
100% MF + RS + PGPR	4.557a	4.736 a	0.577 a	0.599 a	4.630 a	4.840a
100% MF + RS + RSDF + PGPR	4.667a	4.851 a	0.607 a	0.628 a	4.747 a	4.962a
50% MF + RS	2.677d	2.713 e	0.230 d	0.236 d	2.350 f	2.438f
50% MF + RS + RSDF	2.867d	2.905 d	0.247 d	0.254 d	2.557 e	2.653e
50% MF + RS + PGPR	3.660c	3.877 c	0.327 c	0.342 c	3.380 d	3.592d
50% MF + RS + RSDF + PGPR	3.807c	4.004 c	0.343 c	0.360 bc	3.523 cd	3.710cd

Means in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MF = mineral fertilizer RS = rice straw

RSDF = rice straw decomposing fungi PGPR = plant growth promoting rhizobacteria

Data in Table 6 show yield properties (early, total yield and fruits number) of eggplant as affected by the different treatments. In both seasons the results cleared that the highest values of early, total yield and fruit number on plant were obtained by 100% MF plus rice straw plus PGPR with or without RSDF treatments compared to the other tested treatments. In addition, the treatments of 100% MF plus rice straw with or without RSDF came in the second order with no significant differences in comparison with 100% MF without rice straw treatment, then the treatments of 50% MF plus rice straw plus PGPR with or without RSDF came in the third order. finally, the treatments of 50% MF plus rice straw with or without RSDF gave the lowest values of early, total yield and fruit number on plant. In general, the most favorable treatments were 100% MF plus rice straw plus PGPR with or without RSDF compared with the other treatments. The superiority of these treatments may be due to increased uptake of N, P and K by these plants as shown in Table 4 which resulted in increased plant growth characteristics as shown in Table 3. The improved plant growth led to better carbohydrate build up which increased the early and total yield of eggplant. In this concern, Suge *et al*. (2011) reported similar results and explained that addition of suitable organic matter in the soil improves the soil physical and chemical properties which encourages better root development, increased nutrient uptake and water holding capacity which leads to higher fruit yield and better fruit quality of eggplant. These results confirmed the study by Man *et al*. (2003), they indicated that rice straw after harvesting was incorporated into soil within a week by tilling the land with power tiller plus NPK fertilized, grain yield offered higher than treatment of fertilizer without addition of rice straw. These results also supported the finding of Man and Ha (2006), they mentioned that rice yield in treatment of rice straw after decomposition combined with 50% recommended rate of chemical fertilizer (NPK), was not significantly different from treatment of 100% recommended rate of chemical fertilizer application.

TABLE 6. Effect of incorporation of rice straw into soil with RSDF and PGPR on early, total yield and fruits number of eggplant during 2013 and 2014 seasons.

Treatments	Early yield Kg/m^2		Total yield Kg/m^2		Fruit No/plant	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
100% MF (control)	0.795 b	0.760 b	3.197 bc	3.230 bc	18.18 c	18.36c
100% MF + RS	0.799 b	0.764 b	3.242 b	3.349 b	18.83 bc	18.91bc
100% MF + RS + RSDF	0.805 b	0.770 b	3.269 b	3.351 b	19.04 b	19.45b
100% MF + RS + PGPR	1.052 a	1.089 a	4.360 a	4.368 a	24.31 a	24.38a
100% MF + RS + RSDF + PGPR	1.062 a	1.099 a	4.473 a	4.482 a	24.95 a	25.01a
50% MF + RS	0.283 f	0.248 f	2.063 e	2.073 f	11.50 f	11.56f
50% MF + RS + RSDF	0.373 e	0.338 e	2.243 d	2.256 e	12.52 e	12.59e
50% MF + RS + PGPR	0.627 d	0.594 d	3.078 c	3.088 d	17.20 d	16.99d
50% MF + RS + RSDF + PGPR	0.712 c	0.679 c	3.082 c	3.118 cd	17.20 d	17.40d

Means in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MF = mineral fertilizer RS = rice straw
RSDF = rice straw decomposing fungi PGPR = plant growth promoting rhizobacteria

Conclusions

In conclusion, this study showed that application of rice straw into soil with rice straw decomposing fungi and plant growth promoting rhizobacteria, improved the production of eggplant in the clay soil at Giza governorate, Egypt. As well as reduced the amount of mineral fertilizers and avoid the serious environmental air pollution (Black Cloud), caused by the burning of rice straw annually.

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إنتاج الباذنجان تحت ظروف دمج قش الأرز بالتربة الطينية مع الفطريات المحللة وبكتريا منطقة الجذور المشجعة لنمو النبات

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*المعمل المركزى للزراعة العضوية ، **المعمل المركزى للمناخ الزراعى و***معهد الاراضى والمياه والبيئة –مركز البحوث الزراعية –القاهرة –مصر.

أجريت تجربة حقلية بتربة طينية فى الموقع البحثى التابع للمعمل المركزى للمناخ الزراعى - مركز البحوث الزراعة - الجيزة - جمهورية مصر العربية خلال موسمى ٢٠١٣ و ٢٠١٤. الهدف من هذا البحث هو دراسة تأثير إضافة قش الأرز داخل التربة مع او بدون اضافة فطريات محللة لقش الارز وبكتريا منطقة الجذور المشجعة لنمو النبات مع معدل تسميد ٥٠ و١٠٠٪ من الاسمدة الموصى بها لعناصر ن، فو، بو على إنتاج الباذنجان. استخدم تصميم قطاعات كاملة العشوائية ثلاث مكررات لكل معاملة. مزرعة سائلة من *Trichoderma verdi* استخدمت كفطريات محللة لقش الارز.

مخلوط من البكتريا التالية:

Azotobacter chroococcum, Azospirillium brasilense, B. megaterium, B. circulans استخدمت كبكتريا مشجعة لنمو النبات بمنطقة الجذور. كانت معاملة المقارنة فى هذه الدراسة عبارة عن التسميد بمعدل ١٠٠٪ من ن، فو، بو بدون اضافة قش الارز.

أظهرت النتائج المتحصل عليها تحسن معنوى فى صفات النمو الخضرى والمحتوى الغذائى ومكونات محصول الباذنجان صنف البلدى الاسود باستخدام ١٠٠٪ سماد معدنى مع اضافة قش الارز الى التربة + بكتريا منطقة الجذور المشجعة لنمو النبات. معاملة ٥٠٪ سماد معدنى مع اضافة قش الارز الى التربة + الفطريات المحللة لقش الارز وبكتريا منطقة الجذور المشجعة لنمو النبات اعطت محصول جيد لم تكن به اختلافات معنوية بمقارنته بمعاملة ١٠٠٪ تسميد معدنى بدون اضافة قش الارز.

اوضحت هذه الدراسة ان اضافة قش الارز الى التربة مع الفطريات المحللة لقش الارز والبكتريا المشجعة لنمو النبات تؤدى الى تحسن فى انتاج الباذنجان كما تقلل من استخدام الاسمدة المعدنية وتعمل على تجنب واحدة من اكثر مخاطر التلوث البيئى للهواء فيما يعرف بالسحابة السوداء الناتجة عن حرق قش الارز سنويا.