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RELATIONSHIP BETWEEN GRAIN YIELD AND SOIL BACTERIAL POPULATION AS INFLUENCED BY SOIL ORGANIC MATTER CONTENT IN RAIN-FED RICE

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ABSTRACT

The relationships between grain yield and soil bacterial population as influenced by soil organic matter content which was varied by applying different levels of straw under inorganic fertilizer free environment in rain-fed wetland rice were studied. An experiment with three treatments namely straw 2 t/ ha, straw 3 t/ ha and the control with no added straw was conducted in two locations. Treatments were applied for four seasons before conducting the experiment for two seasons. Bacterial population in soil, soil organic matter content and grain yield were determined. Multiple regression analysis with soil organic matter content and bacterial population as dependent variables showed that not the soil organic matter content but the soil bacterial population has a significant relationship on grain yield of rain-fed rice. Increase in soil organic matter content resulted in increase in soil bacterial population, as measured by bacterial count but not the grain yield of rice. With increasing soil bacterial population, grain yield of rice increased. All these relationships were found in rice fields with no added inorganic fertilizer. Thus, increase in organic matter content would result in increase in bacterial population in rice soils and increase in grain yield of rice under an inorganic fertilizer free environment.

Keywords: *Grain yield, Rice, Soil bacterial population, Soil organic matter, Straw*

INTRODUCTION

Rice is the staple food for more than 50 % of the people in the world (Maclean *et al.*, 2002). Factors such as poor water management, adverse soil conditions, poor soil fertility, improper land preparation, poor seed quality, improper selection of rice varieties for cultivation and non-adoption of proper integrated pest and weed management practices have been identified by the Department of Agriculture as causal factors for low yield in rice in Sri Lanka (DOA, 2000).

Supplementation of chemical fertilizer with organic manure will be beneficial in maintaining overall soil fertility while chemical fertilizer can help to replace some of the nutrients lost from the soil by crop removal (Amarasiri, 1984). An organic carbohydrate source should be present as the C-energy source for soil microorganisms (Killham, 1994). The presence of soil organic matter improves the sustainability of agricultural soil productivity by improving physical, chemical and biological properties of the soil (Syers and Craswell, 1995). Application of rice straw is the most convenient, practical and economical way to supply organic matter for rice soils (Amarasiri, 1984). Importance of soil micro-organisms, particularly bacteria, in the decomposition process of soil organic matter is well known.

Studies on micro-organisms, particularly bacteria, in rice soils in the past have been limited to laboratory experiments (IRRI, 1988) and surveys and identification of soil microbes (Kulasooriya, 1991). In contrast, information on the relationship between grain yield and soil organic matter content in rice is available (Arshad and Coen, 1992; Ponnamperuma, 1984). However, available literature on the relationship between soil bacterial population and soil organic matter content is little (IRRI, 1988) while hardly any information is available on the direct relationship between grain yield and soil bacterial population in low land rice, particularly under rain-fed conditions. Studies on soil microbiology in rice fields may be immensely important to improve productivity with the lowest cost of low productive rice soils where the rice crop is poorly managed. Therefore, the objective of the present study was to determine the direct relationship between grain yield and soil bacterial population as influenced by soil organic matter content in poor yielding rain-fed rice in Sri Lanka.

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MATERIALS AND METHODS

The study was carried out in the Low Country Intermediate Zone (IL) of Sri Lanka in two locations; Makandura and Wariyapola representing two rain fed conditions being Wariyapola drier than Makandura. Three rates of straw, 0 2 and 3 t ha^{-1} as treatments to achieve different soil organic matter contents were tested in a randomized complete block design with two replicates in each location. The plot size was 6Ì3 m.

Treatments were applied and rice was planted over four seasons including both *Yala* and *Maha* seasons before conducting the experiments to achieve stable Organic Matter levels and bacterial populations, and to remove any residues of previously applied chemical fertilizer. In this period land was prepared using a four wheeled tractor to a depth of 25 cm in both locations. Initially land in subsequent seasons was prepared manually using *mammoty* to keep the plots intact.

Sun-dried straw was evenly added on to the soil in respective plots just after initial ploughing in each season. Straw was incorporated into the soil two weeks later when soil was puddled. Pre-germinated rice seeds of variety Bg 94-1 were broad cast sown at the rate of 180g per plot (100 kg/ha). Plots were maintained under rain-fed condition and with supplementary irrigation whenever the expected rains were not received. Hand weeding was adopted for weed control and insects were controlled as per recommendation by the Department of Agriculture. At harvesting, rice crop was cut at approximately 15 cm above the ground level. During the study period (2 seasons) straw was applied and cultivation practices were done as described earlier.

Harvesting was done at maturity using a net plot area of 5.40m x 2.40m after removing a 30 cm broader around each plot. Soil organic matter was determined as Walky and Black (1934) method and total bacterial count by Kepner and Pratt (1994) was determined for top soil layer (0-2 cm). Soil sampling was done one month after sawing. Soil bacterial count was determined at two months after straw application or one month after sowing at the top most layer of the soil.

DATA ANALYSIS

Combined analyses of variance over environments (location X season combinations) were run for grain yield data, soil bacterial count and soil organic matter content. Relationships of soil bacterial count with grain yield and soil organic matter content were studied using multiple and simple linear regressions Each data point of a regression was an average of two replicates and the error term used to test the significance of parameters in regressions was the deviation from regression term. As experiments were conducted over locations and seasons, location X season combination was considered as an environment. Thus, there were four environments (2 locations X 2 seasons) and three treatments in each environment so that there were altogether 12 data points (3 treatments X 4 environments) per regression.

As data from different environments with different bacterial populations (4 environments) were pooled to increase the number of data points for the regression analysis, data were adjusted to remove the environmental effects by taking deviation of each datum from the relevant environmental mean. For example the mean of the environment one was subtracted from the data from three treatments in that environment to measure the deviation from the environmental mean. These deviations are independent of environment effect so that they can be pooled into one data set regardless of the environment for regression analysis. When deviations are taken, minus values are possible. In order to remove minus values of a given set of data the lowest minus value was added to each data point so that the lowest minus value in the data set became zero without affecting the original variability of the data set..

RESULTS

The soil bacterial populations as measured by soil bacterial count, soil organic matter content and grain yield in *Maha* and *Yala* seasons at Makandura and Wariyapola are presented in Table 1. The values adjusted for environment means are given in the parenthesis and they were used to study all the relationships.

Table 1 Grain yield, soil organic matter content as a % and total soil bacterial count / 100 grams of dry soil at Makandura and Wariyapola in *Maha* and *Yala* seasons.

Location/ Treatment*	Season**					
	Maha			Yala		
	Grain yield (t/ha)	Soil organic Matter%	Bacterial Count ($1x10^6$)	Grain yield (t/ha)	Soil organic Matter%	Bacterial Count ($1x10^6$)
Mâkandura						
2S	2.36 (1.53)	2.35(0.73)	6.49(6.05)	1.84(1.23)	2.11(1.04)	2.56(4.85)
3S	2.47 (1.61)	2.45(0.83)	6.67(6.23)	1.69(1.08)	2.31(1.24)	2.92(5.21)
Control	1.39 (0.53)	2.15(0.00)	2.59(2.15)	1.63(1.02)	1.35(0.25)	1.55(4.35)
Wariyapola						
2S	2.95(1.61)	3.19(1.43)	9.45(6.85)	0.59(1.41)	2.02(0.69)	3.33(5.16)
3S	3.04(1.70)	3.16(1.30)	9.93(7.33)	0.67(1.40)	2.37(1.45)	3.82(5.65)
Control	1.34(0.00)	1.56(0.09)	2.60(0.00)	0.50(1.23)	1.58(0.48)	2.30(4.13)

*2S and 3S – 2 and 3 tones /ha straw, respectively; control = no straw.
** Values in the parenthesis are adjusted values for environment means

In the combined analysis of variance over four environments (2 location × 2 seasons), interaction effect of environment × treatment and the main effects of environment and treatment were found to be significant at 5% probability level with respect to grain yield, soil organic matter content and soil bacterial count. The error term in the combined analysis was reps / environment × treatment combination. Thus, the results allowed valid regression analysis.

In the multiple linear regression analysis of soil organic matter content and soil bacterial count on grain yield with a r value of 0.965, only soil bacterial count was found to be significant at 1% probability level while the soil organic matter content and the interaction between soil organic matter content × soil bacterial count were found to be not significant. Interestingly, this indicated that 93% ($R^2 = 0.93$) of the grain yield variability could be explained by the variability of soil bacterial count. Therefore, the relationship between grain yield and soil bacterial count or population was separately studied using simple linear regression. As the variability of soil bacterial population was expected to be created by varying the level of organic matter content in the field in different locations and seasons, the relationship between the soil bacterial population and the soil organic matter content was also studied.

RELATIONSHIP BETWEEN SOIL BACTERIAL POPULATION AND SOIL ORGANIC MATTER CONTENT

The adjusted values for environment means as indicated in the methodology, of soil bacterial count and the soil organic matter content measured as a percentage were taken for this study. According to the regression curve (Fig. 1) with the correlation coefficient r = 0.7996, the association of soil bacterial count with soil organic matter percentage was found to be significant at 1 % probability level. The R^2 value was 0.6395 indicating that about 64% of the variability of soil bacterial population could be explained by the variability of organic matter content in the soil.

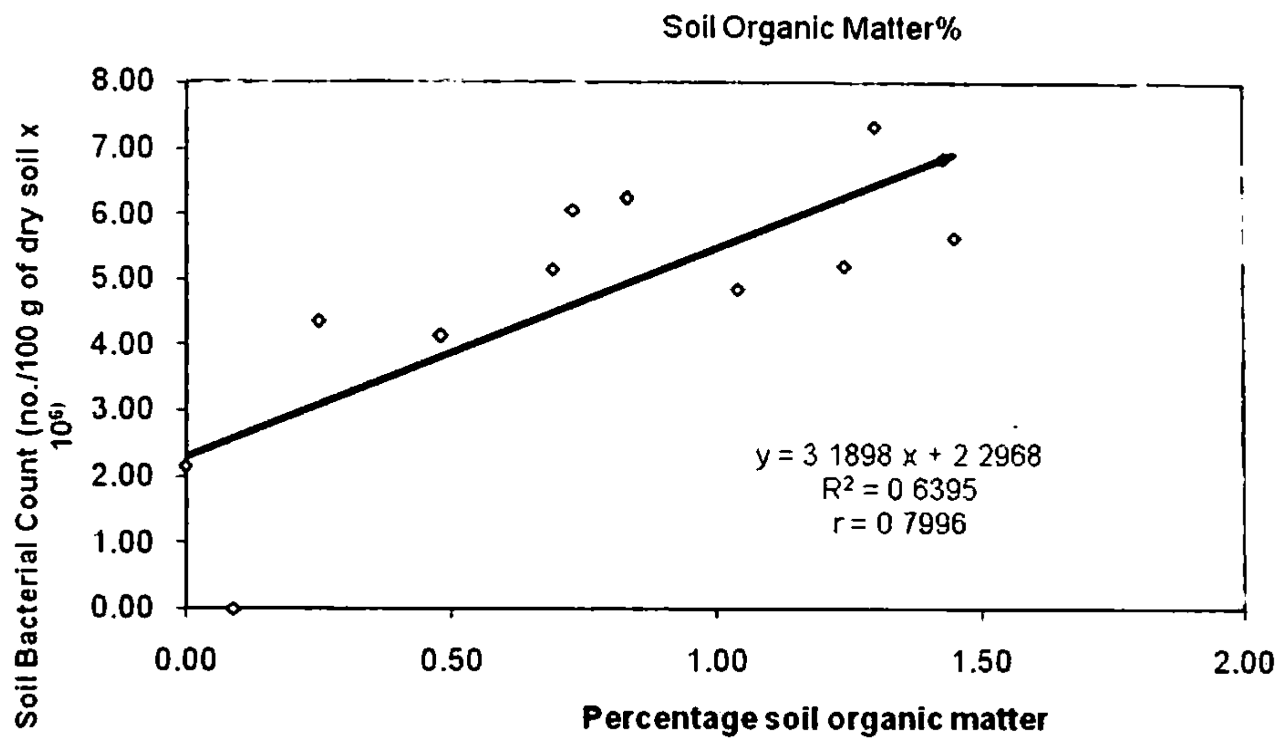

Figure 1. The relationship between adjusted soil organic matter percentage and adjusted soil bacterial count in rain-fed rice fields

RELATIONSHIP BETWEEN GRAIN YIELD AND SOIL BACTERIAL POPULATION

The adjusted values of grain yield and soil bacterial count for environment means were used to study the relationship. According to the regression curve (Fig. 2), the association between grain yield and soil bacterial count ($r = 0.9759$) was found to be significant at 1% probability level. The R^2 value was 0.95 indicating that about 95% of the variability of grain yield could be explained by the variability of total bacterial count in the soil.

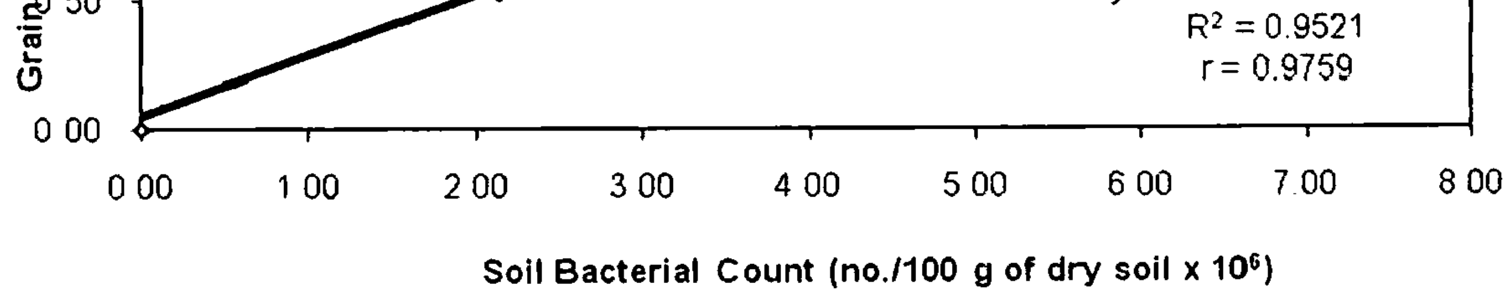

Figure 2. The relationship between the adjusted grain yield and adjusted soil bacterial count in rain-fed rice

DISCUSSION

Soil bacterial count was determined at the particular time of the crop growth and at the particular layer of the soil when and where the highest bacterial count could be observed. The highest bacterial count could be observed at the top most layer of the soil at two months after application of straw (one month after sowing) in rain-fed rice soils (Jayakody *et al.*, 2008).

RELATIONSHIP BETWEEN SOIL BACTERIAL POPULATION AND SOIL ORGANIC MATTER CONTENT

Soil bacterial varies with the level of organic matter content in rice soils as evidenced by the highly significant relationship ($r = 0.7996$, $b = 2.2965$) between bacterial count and organic matter content in the soil. The accuracy of the predictability of the association was more than enough to establish a relationship between soil bacterial count and soil organic matter content in rice fields. In addition, a course and result relationship can also be built between soil bacterial count and soil organic matter content as food source for soil bacteria (Margeret and Ladha, 1996). Thus increase in soil organic matter content by 1% would increase soil bacterial population by 3.2×10^6 in a rice field which is free from chemical fertilizer.

RELATIONSHIP BETWEEN GRAIN YIELD AND SOIL BACTERIAL POPULATION

Soil organic matter content was varied by application of different levels of straw that influence on the soil organic matter content differently in different environments (location × season combinations) as evidenced by the significant straw treatment × environment interaction effect in the combined analysis of soil organic matter content. Soil organic matter content influences grain yield of rice (Ponnamperuma, 1984; Sharma and Mittra, 1990; Arshed and Coen, 1992; Jayakody, 1995) and soil bacterial population (Krishnakumar *et al.*, 2005). Thus, if the influence of soil bacterial population on grain yield of rice is needed to be studied, it has to be independent of the direct influence of the soil organic matter content on grain yield as, in general, soil bacterial population increases with the increase in soil organic matter content. However, in the present study, the direct influence of the soil bacterial population on grain yield of rice has been separated from the direct influence of the soil organic matter content on grain yield through multiple linear regression where dependent variable was grain yield while independent variables were the soil bacterial population as measured by the bacterial count and the soil organic matter content. Interestingly, in the multiple linear regression analysis, only soil bacterial count was found to be significant indicating that 93% of the grain yield variability could be explained by the variability of the soil bacterial count alone. Thus, the simple linear relationship between grain yield of rice and soil bacterial count was established.

The association between grain yield and soil bacterial count ($r = 0.9759$) was found to be highly significant and at least 95% ($r^2 = 0.95$) of the grain yield variability of rain-fed rice could be indicated by bacterial count. The accuracy of the predictability of the association was adequate to establish a relationship between soil bacterial population and grain yield of rice. The established linear relationship between soil bacterial count and grain yield of rice was very strong indicating that increase in soil bacterial count by 1×10^6 would increase grain yield by 0.2365 t/ha in rain-fed rice fields which are free from chemical fertilizer.

Present findings are limited only to organic farming where chemical fertilizer is not applied. Based on the present findings, application of organic matter has an indirect influence through increase in soil bacterial population rather than a direct influence, on grain yields of rain-fed rice However, an explanation for the increase in grain yield with the increase in soil bacterial population is beyond the present study. In addition, application of chemical fertilizer may disturb the relationships established in the present study as chemical fertilizer will definitely influence grain yield and may influence soil bacterial population too. However, these are the subjects of future studies.

CONCLUSIONS

The relationship between soil bacterial population as measured by bacterial count and grain yield of rain-fed rice under chemical fertilizer free condition was found to be significant. Increase in soil bacterial count by 1×10^6 would increase grain yield by 0.2365 t /ha. The relationship between soil bacterial count and organic matter content which was varied by application of straw was also found to be significant. Increasing soil organic matter content by 1% would increase soil bacterial population by 3.2×10^6. Increase in organic matter content would result in increase in bacterial population in rice soils which in turn results in increase in grain yield of rain-fed rice under an inorganic fertilizer free environment.

REFERENCES

Amarasiri, S.L. (1984). An Integrated approach towards supply of plant nutrients and maintenance of soil fertility of rice lands. *Proceedings of the Sri Lanka Association for the Advancement of Science* 40 (2) 29-43.

Arshad, M. A. and Coen, G. M. (1992). Characterization of soil quality. Physical and chemical criteria. *American Journal of Alternative Agriculture*. 7, 5-12.

DOA (2000). Department of Agriculture at the Century, The Department of Agriculture, Peradeniya, Sri Lanka.

IRRI (1988). Annual Report for 1988 International Rice research Institute phillipines.

Jayakody, D. P. P. (19950 Effect of different levels of straw mulch on weed growth and grain yield of Bg 300 under dry seeding "Kekulan Condition", Proceedings of the 52nd Annual session of Sri Lanka Association for Advancement of Science.

Kepner, R. L. J. R. and Pratt, J. R. (1994). Use of Fluorochromes for Direct Enumeration of Total Bacteria in Environmental Samples: Past and Present. *Microbiological Reviews*, 58 (4), 603 –615.

Killham K. (1994). Soil Ecology. University press, Cambridge, 242p.

Krishnakumar, S., Saravanan, A., Natarajan, S. K., Veerabadran, V. and Mani, S. (2005). Microbial population and enzymatic activity as inflenced by organic farming. *Research Journal of Agriculture and Biological Sciences* 1 (1): 85 – 88.

Kulasooriya, S. A. (1991). Biological Nitrogen Fixation in Acid Rice Growing Soils, *In rice production on acid soils of the Tropics*, P. Deturec and F. Ponnamperuma (eds.) p77- 80, Institute of Fundamental Studies, Kandy, Sri Lanka

Maclean, D. C. D., Hardy, B. and Hettel, G. P. (2002). *Rice Ulmanac*. Source Book for the Most Important Economic Activity on Earth, Third Edition, International Rice Research Institute, Philippines.

Margeret, M. R. and Ladha, J. K. (1996). Biological N fixation by heterotrophic and phototrophic bacteria in association with straw. *Plant and Soil*, 174, 211-224.

Ponnamperuma, F. N. (1984). Straw as a source of nutrients for wetland rice. In Organic Matter in Rice. International Rice Research Institute, Philippines.

Sharma, A. R. Mittra B. N. (1990). Response of rice to rate and time of application of organic materials. *Journal of Agricultural Science*. 114 (3) 249-252

Syers, J. K. and Craswell, E. T. (1995). Role of organic matter in sustainable agriculture systems. In *Soil and organic matter for sustainable agriculture*. Proceedings of a workshop, 24-26th Augast, 1994. Ubon, Thailand. R.D.B. Lefroy, G.J.Blair and E.R.Craswell (eds), Australian Centre for International Agricultural Research

Walky, A. Black, C. A. (1934). An examination of the Dedtjaraff method for determining soil organic matter and proposed modification of the chromic acid titration method, *Soil Science*, 37 : 29-38